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2	Drawings-only black and white line drawings	SPP_X_drawings_continuation.pdf	1324163 b3e39b711b18acb35698e05ef0d3dc974122cb65	no	19
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DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS

ABSTRACT OF THE DISCLOSURE

A system is disclosed for the automated correction of optical and digital aberrations in a digital imaging system. The system includes (a) digital filters, (b) hardware modifications and (c) digital system corrections. The system solves numerous problems in still and video photography that are presented in the digital imaging environment.

PATENT APPLICATION

DIGITAL IMAGING SYSTEM

FOR CORRECTING IMAGE ABERRATIONS

Inventor(s): Neal Solomon

Entity: Small Entity

DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS

CROSS-REFERENCES TO RELATED APPLICATIONS

The present application claims the benefit of priority under 35 U.S.C. section 119 from U.S. Patent Application Serial Nos. 12/586,221 filed on September 18, 2009 and 11/825,521 filed on July 11, 2007 and Provisional Patent Application Serial No. 60/807,065 filed on July 11, 2006, the disclosures of which are hereby incorporated by reference in their entirety for all purposes.

FIELD OF THE INVENTION

The present invention pertains to imaging systems. The invention presents electronic methods to optimize optical processing, the digital capture of light and post-capture image organization of digital data sets. The system may be used in any device that captures, records, replicates, scans, reproduces, accesses, organizes, modifies, edits or stores images digitally. The invention applies to any imaging system that includes interaction between optics, digital image sensors, post-capture integrated circuits and digital storage components. The system includes self-organizing apparatus for optical image collection, electronic organization and optimization of digital data using integrated circuits and software applications. The system applies to consumer and professional still and video photography, including cinematography, to the processing of images with digital sensors, and to copying and scanning technologies. The system also applies to complex grids of multiple video cameras and satellites for surveillance and reconnaissance.

BACKGROUND OF THE INVENTION

The history of photography in the twentieth century is a story of finding solutions for optimizing optical problems. The main challenges have involved improving lens configurations to optimize image quality for film capture. As an example of this, lens aberrations have been reliably corrected by creating aspherical lens elements in wide-angle lenses and by creating apochromatic lens elements in telephoto lenses. The use of lens element coatings has also improved optical quality. Similarly, the evolution of zoom lenses has included improvement in optical quality via the combining of complex optical element configurations; as the optical

quality of zoom lenses improved dramatically, their simplicity and utility led them to dominate lens sales. Complex computer-aided design (CAD) software has been used to test a broad range of possible lens configurations so as to optimize the optical performance in terms of clarity and contrast of each lens type, as much as optically possible within economic constraints.

In the last twenty-five years, an additional revolution has occurred with the advent of auto-focus (AF) technology in still photographic and video cameras. Invented by Minolta in the early 1980s, AF technology was a photographic application of technology developed for the U.S. military. The AF system used an infrared light sensor to reflect light onto an object that allowed a camera's lens to focus on the object by employing a motor in the camera. Canon eventually developed improved methods of auto focus by using electronic means (viz., micro ultrasonic motors) to increase speed and accuracy. This AF technology was integrated with automatic exposure (AE) technology which developed complex algorithms in a "program" mode to combine shutter and aperture data to match each lens with particular subject matter, as well as an aperture-priority exposure mode and a shutter-priority exposure mode. Of course, the photographer could use manual focus and manual exposure at any time, but these improvements increased the creative process and the competitive advantages of camera makers and photographers that employed them. Ultimately, the combination of these developments allowed ordinary photographers to achieve high quality standards.

AE was improved by Nikon, particularly with the use of a "3D color matrix" system, which included a library of pre-programmed image types. The combination of the improved AF and AE subsystems allowed a dramatic simplification of photographic imaging because the photographer no longer labored over the time-consuming focus and the exposure variables. Automated film advance, in the form of built in motor drives, increased the working speeds of camera operation as well. Nearly all consumer and professional cameras became automated to some degree by the mid-1990s, including formats beyond the 35mm film standard.

In the last decade, a new technology of image stabilization (IS) has emerged to help correct the problem of vibrations caused camera shake that lead to image blur. This technology is implemented in lenses by the use of gyros to reorient the light plane to compensate for camera shake; when combined with the earlier automated camera technologies such as AF and AE, IS further improves the photographic experience, particularly for larger lenses.

In addition to these advances in camera automation, technologies improved in the category of artificial flash as well. With microprocessors and sensors employed to measure minute variances, the development of photographic flash systems allowed the photographer to control the lighting in an environment to some degree. Nikon's use of distance information in its flash system advanced the state of the art in flash photography. The combination of AF and AE with automated flash mechanisms provided increased efficiency and simplicity in image capture processes.

The last several years have witnessed a revolution in digital photography. Because of its simplicity, potential quality improvement, immediate feedback and cost savings, digital photography has captured an increasing market share relative to film-based cameras. Kodak holds a number of patents involving the charge coupled device (CCD) for converting and recording light into electronic format. A competing technology for digital capture is complementary metal-oxide semiconductor (CMOS) which, though developed by Fairchild Semiconductor over forty years ago, is predominantly used in photographic cameras by Canon. Although there are trade-offs in the application of CCD and CMOS digital sensors for image capture, they both find wide acceptance in the market.

In order to correct for digital artifacts in image capture mechanisms, anti-aliasing filters are placed in front of digital sensors. Despite this improvement, digital imaging still has some challenges to overcome in competing with the image quality of film.

At the present time, the most recent advances in digital imaging for professional still photography have come from Hasselblad, which offers a Phase One camera back with a 39 MP digital sensor from Kodak. This system uses software that automatically corrects for digital capture limitations to produce a quality image. Their "digital APO correction" (DAC) technology performs an analysis of meta-data to color-correct the digital capture resulting in moiré-free images.

At the limits of current technology, a Canadian company, Dalsa, has produced a 111MP (10,560 by 10,560 pixels) CCD digital sensor that measures four inches square. This technology must be mated with large format-type lenses with large image area, and may be used for satellite surveillance applications and for other astronomical applications.

With both the larger sensor surface area of a medium format camera system and the high-quality fixed focal-length lenses of Zeiss, Schneider and Rodenstock, the quality of even the top

optics will be a limiting barrier to advanced digital sensors' ability to perceive maximum resolution. Without new improvements in optical and digital technologies, further progression of photographic camera systems will be limited.

Photographic Problems

Though every major advance in photography has solved an important problem, there are still remaining photographic problems to be solved in order to meet the goals of optimizing optical imaging quality while increasing simplicity and efficiency and lowering cost. Despite the advent and evolution of digital imaging, a number of problems have emerged in the digital realm in addition to earlier problems involving optics. Nevertheless, an opportunity exists to solve some of these problems via digital approaches. These problems are generally categorized as optical or digital.

Optical Problems

In the case of optics, lens aberrations are characterized according to lens type, with wide-angle lens problems differentiated from telephoto lens problems. Some of the problems affecting wide-angle lenses arose from the creation of the single lens reflex (SLR) camera. Before the SLR, the rear element of a lens could be placed in a rangefinder to protrude to a point immediately in front of the film plane in order to correct for aberrations. While the advantages of the mirror mechanism include ability to see exactly what one is photographing, because the mirror of the SLR flips up during exposure, the rear element of the lens must be placed in front of the mirror's plane of movement. This mechanical fact limits lens designs in most 35mm and medium-format camera systems and particularly affects wide-angle lens configurations.

It is very difficult to control the five aberrations of Seidel – spherical aberration, distortion (barrel distortion and pin cushion distortion), comatic aberration, astigmatism and curvature of field. In wide-angle SLR lenses as they are currently designed, these aberrations are particularly prominent.

For wide-angle lenses, optical vignetting affects peripheral illumination. Though optical vignetting will affect even retrofocus wide-angle lenses in rangefinders, it is particularly prominent in SLR cameras. According to the Cosine law, light fall-off in peripheral areas of an image increases as the angle-of-view increases. While optical vignetting can be reduced by

stopping down the lens, the aberrations in rectilinear wide-angle lenses generally exhibit more distortion the wider the lens.

In the case of wide-angle lenses, the depth of field range is much broader, with close focusing causing aberrations without stopping down the aperture. To solve this problem, close-distance focusing is improved by the creation of floating groups of lens elements. The rear lens group elements float to correct close-distance aberrations. With wide-angle lenses that have wide apertures, floating lens elements improve lens aberrations in focusing on distance points also.

Modulation transfer function (MTF) curves represent a quantitative methodology used to assess the resolution and contrast of lens performance at specific apertures. Each lens type has a specific lens element composition, formula and behavior as measured by MTF. In general, MTF measures lens sharpness to 30 lines/mm and contrast to 10 lines/mm.

Because different colors of the visible light spectrum behave uniquely, the goal of lens design is to have all colors accurately hit a film plane or digital sensor plane. The particular challenge for telephoto lenses is that the red and green light colors strike the film plane at different times than blue light colors; thus a compensation must be made in the lens configuration to adjust for chromatic aberrations. Camera lens manufacturers have used extra low dispersion glass and fluorite glass elements in telephoto lenses primarily to adjust the red color light spectra to the film plane. In addition, telephoto lenses use carefully designed lens coatings to limit light diffraction-based aberrations.

Due to their construction, super-telephoto lenses are very large and heavy. While modifying the materials used in the lens barrels could reduce size and weight problems, a technological improvement in telephoto lens design was developed by Canon with the addition of diffractive optical (DO) elements, which behave as a sort of highly-refined fresnel lens magnifier. Though the MTF analyses of wide-angle lenses show dramatic latitude in performance of even high quality SLR lenses, with particular loss in resolution and contrast toward the edges of the image, high quality telephoto lenses show control of aberrations. However, the price of these lenses is prohibitively high.

In the case of zoom lenses, as many as four distinct groups of lens elements correct various optical aberrations. These lens element groups include (a) a focusing group, (b) a magnification variation group, (c) a correction group and (d) an image formation group.

Modulating the focal length range of a zoom lens enables the lens to perform within the scope of operation, yet the zoom lens architecture has limits. In particular, the zoom lens configuration sacrifices resolution and wide potential aperture. Generally, the degree of resolution and contrast at the smaller angle of view is traded away in favor of competence at a wider angle of view, or vice-versa. This explains why MTF analyses of zoom lenses generally show a dramatic lowering in resolution and contrast relative to excellent fixed focal length lenses.

Digital Problems

Digital photography has built on the edifice of *film* camera systems. For instance, the size of the sensor is generally limited to the size of the optical circumference of a lens system. In the case of 35mm lenses that are designed for a specific angle of view, the largest that a digital sensor in a 35mm lens system could be, is 24mm by 36mm, with a corresponding maximum image circle of 43mm. In the case of medium format lenses, the largest digital sensors would duplicate the corresponding film plane size, whether 6x4.5 cm, 6x6 cm, 6x7 cm, 6x8 cm, 6x9 cm, 6x12 cm or 6x17 cm (which results in an effective image circle as large as 7 inches).

Digital sensors that are smaller than the limits of a corresponding lens system have been introduced. For example, Nikon digital sensors are smaller than 24mm x 36mm, or advanced photo system (APS) size. Efficient stacking of pixels allows a smaller sensor to eventually match the performance of a corresponding film system, while using the smaller circumference of the same lenses. Since the outside edges of the lens typically degrade resolution and contrast, this model using the smaller digital sensor can have an advantage of using primarily the centralized "sweet spot" of the image area. However, this smaller sensor size sacrifices the peripheral effects of a wide-angle lens, so a 14mm becomes a 21mm in a 1.5x conversion-sized sensor in a 35mm lens system. On the other hand, with telephoto lenses, the angle of view is limited to the center 65% of the image. This gives the appearance of upconverting a telephoto lens by 1.5x and thus provides an impression of increased magnification; a 400mm f/2.8 lens appears as a 600mm f/2.8 lens on a camera with a cropped digital sensor. Ultra-wide-angle lenses have been introduced with smaller image areas than 35mm to compensate for smaller sensor size.

Though invented over thirty years ago by Dr. Bayer, the charge coupled device (CCD) that is used in many digital cameras generally emulates the behavior of film. Specifically, since

most photographic film has three layers of green, red and blue, with green representing fifty percent of the emulsion and red and blue twenty-five percent each, the CCD architecture also configured pixels to capture fifty percent of the green photonic visible light spectrum and twenty-five percent each for pixels recording red and blue light. Human eyes see more green than red and blue, so both film and digital sensors seek to emulate the way that we see. Each light color is captured by a different pixel in the CCD, just as there are three emulsion layers of film. In recent years, Foveon has developed a digital sensor for image capture that further seeks to emulate film by structuring the pixels into three *layers*, again with fifty percent capturing green light and twenty-five percent each capturing red and blue light.

Unfortunately, unwanted artifacts are also captured by the digital image capture process. These include banding and moiré effects that present false patterns and colors. Moiré patterns are created because the dot pattern of a sensor will intermittently overlap with the pattern of a subject to create a third pattern; these effects are optically-generated digital distortions that represent the effect of light hitting a pixel without correction. In order to compensate for these effects, digital sensors have employed low pass filters consisting of liquid crystal structures; however, these filters tend to have the effect of softening image resolution. Additionally, RGB or CMYG color filters are placed in front of digital sensors to ensure the accurate capture of colors.

CMOS digital sensors present an alternative to CCDs. By employing alternating positive and negative transistor networks, the CMOS sensors use less power. While they do not have the low noise ratio of the CCD, they do have greater light exposure latitude, in both range of ISO and dynamic range of detail in highlight and shadow. More importantly, CMOS sensors contain the circuitry, including analog to digital converter (ADC) and digital to analog converter (DAC), for post-processing digital images on the chip itself and enabling increased micro-miniaturization of the digital imaging process. An increase in the bit rate of the CMOS chip up to 32-bit makes possible a much richer color palate and level of detail than with earlier generation CCDs.

CMOS sensors can be full-frame, matching the lens specifications for the camera systems for which they are designed. A relatively bigger sensor has a wider depth of field capability, so the background can appear as a blur to set apart the main subject. Given these capabilities, one problem that emerges is that a digital sensor's enhanced capabilities to capture details may exceed the maximum optical resolution capabilities of many lenses. Nevertheless, CMOS

sensors still require an anti-aliasing filter to be used in front of the sensor, which marginally degrades resolution.

Over the years, cameras have gotten smaller. While in the 19th century cameras were 11x14 or 8x10, literally capturing images on large emulsion plates, cameras of today are smaller and more automated. Yet the larger the film size, the bigger the enlargement potential and the increase in relative detail in the overall image. Similarly in digital photography, the larger the sensor, the more detail available and the bigger the output print can be enlarged. Because of this correspondence of digital sensor to film, the evolution of digital photography has been restricted to respective film camera systems, with 35mm and medium format systems dominating the field because well-developed lens systems have already been organized for these camera formats. The potential exists, however, to develop 35mm camera system digital sensors that rival film-based medium format or large format camera system quality or to surpass the limits of 35mm camera systems with medium format camera system digital sensors. The relative size, cost and automation advantages of 35mm camera systems generally show that these systems not only are competitive, but that these markets are increasingly accelerated relative to larger format systems. For example, the development of large aperture lenses, super-telephotos, rapid auto-focus, refined automated exposure and image stabilization systems in 35mm systems has solved various problems that have emerged in the last century and has improved image quality and camera system efficiency.

However, in the digital imaging realm additional problems have emerged, including the need to improve color (hue and saturation) quality, exposure highlight range, contrast range and other tonal adjustments. In addition, digital image capture brings its own set of aberrations, including moiré and banding effects and noise and ISO range limits. Additional aberrations are linked to the unique design of each type of digital sensor, with trade-offs presented between types of CCDs or CMOS chips. Moreover, there are still optical problems in the digital realm, namely, a range of optical aberrations created particularly by wide-angle and zoom lenses as well as the limits of very large, costly and heavy super-telephoto lenses.

In order to transcend the optical and digital limits of present camera systems, software systems have been developed that deal with the problems in post-production. While the most notable of these post-production digital editing software programs is Adobe Photoshop, each camera manufacturer has its own proprietary program. In the main, these post-production

software programs are limited to color correction and sharpening/softening of images. Additionally, some of these software programs are able to emulate specific artificial filter techniques to produce creative modifications of an original image. Nevertheless, manipulating unfiltered RAW image files in post-production processes is time-consuming and expensive and requires considerable skill.

One unintended effect of using digital sensors to capture images in digital photography is that dust accumulates on the sensor surface and thereby obstructs a clear optical image. The vacuum behavior of increasingly ubiquitous zoom lenses moves dust in lenses that are not internally sealed and the existence of dust is a prevalent feature of digital photography. Dust on the sensor is a non-trivial problem that requires tedious post-production correction for each image. The existence of dust on a digital sensor is an inconvenient impediment to achievement of optical imaging quality.

What is needed to correct these various optical and digital aberrations and unfiltered image files is in-camera modification capability for each specific image problem. The present invention describes a digital imaging system to optimize optical results.

Applications of the Present Invention

The present invention has several practical applications. The digital imaging system applies to consumer and professional still and video camera technologies, to cellular telephones and to personal digital assistants (PDAs). Since video technologies are evolving into digital formats, including HDTV and its successors, the present invention would be applicable to these technologies. The present invention also applies to networks of remote camera sensors for surveillance. The system also applies to native digital cinematography and telecine conversion from analogue to digital media. The system may be applied to image scanning and image copying technologies. Finally, the present system may be applied to any optical digital capture, processing and storage sub-system technologies, including groups of sensors or satellites.

Advantages of the Present Invention

There are several important advantages of the present invention. The present system dramatically improves image quality. This digital imaging system eliminates, or minimizes, post-production processes. In addition, the system presents substantial cost savings as well as

time savings relative to existing digital imaging systems because of the automation of integrated in-camera optical and digital corrections of aberrations.

With the present system, in-camera digital filters will largely replace optical filters. With less distortion, cost and weight/size than current optical filters and with far more control and quality results, the present system demonstrates that in-camera digital filtration out-performs better than external filters. The in-camera filter system is also an improvement over post-production digital filter systems which require substantial time, cost and skill to implement.

By using the present invention, users will be able to use lens apertures that are wider open, because lens aberrations will be corrected. In turn, this increased latitude will allow more efficient (2+ stops) use of available light and will allow slower lenses to achieve quality images that have traditionally been in the domain of expensive fast lenses. The process of photography will be made generally more efficient.

The present system allows camera manufacturers to design different, predominantly smaller, lenses. Moreover, with providing a system for digital corrections, camera lenses may use less expensive optics and still obtain good results. This process will, in turn, accelerate the adoption of low-cost digital photographic systems and, in the aggregate, increase the overall size of the digital photographic market. Similarly, there will be an increase in the effectiveness of zoom lenses, which are already becoming popular. With the present system, 35mm optics may obtain the quality typically recognized by 4x5 film camera systems. The present system will thus facilitate photographic digital imaging to supplant the film era.

Its application to digital scanning and copying will allow the present system to become ubiquitous as a system to improve imaging.

Because the system presents an integration of several critical subsystems that are centered on digital imaging processes, the system has applications to video photography, satellite systems and surveillance systems. The dynamics of the operation of the subsystems of the present digital imaging system reveal the refinement, efficiency and optimization of the digital photographic paradigm.

Importantly, since the present system uses apparatus and methods that are implemented with software processes, in-camera software can be constantly upgraded and remotely downloaded, while image files can be automatically uploaded, organized and published.

If the goal of the evolution of photographic technology is to increase the number and quality of excellent images, the present system will revolutionize photography.

Solutions to Digital Imaging Problems that the Present System Presents

The present system provides in-camera digital corrections to both optical and digital aberrations. In the case of optical aberrations, distinct lens-specific imperfections are caused by wide-angle, telephoto and zoom lens types. In the case of digital aberrations, specific digital artifacts, such as aliasing and dust, must be corrected.

The present invention also designs specific improvements to digital sensor design. These hardware architecture modifications allow digital imaging to maximize both optical resolution and image exposure range.

Post-capture in-camera filtration is only part of the solution. There is also a need to modify the digital sensor, whether CCD or CMOS, with specific filtration in some cases, including a low pass anti-aliasing filter and a polarizing filter. This post-optic pre-sensor filtration works with post-sensor in-camera filtration processes.

In the context of specific complex processes, such as in zoom lens modifications of focal length and in full-motion video processing, additional corrections are performed using the digital imaging system which continuously optimizes performance.

Finally, the present system reveals approaches to improve network coordination and wireless external storage and publication capabilities for digital imaging systems.

BRIEF SUMMARY OF THE INVENTION

The present invention is divided into several main sub-systems: (1) digital filters to correct optical and digital aberrations; (2) digital sensor improvements and nano-grids; (3) digital system improvements that link multiple digital corrections; (4) dynamic digital imaging system improvements that apply to zoom lenses and video imaging; and (5) digital image network improvements. There are several distinct improvements for each category of sub-system listed.

DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic drawing of a digital imaging system.

Fig. 2 is a flow chart of an analog to digital signal process.

Fig. 3 is an image of the vignetting corrective filter in an optical lens.

Fig. 4 is a list of wide angle 35mm lens types.

Fig. 5 is a flow chart of the digital corrective process.

Fig. 6 is a schematic diagram of different types of optical aberrations in different configurations of the same lens.

Fig. 7 is a flow chart of the process of digital image capture, processing and storage.

Fig. 8 is a flow chart illustrating the process of selecting filtration settings.

Fig. 9 is a pair of diagrams showing the varied depth of field optimization at different apertures.

Fig. 10 is a flow chart showing exposure optimization using digital correction in camera.

Fig. 11 is a flow chart illustrating the use of in-camera special effects filtration.

Fig. 12 is a flow chart showing the selective in-camera filtration of specific objects.

Fig. 13 is a flow chart describing the exposure adjustment of an image using in-camera filtration.

Fig. 14 is a flow chart showing the process of in-camera special effects filtration.

Fig. 15 is a flow chart showing the process of in-camera digital correction for sensor dust.

Fig. 16 is a diagram showing a digital camera with an ASIC array.

Fig. 17 is a diagram illustrating a digital camera with interchangeable CCD and CMOS sensors.

Fig. 18 is a diagram of a digital camera with a nano-grid before the sensor.

Fig. 19 is a diagram of a nano-grid.

Fig. 20 is a diagram showing the feedback loop connecting the processor and the nano-grid.

Fig. 21 is a diagram illustrating the tri-pixel architecture in a digital sensor.

Fig. 22 is a flow chart showing the pre-programmed modules for in-camera functionality.

Fig. 23 is a diagram showing the pre-sensor modification process in a digital camera.

Fig. 24 is a flow chart showing the integration of optical and digital corrections with feedback.

Fig. 25 is a flow chart showing the interactive feedback mechanism of integrated corrections.

Fig. 26 is a flow chart describing the adaptive user pattern learning process to process images.

Fig. 27 is a flow chart describing the feedback process in filtering images.

Fig. 28 is a flow chart showing software privacy function in a digital imaging system.

Fig. 29 is a flow chart showing the dynamics of zoom lens corrections in digital imaging.

Fig. 30 is a diagram illustrating object tracking in dynamic changes in video corrections.

Fig. 31 is a flow chart showing object tracking of a digital imaging system.

Fig. 32 is a flow chart showing the caching process of an object in motion in a stationary scene.

Fig. 33 is a diagram showing network coordination of fixed sensor grid tracking multiple objects.

Fig. 34 is a diagram showing the wireless communication features of the digital imaging system.

Fig. 35 is a flow chart showing an image organization system.

DETAILED DESCRIPTION OF THE INVENTION

(I) Digital Filters to Correct Optical and Digital Aberrations

(1) Lens-specific digital correction of fixed focal-length lens for specific optical aberrations in camera.

Each lens has some sort of aberrations because of the trade-offs involved in producing lenses of usable size and practical commercial cost. The challenge of building lenses for SLR camera systems lies in accounting for particular restrictions and compromises, particularly for wide-angle and zoom lenses. In the case of wide-angle fixed focal length lenses, several main kinds of aberrations occur, including spherical aberration, distortion (pin cushion distortion and barrel distortion), astigmatism, curvature of field (manifesting as the reduced corner exposure of vignetting) and comatic aberration (a distortion evident with long exposures). The extremes of each of these aberrations have to be corrected in post-production.

In the case of vignetting, a type of aberration in which the corners of an image are exposed a stop less than the image's center area, software can digitally emulate a center-neutral density filter to compensate for the light fall-off on the edges. This operation identifies the

degree of light fall-off for each specific lens and adjusts the brighter areas in the center of the lens by appropriate exposure compensation. A consequence of this digital equivalent of the traditional optical solution to vignetting is that the image will require exposure metering of the subject at a level consistent with the outside edges of the image rather than the typical inner section. In the present system, the camera will use pre-set calculations compensating (generally one stop) for the specific gradations of the curvature of the field for each lens, with an increasing compensation correlated to an increased angle of view. Similarly, barrel distortion and pin-cushion distortion, which also manifest in image corners, are corrected using processes of employing pre-set calculations, to compensate for optical distortion, particularly in wide-angle and zoom lenses.

In addition to integrating into the camera the traditional process of image correction for exposure gradations of vignetting, the present invention offers two further embodiments. First, instead of darkening the center to match the darker corners, the in-camera digital compensation system will lighten the corners to match the exposure of the center of the image. In the second embodiment, the in-camera digital compensation system will both lighten the corners somewhat and darken the center of the image somewhat, to produce a more pleasing and realistic effect. The in-camera digital corrections of the vignetting problem dramatically improve the traditional optical solution of a center-weighted neutral density filter, which typically degrades image quality as it evenly illuminates the full image.

Since each lens has specific aberrations, depending on manufacturer and even differences in the specimens themselves, the camera software system will have preprogrammed general corrections for each specific lens type. For instance, while a 20mm f2.8 lens varies among manufacturers, the general optical aberrations will be similar. An effective software solution is one which brings the optical image quality to a level consistent with a benchmark as measured by low MTF curves for each lens in its class in terms of both resolution and contrast throughout the image. To exemplify this benchmark, retrofocus rangefinder lens performance results of wide-angle lenses, which lack a shutter mechanism to design around, can be used for comparison. To accommodate the mirror in the SLR design type, the rear nodal point in SLR lenses are shifted forward, creating distortion. In contrast, the present system suggests applying a digital solution to compensate for this problem.

In a general sense, this process of correction is similar to correcting an ocular astigmatism with reading glasses. However, rather than using an optical solution to an ocular problem, the present system reveals a digital solution to an optical problem.

In the process, the camera identifies a specific lens and refers to a database that matches the lens type with the specific aberrations. The aberrations are consistent throughout all images for each formula of a specific prime lens type and are thus corrected by adjusting for each specific aberration category. Generally, the larger the angle of view of a lens, the greater the distortion and the greater the need for in-camera digital corrections.

In addition to the kinds of distortions created in wide-angle lenses, other types of distortion occur primarily in large aperture telephoto lenses, most notably chromatic aberrations that require apochromatic corrections. Rather than employing large, heavy and expensive extra dispersion glass, such as fluorite elements, the present system allows each lens type to be digitally corrected for these types of aberrations. The in-camera digital process works by identifying a specific lens and comparing the lens pattern to an internal database. Mathematical calculations compensate for the shift in red and green light that apochromatic corrections require for very low MTF curves registering high standards of resolution and contrast by emulating the optical benefits of extra low dispersion glass elements.

Since lenses of the same focal length but with different maximum apertures represent completely different lens designs, modifications of their aberrations will vary relative to each specific lens type. For example, a 24mm f/2.8 lens will have a different optical formula than a 24mm f1.4 lens in a 35mm camera system. Similarly, a 28mm f/2.8 will differ from both a 28mm f/2 lens and a 28mm f1.4 lens and will thus each require different adjustments for vignetting, spherical aberration, pin cushion distortion, barrel distortion and coma. In other words, each lens with a unique optical formula will have specific aberrations, the corrections for which will be accessible in a database.

Another type of optical aberration that affects lenses involves flare, which is a sort of specific reflection of light sources. While improvements in lens coatings have been used to correct for flare, high refractive glass also eliminates flare. The present system uses digital processes to emulate these flare reduction functions on lenses even at maximum apertures.

In addition to the lens-specific types of corrections that are supplied by in-camera software, a function that optimizes contrast provided by limited reflected light is required. In

general, lens hoods reduce reflected light. However, in the absence of a lens hood, scattered light will adversely affect contrast in all lenses. Thus, a general digital solution will optimize contrast from reflected light by emulating the effects of a lens hood.

Because the pixels on a digital sensor behave as neutral intermediaries to record light, the aberrations on specific fixed focal length lenses will be prominent. It is therefore necessary to filter out various optical impurities. In all cases, the digital in-camera software program emulates specific filters to effectively correct specific optical aberrations.

By digitally adjusting for optical distortions, the present system advances the state of the art for fixed focal length lens optics, beyond any opportunities available in film cameras. The following chart illustrates a list of optical distortions that are corrected by in-camera digital solutions.

	Fixed Focal Length Lens Type		Zoom Lens Type		
Specific Aberrations	**Wide-angle**	**Telephoto**	**Wide-angle**	**Wide-to-Tele**	**Telephoto**
Spherical	X		X	X	
Comatic	X	X	X	X	X
Astigmatism	X		X		
Distortion (Pin Cushion and Barrel Distortion	X		X		
Curvature of Field	X		X		
Chromatic		X		X	X
Flare	X	X	X	X	X
Scattered light (Unpolarized)	X	X	X	X	X
Color Accuracy	X	X	X	X	X
No Lens Coatings	X	X	X	X	X

(2) Multivariate digital correction using matrix filter system in camera

Since typically several distinct aberrations exist in a lens, it is necessary to correct each of the aberrations. For this multi-dimensional problem there is a multivariate digital in-camera software correction solution. The problem of correcting multiple aberrations presents the additional challenge of requiring acceleration to complete multiple tasks rapidly. In most cases, the hardware employed in a camera's chip set will include an application specific integrated circuit (ASIC) which processes a particular program rapidly. It is appropriate to facilitate the combination of corrections to multiple simultaneous aberrations with an ASIC or multiple ASICs.

There is a need to optimize both resolution and contrast across the image area for accurate light reproduction. One way to do this is to stop down the lens to an optimum aperture of about f/8. However, this solution sacrifices the advantages of a fast lens design and capability, namely, limited depth of field and bokeh (smooth out-of-focus area). Though

resolution is typically improved by stopping down a lens, digital sensors are generally still restricted in their latitude of contrast. Therefore, regarding both resolution and contrast, it is necessary to provide multiple adjustments of the native image with in-camera digital corrections.

While it is possible to produce mathematical algorithms for automatic correction of optical aberrations, it is also useful to have manually adjustable variables. Therefore, the present system includes a function whereby one may omit a specific correction in an image by using a lens with multiple aberrations in order to induce a particular creative effect. This factor may involve a lack of exposure compensation, a lack of correction for spherical aberration or an improperly or partially corrected apochromatic modification.

In one example of the use of multiple corrections, simultaneous application of multiple digital filters concurrently corrects multiple aberrations. In effect, this is like adding layers of different eye glasses to repair multiple types of astigmatisms for each specific ocular condition. The dynamics of correcting multiple simultaneous aberrations may be complex, but since the number and type of aberrations are constrained to a specific lens type, a centralized database may be accessed with specific corrections for each respective aberration. For example, lenses with multiple complex aberrations, such as in very wide-angle lenses, will require multiple corrections. These combinations of corrections become complex as focal length modes change in zoom lenses and as aperture changes.

The following is a list of filter types that provide digital methods of correcting image problems or creating specific effects. The list is not intended to be comprehensive or systematic.

Filter Type in Digital App.	**Most Common Uses**	**Other Filter Types**
UV (and Sky)	General Use	Polarizer
Color-enhancing (and warming)	17mm-200mm (in 35mm)	Close-up
Contrast	17mm-200mm (in 35mm)	Special effects filters
Black and White (Red, Orange, Yellow, Green)	17mm-200mm (in 35mm)	
Infrared	17mm-200mm (in 35mm)	
Color Graduated (Neutral Density)	17mm-200mm (in 35mm)	
Diffusion (Soft, mist/fog, star, streak)	24mm-135mm (in 35mm)	
Combinations (Neutral density and enhancing, Polarizer and UV)	17mm-200mm (in 35mm)	

In the past, these optical filtration processes were added after the production process via editing software such as Photoshop. However, in the present system, these combinations of processes are performed in-camera by user-adjusted settings. In the case of artificial color changes to an image, digital processes emulate specific optical filters by adding a specific color or a combination of colors. On the other hand, in the case of diffusion filtration, the in-camera digital process creates an emulation of optical filters. The classic example of this diffusion approach is the soft filter, which is used for portraiture. In this case, various user-adjustable settings in the camera digitally manipulate soft filtration.

(3) Depth-of-field optimization using digital correction in camera

In addition to correcting optically-generated aberrations with in-camera digital processes, the present system allows in-camera depth-of-field (DOF) optimization by affecting the aperture of the lens that is used.

DOF in an image is dependent on the aperture setting in a lens, in which a moderate DOF range – allowing a subject to be isolated in an image – can be manipulated, that is, extended or narrowed, by the camera's digital processing capability. In the film paradigm, one obtains a specific aperture, and thus the corresponding DOF, that is preset by the photographer. However, in the digital paradigm, by contrast, one can *narrow* an image's surplus DOF range in-camera by manipulating the aperture. This process can only be done in the camera, because once the digital file is sent to post-production editing, the aperture and DOF is already set and incapable of being changed. The aperture is narrowed in camera by isolating the subject and shifting the field of view (forward from the rear range of DOF and backward from the front range of the DOF). Distance information is used to recalculate an optimal DOF. In another embodiment, the camera provides feedback from an internal computational analysis that results in a specification of less DOF and takes another image (or images) with a larger aperture to accomplish reduced DOF at a specific focus point.

The camera will effectively identify a type of subject and provide an optimal aperture for this subject. For instance, for a portrait, the camera will select a shallow DOF around the subject. In the case of a distant landscape, the camera will focus on a distance at infinity and provide a nominal aperture to correspond to shutter speed that will fit the available light as matched to a specific lens. A near landscape photographed with a wide-angle lens will, on the other hand, have a near focus and a maximum DOF; specific subjects will be highlighted with

ample DOF. The camera will also have the capability to bracket exposures in several successive images based on DOF variations.

The DOF manipulation thus depends on a combination of data sets including the particular lens used (wide-angle lenses have greater DOF at moderate distances than telephoto lenses), the distance information and the unique combinations of aperture and shutter speed. DOF will narrow with less distance, with use of a telephoto lens and a fast aperture; contrarily, DOF will expand with a further distance, with use of a wide-angle lens and a slower aperture.

In another embodiment of this process, test images are taken and analyzed, then later images taken with new settings optimize DOF for each image type.

(4) Exposure optimization using digital correction in camera

One phenomenon that film currently records better than digital photo technology is exposure latitude. Film is capable of greater exposure latitude than either CCD or CMOS digital sensors, though each digital sensor type has strengths and weaknesses. For the crucial detail recorded in a scene, film provides far more depth of tonal range. Yet some of this problem – caused by the limits of digital sensors themselves and the way that photons are recorded by electrically charged pixels – can be digitally corrected and optimized in-camera.

The problem derives equally from the method of measuring exposure as well as the method of image capture by a digital sensor. In general, since there is less exposure latitude in digital sensors, as compared to film, the maximum scope is two or three stops in the image tonal range. Consequently, the camera must meter the image within constraints of the tonal range of the digital sensor, with the sacrifice of either shadow detail or highlight detail. In an image with broad exposure range, then, the image will generally be either too light or too dark because metering for one area sacrifices the other tonal category.

One way to solve this problem is to manipulate the lens aperture, because increased aperture within an optimal limit generally increases detail. An optimal aperture of f/8 provides more detail and clarity than at f/2 or at f/32. The in-camera processor may thus seek out more detail in the image by manipulating the aperture to the optimal range of f/5.6 to f/11, depending on the type of subject and the availability of light. With more detail in the original image, it is possible to interpolate the digital data in the image file by increasing both shadow and highlight detail and to gain an additional stop or two of tonal range.

In another embodiment, the tonal range of an image data set is enhanced in-camera by using meta-data to sample the range of shadow and highlight detail. The data sets are interpolated to add requested shadow detail and/or highlight detail. Obviously, some subjects require more or less shadow or highlight (or both), which the camera can correspondingly adjust. These tonal range corrections are user-adjustable.

In an additional embodiment of in-camera tonal range corrections, exposure data are bracketed by manipulating the aperture and shutter speed to lower or raise the overall exposure in one-third to one-half stop increments. This bracketing method may be correspondingly limited to a specific image type. For instance, in a portrait, the extraneous background, which ought to be out of focus, is not emphasized in the exposure data, while the main subject is carefully nuanced for balancing an optimum of both highlight and shadow, or for an exclusive emphasis on either highlight or shadow.

The overall problem of limited tonal range in digital photography stems from mismatched exposure-metering mechanisms of digital sensors with substantially restricted tonal range capabilities. One interesting example of this problem occurs in scenes with two or more stops of difference, such as a landscape with sky on top and earth on bottom. A filtration process will operate on the key parts of such an image, as described above regarding the vignetting phenomenon; the overexposed top half of the scene will be gradually underexposed while the lower half of the scene will be gradually overexposed. This scene-specific adjustment of exposure greatly increases the tonal range of digital images and is made possible via analysis of the scene and comparison to a database of typical scenes categorized by the in-camera digital processor which effects correction using the methods described herein. In this example, the corrective process emulates the use of neutral-density optical filters.

(5) Special effects digital filtration of specific objects

Though there are several main categories of special effects optical filters, including color enhancing, infrared and diffusion, the use of diffusion filters appears to elicit the most dramatic effect. Diffusion filters are categorized as soft effect, mist/fog, black mist, gold diffusion, and star and streak, with various degrees of diffusion producing lesser or greater distortions. In effect, rather than removing optically-generated distortions, we are deliberately creating photographically desirable distortions. It is possible to reproduce these special effects by using

the digital post-capture production processes in the camera. In this case, the camera digitally emulates the special effect by applying user-adjustable filter settings.

Portraits have traditionally used some sort of soft effect filtration approach which is producible in the camera using the methods described here. After the image is captured, the camera analyzes the image's meta-data and applies a correction by interpolating the data with specific filter emulation. In the past, specific camera lenses, such as the 135mm soft effects (also called "defocus control") lenses performed this function optically with an included adjustable lens element. This defocus control lens type will focus on the main subject and a lens element setting of the telephoto lens to produce a soft filter effect. In addition, because this lens type uses a nine blade aperture, the background that is out of focus has a pleasing bokeh in which the gradations of tone are evenly smooth. Nevertheless, a sophisticated digital camera is able to produce the same results with more information provided by a normal telephoto lens, using the method of emulating special effects in-camera.

Another novel special effect that is a further embodiment of the system is the ability of the in-camera digital corrective system to use complex data sets contained and analyzed in an image to create a three dimensional (3-D) representation of the image. The camera creates a 3-D image by arranging the DOF in a way that optimizes the aperture by using distance information and autofocus data to isolate a subject. By removing the foreground and background of the image as a center of subject focus, the DOF will emphasize the subject only as 3-D. The key to this effect is the application of specific exposure data as indicated above, because it is in the increased extension of the range of highlight and shadow that the subject in the image will attain a 3-D quality in contrast to its out of focus foreground and background.

An additional embodiment of the present system would extend the still photography in-camera special effects to video with full-motion ranges of filtration actions.

Finally, it is possible to *combine* different user-programmable special effects in-camera by adding the various types of diffusion methods for a specific image.

(6) Selective in-camera filtration of specific objects

The combination of sophisticated auto-focus technologies and in-camera auto-exposure systems provides the opportunity to isolate a subject by focusing on the subject and narrowing the DOF range by manipulating the aperture. In a further extension of the subject-isolating capabilities of these technologies, it is possible to digitally filter out specific objects in a scene

in-camera while focusing on other selected objects that are in a specific range of DOF. In other words, one may apply filtration to correct aspects of a single object or only the background of a scene to the exclusion of an isolated object, rather than correcting a whole scene. Selective filtering of specific objects in an image by in-camera digital processing affords greater creative flexibility.

Because the camera uses distance information to isolate a specific object by focusing on the object within a range of DOF, it is possible to isolate a particular object for the purposes of applying a specific filtration preference, such as manipulating the color, correcting the optical aberration (say, if the object is in a corner of the image of a wide-angle lens), providing a special effect (such as a soft effect only on a specific object rather than the scene as a whole) or using some combination of these corrections. Once the camera isolates the selected object (using auto-focus mechanisms and distance information), the user selects programmable correction features to perform a corrective function only on the specific object (or only on the parts of the scene that are exclusive of the object). In a further embodiment, contrastively, once the object is isolated, only the background may be selectively manipulated with filtration, achieving pleasing effects. This in-camera corrective feature provides a powerful tool to rapidly manipulate an image without using post-production editing software tools.

These object-specific in-camera selective filtration capabilities are particularly dramatic with fast-moving action photography in which split-second timing produces the preferred complex effects. Selectively identifying a particular object for intensive combinations of filtration is a highlight of the present system.

(7) Digital correction in-camera of intermittent aberrations caused by dust on digital sensor

Dust on a digital sensor is a major concern for photographers. The use of zoom lenses compounds this condition, because as the zoom lens changes focal-length positions, air is transmitted, which results in the proliferation and diffusion of sensor dust. Unless photography is isolated to a clean room, the problem of dust on a digital sensor will remain prevalent. The present system provides a method to correct for this phenomenon.

In the case of dust on a sensor, a specific consistent pattern emerges on each image captured by the digital sensor. Consequently, information from various images is analyzed, and the pixels affected by dust are identified. Information from the consistent fixed pixel positions that are affected by the dust are then isolated. The specific positions with the dust are then

analyzed by comparing the immediate areas surrounding the dust that are not affected by it. These unaffected areas are analyzed, and the affected areas are interpolated to provide a continuous tone. In effect, the images identify the locations with dust by using caching technology. The continuity of the location of the dust between multiple images provides information to the in-camera image processor to detect the specific pixel locations. The camera will then apply a corrective process to the isolated dust locations with adjoining exposures by interpolating these distinct locations for each specific image configuration.

In another embodiment of the present system, "hot" (too bright) or "dead" (too dark) pixels are interpolated out of the scene using the method described above. Unlike hot or dead pixels, dust is a similar but temporary version of the same problem of an artifact that requires in-camera modification. In effect, a map is built to discover, isolate and interpolate bad pixels, which are a permanent problem revealing a key limit in digital sensor technology. Separate maps are constructed for permanent pixel dysfunctions and temporary pixel aberrations (viz., dust). In both cases, the camera works from these maps to correct the aberrations on a pixel-level.

In a further embodiment of the present system, Monte Carlo analysis is applied to the problem of identifying the location of dust on specific pixels (or partial pixels) by randomly creating an initial map from information of at least two contaminated images.

In still another embodiment of the present system, the process of modifying pixel aberrations (either permanent or temporary) uses a sequence of operation which begins by correcting the major aberrations first, then repairing the minor aberrations, thereby maximizing efficiency. This is done by starting the corrective process in a specific location of the image and moving to other positions in an efficient pattern.

(8) Sequence of corrections for multiple (optical and digital) types of aberrations in camera

Since it is evident that multiple digital filtration approaches may be used for specific types of problems or aberrations or to achieve specific effects, it is clear that a combination of the techniques may be employed simultaneously on specific images. The present invention allows the various optical and digital corrections to be performed in camera in a sequence of actions. The user selects the various combinations of functions required to be performed, inspects the effects, and chooses the most effective combination of effects. Thus the invention offers a combinatorial optimization of the totality of corrective filtration approaches.

After the images have been taken, it is possible to inspect them in the camera using the camera's image read-out. This makes it possible to create new files, or to adapt a RAW file, in real time, by manipulating the various corrections in sequence. This post-image-capture in-camera editing process allows multiple corrections to be applied to a range of optical and digital aberrations by combining various specific corrective techniques.

In some cases, the user can pre-set specific corrections. For instance, to correct for optical aberrations, a user may leave this function on permanently. In other cases, such as selective filtration of a specific object or optimization for DOF or exposure, there may be discriminating use of specific corrective functions. In the case of selective user choice, it is possible, by using the present invention, to select a priority sequence of corrections in layers. While specific select layers may be permanently activated, for example to automatically adjust specific optical aberrations, additional sets of layers may be manually selected in order to modify the specific aspects of each image, particularly to adjust or correct digital aberrations. This process can be performed with a single microprocessor, multiple microprocessors, multiple ASICs or a combination of microprocessors and ASICs.

An additional embodiment of the system provides multiple combinations of corrections and effects via multiple independent ASICs, which only perform specific functions, working in parallel. The various tasks are divided into specific-function ASICs for rapid processing. The advantage of this approach is accelerated processing speed in performing multiple simultaneous functions.

(II) Digital Sensor Improvement and Nano-grids

(9) Interchangeable digital sensor system using both CCD and CMOS to optimize best results

Because the main digital sensor types of CCD and CMOS, like film types, each have benefits and detriments, it is sometimes advantageous to provide the utility of both sensor types in a camera system. With the exception of a video camera, which employs three CCDs, the use of multiple sensors has not been adopted. Two generations ago, however, the idea of using a twin reflex camera for medium format photography was implemented. In this case, though focus was coupled between the lenses, one lens was used to see the subject, while the other lens took the picture. This method was used to obtain the benefits of a rangefinder camera with a single lens reflex camera.

The use of two types of sensors in a camera is compelling, because the user benefits from the strengths of both. In the present invention, one sensor is selected from among at least two different types of sensors that are rotated to an active position by the user. One advantage of this approach is that if one sensor experiences a problem, there is a reserve sensor available at the push of a button.

This capability usefully exploits the strengths of each particular sensor. For instance, in situations in which high resolution is required, a CCD may be preferable, while in cases in which increased tonal range or low noise is preferable, a CMOS sensor may be preferable. With this approach, a customer does not need to choose between different types of sensors.

The process of interchanging the two chips is performed by placing the two chips on either façade of a plane that "flips" over (i.e., rotates 180 degrees) upon demand to obtain the requirements of the chosen chip type. This mechanism would fit behind an SLR's mirror and could easily be performed as long as the mirror is in the "up" position. In another embodiment, the chip exchange process can occur by sliding alternating chips into a sleeve from a single location and replacing the non-utilized chip(s) into the reserve compartment. In either event, the camera will detect the chip exchange and will automatically reprogram software functions and settings for the usable chip.

(10) Nano-grids for selected pixels on CCD or CMOS integrated circuits to optimize selective modifications of exposure, ISO and aberrations in digital photography

Digital sensors consist of arrays of pixels, arranged in rows, which behave as tiny buckets for converting photons to electrons. As the pixels fill up with light, they are able to discern slight differences in color and exposure and transfer the energy, in the form of electrons, to storage. Charge coupled devices (CCDs) have been the predominant form of digital sensor because they use a form of electronic charge which creates the behavior of a bucket brigade of transferring data, once the buckets in a row are filled up, to successive rows for digital data storage of the electronic charge sets. CMOS digital sensors may be structured with larger bucket pixels, which can increase the depth of the light captured and thus the latitude of light exposure that is stored. However, for the relatively larger buckets to provide increased photon capture capacity, it is necessary to control the width of the opening in the top and the width of the buckets so that the amount of light captured may be modulated.

The present invention introduces a key advance in the ability of digital sensors, particularly CMOS sensors, to modulate the size of the openings of the pixels. Specifically, the present system provides for a nano-grid, or a very small matrix of filaments, which fits over the sensor. The nano-grid is carefully calibrated to match the rows of pixels on the sensor so as to limit the amount of light that each of the buckets may receive. Use of the nano-grid allows a selective closing of the large buckets in order for photons to be restricted. Selective modification of specific pixels on the neutral grid makes it possible to identify specific sets of pixels to correct for various exposure or lens aberrations.

In this embodiment of the present system, data about a specific lens are provided to the camera in order to correct specific lens aberrations, while exposure data is used to modify image capture using nano-grids for optimum image performance.

Nano-grids may be selectively switched at different pixel sites, akin to continuously programmable field programmable gate array (CP-FPGA) semiconductors, which modify architecture in order to optimize effective operation by constantly manipulating the chip's gates.

Nano-grids may be used for specific image modes, for example, nocturnal imaging, which requires more time to read a sufficient amount of light. In this case, a specific software module may provide lens and exposure data to the camera, which then determine the precise composition of nano-grid correction to provide to specific sets of pixels on the digital sensor. In effect, nano-filaments move to positions to effectively block out the full capacity of the pixel buckets and thus change the pixel effects. With use of preset nano-grid positions for particular applications, the identification of specific vectors of nano-filaments is performed, and exposure adjustments are made on specific images in hardware.

The nano-grid is overlaid over the surface of the pixel architecture. The nano-grid is used not only in specific pre-set positions, but it also provides feedback to the post-capture system for analysis and repositioning to achieve the desired effects. One effect of the nano-grid is to manually expand or narrow the range of a set of pixel buckets; this process in turn effectively modifies not only the exposure range but also sharpness at high ISO, thereby dramatically reducing noise. Consequently, it becomes possible, by modifying the pixel bucket width and height, to obtain extremely sharp images with excellent contrast and tonal range even in poor lighting, a feat heretofore impossible.

The nano-grid performs these mechanical functions by moving the nano-filaments in an arc, like expandable windshield wipers. Though nano-grids are particularly useful in CMOS chips, they are also useful with CCDs. In fact, with the advent of nano-grids, CCD pixel size (and density in pixel-rows which will affect the overall sensor size) may be expanded and thus made substantially more versatile.

In a further embodiment of the present invention, multiple screens, or grids, would be placed over the digital sensor. The use of multiple nano-grids provides increased capacity to perform the function of closing off the pixel buckets and, in fact, to completely close off selected pixels to make the image effect completely dark. The combinations of nano-grids behave as multiple screens that move left and right to achieve the desired effect. Although there is a need to periodically calibrate the screens to effect their precise positions, this system will employ an electric charge to push the nano-filaments to the desired locations.

Nano-filaments move to block the space allowing photons to hit the pixel in order to limit the amount of light capacity available to the pixel. The complete darkening of the pixel will result in a total black color in the resulting image.

Exposure data feedback is provided to the digital sensor to effect the precise positioning of the nano-grid(s). In a further aspect of the present system, the camera's computer will anticipate the exposure data by statistically extrapolating from the pattern created by at least three data sets. A microprocessor (or ASIC) controlled nano-grid mechanism will use the feedback to anticipate specific nano-grid positions in order to optimize the exposure and corrective functions.

In one application of the nano-grid, the problem of vignetting in wide-angle lenses may be solved by activating nano-filaments in nano-grid(s) primarily in the corners to correct for the darkening from the limits of the optical aberrations, while still maintaining very low noise in a high ISO (low light) photographic situation. The use of the nano-grid would thus contribute to solving multiple problems.

Nano-grids will also be useful in accurately correcting for both color and exposure detail. In fact, with nano-grids, the capacity of digital sensors' range should be substantially increased, because the chips' pixel bucket sizes can be modulated. Therefore, not only will the lighting and color be accurate, but sharpness and optical aberrations will also be optimized, in ways not possible before.

(11) Integrated nano-grids in digital sensor

In a further embodiment of the system, nano-grids may be integrated into the digital sensor. In this form of the nano-grid, the nano-filaments are constructed *within* the pixel buckets in order to increase their accuracy and responsiveness. The nano-filaments mechanically move in various directions to perform the main operation of modulating light into their respective pixels. This method of organizing nano-grids and nano-filaments increases the rapidity of response to feedback. In effect, each pixel has a mask, or flexible lid, contained in it, which may open and close, to allow more or less light into the pixel bucket.

The integrated nano-filaments are activated by oscillation between positive and negative charges. In the context of a CMOS sensor, the transistor networks oscillate between positive and negative charges. This architecture allows a "push-pull" design of nano-filaments in which the negative charge "pulls" and the positive charge "pushes" the activation of the nano-filaments. This charge-enabled nano-grid (CENG) advantageously allows modulating gates (i.e., filaments) integrated into the pixel to reduce spaces between pixels, thereby allowing more pixels to be packed on the same surface area. The net benefit of the use of integrated CENG filaments is that specific sets of nano-filaments will produce specific effects on-demand and allow far more tonal detail than has been possible before.

In a further embodiment of the present system, sophisticated digital sensors may contain combinations of nano-grids that appear on top of the sensor as well as nano-grids that are integrated into the digital sensor. This combination will provide maximum latitude for processing the greatest effect available.

(12) Combinations of nano-grids and digital corrections applied to digital imaging system

Whereas it is possible to exclusively implement nano-grids to control the amount of light penetrating specific pixels, and it is possible to exclusively provide digital corrections as specified above regarding correcting optical or digital aberrations, a further embodiment of the present invention combines the two processes in order to optimize imaging.

Combining these two complex processes makes it possible to modify pixel capacity to maximize exposure latitude, to expand exposure modification and to apply digital correctives for optical and digital aberrations. Hence selective exposure far beyond the limits of present film or digital photography is made possible. The restrictions of film can thus be transcended by using

the present system, whereas use of a static and limited digital system would not be sufficient to facilitate these complex corrections.

The unique combinations of these processes also illustrate a complex system that provides feedback from both the environment and the photographer. The photographer may select preset exposure settings that will activate a range of options in both the nano-grids and the digital corrective system, while the lens aberration corrective system is automatically implemented. Once the camera detects specific conditions, such as a broad range of exposure latitude, from very bright to very dark, in the scene, it computes the precise number and location of nano-grids needed to modulate the pixels for optimum exposure with highlight and shadow detail and extreme sharpness, even in relatively low light. The dynamics of these multiple processes present trade-offs in selecting the best available set of selected modifications.

(13) Tri-well pixels

As indicated above, one of the key problems with current digital sensors involves dynamic range. There is a need to limit the scope of the space in the pixel well, into which light is captured, then converted into electrons. The challenge with current technologies is to balance details in shadow and highlight areas, particularly to acheive low noise at relatively high ISO speeds.

In addition to the concept of nano-grids, both in surface screen and integrated embodiments, as specified in (10) to (11) above, the present system introduces the notion of three side-by-side differentially-sized buckets within each pixel intended to optimize dynamic range for increased sensitivity. In the most common configuration, the three different-sized buckets are arranged with the largest bucket (in both width and height) in the center, with the second and third largest buckets on either side. The buckets are elliptical and concave in architecture to increase efficiency of fitting together in a round pixel structure. Their structures are semi-circular and elongated. The largest and tallest bucket will be tasked with maintaining the details in highlights, and the smallest will be tasked with maximizing the details in shadows, while the mid-sized bucket will be tasked with maintaining the middle range of exposure details. The pixel will have data from all three buckets available, but will select the data from one or more buckets depending on the exposure details.

The system is analogous to the high fidelity sound technology in speakers with crossovers, whose several frequencies are used by the tweeters, mid-range(s) and woofers; the

crossover point at which the frequency changes from one component to another can be modified based on the specific mechanics of each component.

In the case of the multiple buckets in a single pixel, the buckets are connected by filaments to a central grid which captures and stores the electrons. When the photographic scene displays increased light, image data from the larger buckets are selected to be recorded by the processor, while in cases of darkness and increased need for sensitivity, the smaller buckets are selected to be recorded; the mid-sized bucket is used in normal light situations of most cases. Further, this multi-aspect architecture can use pixels in varying positions on the sensor differently, particularly to facilitate processing far more dynamic range and to produce uniform tonal range in scenes that vary more than two or three stops. This novel multi-aspect model solves a number of key problems involving exposure dynamics in digital photography.

In another embodiment of the system, there may be more than three buckets in a pixel, so as to divide out the functions further and create even finer tonal continuity. In a further embodiment of the system, several pixels in a super-pixel allow red, green and blue colors to be segregated by each sub-pixel. This approach will be useful particularly in CCD semiconductors because of limits of this architecture, which require coupling circuitry between pixels to pass a charge between rows of pixels. In this case, outputs will vary between the micro-pixels to facilitate the differential processing required.

While cases of two side-by-side pixels might solve these exposure latitude problems, they represent an inadequate solution, much as a speaker with only two components limits the dynamic range output dramatically in contrast with a speaker with five components. This is similar to comparing a diode and a transistor.

(III) Digital System Improvements that Link Multiple Digital Corrections

(14) Auto pre-programmed modules for specific functions in digital imaging system

To process the functions specified in this integrated digital imaging system, it is necessary for automated pre-programmed modules to detect the specific lens type and the specific digital sensor(s) used to assess the appropriate corrections or alterations. The purpose of the pre-programmed modules is to access a preset library of (a) typical corrections of lenses, (b) typical scene types with appropriate exposure modes, (c) specific effects that may be selected and (d) specific sensor functions. It is important to match a particular lens to a particular sensor

type so that adjustments are calibrated to this pairing. The processing software is stored in either a microprocessor or an ASIC in order to process the images after they are captured by the sensor but before they are transferred to storage on a memory device.

In another embodiment, the system processes image corrections after the digital data is stored and constantly accesses the original stored data file in the production of a corrected file. This process allows for immediate data processing and storage which affords more time to accomplish specific corrective functions. There are thus cases when real-time correctives are neither necessary nor possible. Such increased processing capability may also facilitate a more complete corrective task.

In an additional embodiment, because similar correctives and effects may be provided to images that share the specific combination of lens and sensor, in order to accelerate the process of optimizing the images, batches of similar images may be processed together. This batch processing method may include the creation of duplicate images for each image captured, including a RAW image that contains no changes to the native image capture and a simultaneous auto-corrected image. The optimized image may be simultaneously compressed, to maximize storage capabilities, while the RAW image may be left uncompressed so as to maintain original detail.

(15) Apparatus and process for affecting pre-sensor optical and digital corrections in digital imaging system

Given the nature of light transmission, not all optical corrections are optimized by modification after the image is captured by the sensor. Though a range of important corrections and effects may be made after image capture, such as correction for optical or digital aberrations, there are several types of corrections that are required to be made before the light reaches the sensor. One example of this pre-sensor digital correction involves the use of a low-pass or anti-aliasing filter that resides in front of the digital sensor to minimize moiré and aliasing digital problems (although the use of this filter adversely affects image sharpness).

In the case of optical corrections, one class of filter that requires use before the digital sensor is the polarizing filter, because once light is captured on the digital sensor, the polarizing effect will not be available. Another type of correction that involves use of a filter or lens before the digital sensor is the close-up filter. This latter solution allows a lens's closest focusing plane to be closer to the front of a lens and has the effect of diminishing the rear plane of the depth of

field. The close-up filter may be optimized for use with floating rear-element group lenses which allow increasingly close focusing. In one embodiment of the system, specific pre-sensor optical filters may be used to provide polarization and close up corrections. The use of in-camera optical (circular) polarization would help standardize this valuable process and eliminate the need to maintain several external polarizer filters for each lens mount.

Since the present system entails an embodiment which uses nano-grids to perform specific exposure modifications before the light hits the digital sensor, it is possible to use these nano-grids for the applications of polarization and close-up filter. These filtration capabilities occur between the lens and the digital sensor.

In order to optimize the use of pre-sensor filtration, an image is initially tested and analyzed before the optimized corrections are activated and the pre-sensor changes are made. This process is analogous to the use of automated flash photography in which a feedback mechanism is provided; a scene is evaluated, and the initial flash data analyzed and modified to correspond to the correct exposure before a final flash is produced.

Because the camera system processes post-capture data, in order to optimize images for optical and digital problems, as well as continuously makes changes to pre-sensor filtration, multiple ASICs work in parallel to make the conversion of the image after capture. The use of parallel ASICs to perform specific correction processes solves the problem of capturing images and making post-capture corrections while simultaneously adapting the pre-sensor filtration system.

As an alternative embodiment of the system, a microprocessor (and software) may perform specific pre-sensor adjustments while the ASIC(s) performs specific corrective functions. In another embodiment, the ASIC(s) may perform the specific pre-sensor adjustments while a microprocessor (and software) will perform the specific corrective functions.

(16) Integrated digital imaging system for optical and digital corrections with feedback dynamics

Because the present system consists of, and uses, complex sub-systems, including an auto-focus mechanism, an auto-exposure mechanism, a shutter mechanism, an automatic flash mechanism, a digital sensor mechanism, a digital processing mechanism and a digital storage mechanism, it is possible to realize interaction dynamics that contain feedback. The interactive process of operating these sub-systems involves a learning progression. The image is analyzed,

solutions are tested and an optimal solution is selected and implemented, all in real time. By choosing a specific logic vector in a decision tree involving an initial variable, the process begins again with another key variable in real-time until the final image is captured and optimized.

In order to accomplish these complex processes, specific variables, such as aperture data, shutter speed data, lens data, digital sensor data and subject type are registered and analyzed by the camera. As environmental data changes, the camera mechanisms adapt to the environmental and the photographer's situation.

In order to accelerate these processes, the camera learns to anticipate the user's behaviors, the user's preferences and the subject's behaviors. By providing user-adjusted setting modifications for optical and digital corrections, the camera establishes a reference point for processing rapid image changes. In particular, the camera's software will analyze trends in the user's pattern of behaviors and preferences as well as pattern changes in the subject's behaviors. Anticipation processes are programmed into the autofocus and automated flash systems because of the extremely rapid reaction-time requirements of these specific mechanisms.

In one embodiment of the system, a method of processing a chain of rapid image captures is to employ computer-caching techniques in which a first image is processed in a normal way while later images are processed in an accelerated way. This is possible because the first image provides data to the system to analyze; these data then allow the system to anticipate further similar images and to use similar auto-focus and auto-exposure data. The optical and digital corrections are performed in a batch fashion by applying similar changes to near-identical image problems in order to dramatically accelerate the processing speed of a chain of images. This caching and anticipation approach is very useful in fast-paced action photography.

Another embodiment of the process of rapidly capturing a chain of images in sequence employs multi-threading techniques. Dividing the functions between specific subsystem ASICs allows multiple corrections to be performed in a parallel cascade for efficient task completion. One advantage of breaking down functions to specific processors is the acquired ability to start on one function and, while the system is in the process of completing a task, to begin other tasks. This process eliminates the lag between the specific subsystems.

(17) Adaptive user pattern learning with user-programmable functions in digital imaging system

In order to optimize its functions, the camera needs to learn about the user's preferences. When the user uses the camera, the camera evaluates the use patterns. Since the camera is programmed with a database of common user patterns, it can identify common uses and anticipate common uses of similar users by employing a "collaborative filtering" mechanism (i.e., if you like this camera setting, you should like this other setting because similar users who have liked the first setting have also liked the second setting). By anticipating common uses of each camera user, the camera optimizes its functions for each use and for each user. In effect, the camera's learning of user preferences is a sort of guided process of experimentation. Evolving algorithms learn about the user from actual use patterns.

One positive effect of this learning process of the camera about the user's patterns of behavior is that the filtration process becomes adaptive. The camera builds an initial map of the user's preferences from the user's actual selections. From the starting point of common types of personal selections, the camera uses standard templates of main types of uses that are fulfilled for each user's applications. For instance, if a photographer typically takes portraits with a traditional portrait lens, the camera will be aware of this and will activate filtration processes that are optimal for this type of portraiture photography, such as instilling limited depth of field on a subject and out-of-focus foreground and background. Contrarily, if landscape images are selected, depth of field will be increased substantially and the lens focused on either infinity or a medium point depending on the specific type of subject matter. The camera builds a model for each user based on the accumulation of experience.

In order for the camera to learn about the preferences of a specific user, the camera must adjust to each particular user, much as each individual identity must log onto a computer network privately.

Since the dynamics of the combined subsystems are complex, and adaptive, it is necessary that automated adjustments be interactive. Once detection of the lens type, the sensor type, the exposure settings, the user and the subject is made, optical and digital distortions are identified and specific combinations of corrections are applied both before and after the digital sensor in order to optimize the image. All of this is accomplished in less time than the blink of an eye.

(18) Software privacy function in digital imaging system

Because digital camera systems are able to use software and wireless mechanisms for their operation, it is possible to activate aspects of the camera remotely. Conversely, it is possible to disable operations of the camera remotely.

The present invention embodies a capability to externally disable the camera remotely in specific locations that require privacy, such as secret government areas (courthouses), private homes or businesses that are image-free zones. In these cases, a signal from an external source is provided to disable the shutter from firing. This black-out capability will allow external control of access to specific sites. As a condition of access, only a camera with this feature may be admitted to public buildings, so that even if the camera is permitted to operate, permission is only conditional. For instance, the owner of the building may allow the camera to function only in a specific set of rooms but not in others. Cameras without this feature may not be allowed in private spaces where control must be externally restricted.

This blocking feature will require the addition of specific blocking software, which may be automatically downloaded as one enters specific buildings. Similarly, in order to be granted permission to access the camera, or specific functions of the camera, the downloading of a "key" may be required.

Moreover, a further embodiment of the system may make it necessary to download software keys to get access to filtration capabilities in the camera in order to obtain optimum images. For example, the user may be required to pay a fee to download software in real time that will permit her to access a particular function in the camera to obtain a critical image. A spectrum of quality and complexity in filtration capabilities may be made obtainable for a range of fees on-demand. Therefore, the external downloading of software for the camera need not be limited to a black out function.

(IV) Dynamic Digital Imaging System Improvements that Apply to Zoom Lenses and Video Imaging

(19) Dynamics of zoom lens corrections in digital imaging system

Whereas the optical aberrations of prime (fixed focal length) lenses were discussed above, the modulation of optical aberrations of zoom lenses is another problem to consider. As a wholly different species of lens, zoom lenses have become extremely complex optical mechanisms consisting of multiple groups of lens elements. The general problem with zoom

lenses is the trade-off that must be made: To minimize the distortions of the widest possible focal length, distortions become maximized at the longest possible focal length, and vice-versa. Consequently, zoom lens architecture is inherently compromised on image quality. Over the years, lens designers have developed lens formulas that have dramatically improved image quality and that compete with typical prime lenses. As an example of this evolution in quality, the class of 70-200 f/2.8 35mm zoom lenses, now in their sixth generation, has supplied substantial improvements over earlier telephoto zooms. However, in general, zoom lenses have more aberrations than primes and thus require increased optical corrections. The need to solve the problem of zoom lens aberration correction is accentuated by their increased use in photography because of their simplicity and versatility.

The dynamics of the zooming process present specific difficulties for the purposes of correcting optical aberrations in digital imaging systems. With fixed-focal length lenses, the camera can detect the lens and provide an immediate consistent modification for a varying range of apertures. In the case of zooms, however, where the focal-length is not fixed, the adjustments must correlate to the changes in the focal length. In effect, this condition presents a continuous resampling process. When combined with changing scenes, the zooming process requires far faster responses to changing inputs by the camera system. This process resembles the tracking of a kaleidoscope's changing image structures as the wheel on the device is constantly turned.

In order to solve the problem of distortion at the wide-angle part of select zoom lenses, manufacturers have been using aspherical elements which are complex shapes that require special production techniques. On the other hand, in order to solve the problem of chromatic aberration in select telephoto lenses, manufacturers have used extra low dispersion glass elements, particularly at the front of the zoom lens. Since there are generally three main classes of zoom lenses – wide-angle to wide-angle, wide-angle to telephoto and telephoto to telephoto – aspherical elements have been used in wide-angle zoom lenses, while extra low dispersion glass has been used in the telephoto zoom lenses and both kinds of lens elements have been included in the wide-angle to telephoto zoom lenses.

The changing focal lengths of zoom lenses add a variable to the complex set of variables of the interacting sub-systems in the digital imaging system. The digital camera system must therefore track the movement of the changes in the focal lengths in zoom lenses and continuously make modifications to the varied optical aberrations in these types of lenses.

Unlike in fixed focal length lenses, the aberrations change at different focal lengths in zoom lenses, and the camera must track these changes.

The present system is designed to make the corrections to these changing aberrations in zoom lenses by noting the changed focal length at specific times of each lens. For a fixed focal length lens, the camera refers to a database of information to provide information to correct specific types of aberrations; for a zoom lens, the camera's database contains multiplex information for each focal length in each respective zoom lens type. This is as if each zoom lens contains a combination of multiple lenses of specific focal lengths. When the zoom is moved to a new focal position, the camera reads the lens as a specific focal length and makes corrections to aberrations based on this specific setting. Although the camera reads the zoom lens at a specific moment in time and adjusts the necessary modifications to correct for aberrations at that specific focal length at that time, overall the zoom lens requires the camera to rapidly make these adjustments.

Since zoom lenses employ dynamic processes of change, it is possible to track a moving subject in real-time by changing focal length from a stationary vantage. These changed focal length positions are tracked by the auto-focus system, but also by the auto-exposure system in the camera. The present system thus allows for zoom tracking in order to anticipate the direction of zoom lens changes, much as the focus on the moving subject involves focus tracking mechanisms. These systems use fuzzy logic and evolutionary algorithms to anticipate the movement of the subject and thus of the focal length change of zoom lens. In this way it is possible to accelerate the lens aberration correction process using zoom lenses.

Because the zoom lenses typically increase aberrations precisely because of the lens design compromises, these types of lenses are ideally suited to the present digital imaging system. The present system allows the zoom lens to be used at high quality without needing to stop down the aperture, thereby resulting in superior photographic opportunities.

(20) Dynamic changes in video corrections of digital imaging system

While the zoom lens presents the need to provide a dynamic solution to the process of making corrections to optical aberrations, video photography provides another case of a process that requires dynamic solutions. The same principles that apply to still photography apply to video; auto-focus variability, aperture and depth-of-field variability aspects, shutter speed variability aspects, differences in lens focal length and artificial lighting variability suggest that

video be viewed as merely a very rapid (30 to 60 frames per second) application of still photography. Nonetheless, video presents new classes of dynamic problems, most notably regarding the matter of tracking changing subjects in real time.

The process of shifting subject positions, even if the camera is stationary, presents a change of multiple variables that require the automated subsystems (auto-focus, auto-exposure, auto-flash, etc.) to be integrated. Feedback is presented by subjects in the external environment with changing focus and exposure variables. In these cases, even with a modulating shutter speed, the three main variables of change are a zoom lens to continuously change the focal length, auto-focus to track a subject and aperture modifications to continuously change depth-of-field.

The unique dynamics of these complex sub-systems presents particular challenges for a digital imaging system to produce rapid results with the use of advanced ASICs and microprocessors. By incorporating techniques that track objects with advanced auto-focus mechanisms, anticipate zoom lens changes and predict optimal exposures as well as make automatic corrections to both optical and digital aberrations in real time, the present system continuously optimizes the video imaging process.

(21) "Stationary-scene object-motion" caching process, with application to video, in digital imaging system

Because video imaging processes employ full motion activity, particularly of subjects in the environment, tracking a subject in a video system is problematic. Once a subject is identified and selected, the subject is automatically tracked with auto-focus and auto-exposure mechanisms by a zoom lens apparatus. There is a particular need to identify and track a subject within a broad stationary scene.

The present system accomplishes this task by using anticipatory object-trajectory tracking. The parts of the stationary scene that are not being tracked are cached. In other words, precisely because the background of the scene is stationary, this part of the scene is not tracked for focus or exposure. On the other hand, the object in motion is identified and tracked by subtracting the extraneous data of the stationary scene. Multiple objects are tracked by comparing data about these combinations of objects and their relations and determining the appropriate exposure and focus settings.

While Monte Carlo processes use random settings to self-organize an initial map, which are useful as a baseline for the purpose of anticipating tracking data sets, the present system subtracts the known information about the specific object(s) being tracked from the stationary background in the environment. In other words, the background data is "blanked out" in a caching process while the main subject(s) are tracked. By so using these techniques, the camera system can efficiently calculate the modifications needed to optimize the video scene.

In a further embodiment of the system, a chip-set is enabled in video display devices (i.e., video monitors) to implement select corrections for optical and digital distortions. The user may modify settings for automating the process of achieving optimum video images.

(V) Digital Image Networking

(22) Network coordination of fixed sensor grid to track multiple objects in digital video imaging system

While the previous discussion has focused on employing a single camera to capture images, the present system is also useful for networking sensors in a sensor grid in order to track multiple objects. Specifically, the present system may be used in surveillance and reconnaissance situations to track objects over time. Using a grid of image sensors with overlapping range parameters makes it possible to organize a complex network of sensors for surveillance activities.

After selecting specific objects to track, the system follows the objects as they move from location to location, appropriately modulating the focus, the lens focal length, the ISO and the exposure settings. As the subject moves from one section of a grid to another, the sensors are coordinated to "hand off" the object to other sensors on the grid, much like a cellular phone network hands off calls between cells.

In another embodiment of the present system, the cameras in the network may be mobile instead of stationary in a fixed sensor grid. In this case, self-organizing aspects of the mobile sensor grid track mobile objects in real time. One application of this complex system, which draws on earlier work in collective robotics, is in cinematography, which requires multiple transportable perspectives of mobile subjects. The complex dynamics of a mobile sensor network provides complex feedback in this manifestation of the present system.

(23) Automatic wireless off-porting of back-up images to external data bank

Because the present system uses digital files, it is possible to move these files to an external site for storage. The present system has capabilities to off-port images to an external data bank automatically. This feature is valuable in order to preserve on-board storage capability.

Whether implemented in a local area network (LAN) or a wide area network (WAN), by using a built-in wireless router, the present digital imaging system may be set to send data files directly and automatically to hard-drive storage either in a device in the same room or uploaded to the Internet for storage around the world. This capability is critical for managing massive files of large sensor data sets and preserving valuable in-camera storage space. When automatically sending data files to a nearby computer, the computer may act as a data-port relay to automatically resend the images to an Internet site for storage. The system will maintain the option of keeping some images in the camera and sending duplicate copies of digital files of images to another site for storage as a backup. This automatic back-up process provides insurance for the photographer.

In another embodiment of the system, just as image files are off-loaded to external storage, software files are periodically downloaded to the camera in order to update the camera settings and the database system. For example, as the camera manufacturer provides new lenses for the camera, it becomes necessary to load new updated settings to accommodate corrections for the new lenses. Similarly, as the camera requires new software updates with improved algorithms to further optimize the corrective functions of both the optical and digital mechanisms, the camera will automatically accept these. This feature is particularly important to both manufacturer and user because the ability to update software capability periodically will protect a user from needing to upgrade major hardware such as with a lens replacement.

(24) Image organization system

The present digital imaging system does not merely allow for the storage of image data files on external storage. Because of the problems of protecting storage and the need to make multiple back-ups in the digital sphere, it is also necessary to store digital image files in multiple database locations. The images are organized in a main database by various criteria, such as time, location, subject-type, etc., and then rerouted to various locations around the world for safe storage. While specific sets of images may be stored together, the need to identify the locations is less important than the need to have control of the main database list which identifies the

locations.

In order to maintain security, the digital imaging files may periodically be rotated randomly between locations. Only the main database list, which is constantly updated, maintains information on their location. In fact, specific digital bits of a single image may be maintained at different locations in order to maintain further security. Thus, on many computers around the world bits of each image may be stored, and continuously rotated, with constantly updated registries maintaining their complex hybrid whereabouts. These rotation storage functions are performed by a randomizer logic engine.

In a further embodiment of the present system, once the digital files are off-loaded from the camera system to external storage, specific images may be automatically identified and further specific corrections automatically provided.

In yet another embodiment of the system, the images that are off-loaded from the camera to the external storage system are organized according to various criteria, such as accuracy of focus or exposure or quality of image type, in order to be automatically prioritized. The camera, with the assistance of an initial setting of user priorities, will automatically order new images with a higher or lower priority relative to other images and camera settings. Thus, at the end of a day, the images may be displayed in an order preferred by the user. Lesser images will be automatically routed to a lower position as they do not meet specific criteria, and better images will be routed to a relatively higher position in the organization of files. This feature of automatically assisting in the organization of the digital image files is a very useful one which will save photographers time.

(25) Wireless digital image system automatically generating prints from image capture

The present digital imaging system not only automatically off-loads digital image files to remote locations for storage; the system also will allow one to photograph an image (or sequence of images) in one location (i.e., Paris) and instantly print it in another location (i.e., Los Angeles) for publication in real time. In addition, an image may be captured by the camera and instantly uploaded to a pre-programmed Web site for publication by using wireless technologies. In addition, it is possible to automatically print the digital image file anywhere in the world virtually the moment the image is taken. This system makes this instantaneity particularly possible precisely because the image corrections are automated in-camera. Since there is no

need in most cases to further edit the image files, they are thus generally ready for immediate release.

Description of the Drawings

Fig. 1 is a schematic drawing of a digital imaging system.

Fig. 2 is a flow chart of an analog to digital signal process.

Fig. 3 is an image of the vignetting corrective filter in an optical lens.

Fig. 4 is a list of wide angle 35mm lens types.

Fig. 5 is a flow chart of the digital corrective process.

Fig. 6 is a schematic diagram of different types of optical aberrations in different configurations of the same lens.

Fig. 7 is a flow chart of the process of digital image capture, processing and storage.

Fig. 8 is a flow chart illustrating the process of selecting filtration settings.

Fig. 9 is a pair of diagrams showing the varied depth of field optimization at different apertures.

Fig. 10 is a flow chart showing exposure optimization using digital correction in camera.

Fig. 11 is a flow chart illustrating the use of in-camera special effects filtration.

Fig. 12 is a flow chart showing the selective in-camera filtration of specific objects.

Fig. 13 is a flow chart describing the exposure adjustment of an image using in-camera filtration.

Fig. 14 is a flow chart showing the process of in-camera special effects filtration.

Fig. 15 is a flow chart showing the process of in-camera digital correction for sensor dust.

Fig. 16 is a diagram showing a digital camera with an ASIC array.

Fig. 17 is a diagram illustrating a digital camera with interchangeable CCD and CMOS sensors.

Fig. 18 is a diagram of a digital camera with a nano-grid before the sensor.

Fig. 19 is a diagram of a nano-grid.

Fig. 20 is a diagram showing the feedback loop connecting the processor and the nano-grid.

Fig. 21 is a diagram illustrating the tri-pixel architecture in a digital sensor.

Fig. 22 is a flow chart showing the pre-programmed modules for in-camera functionality.

Fig. 23 is a diagram showing the pre-sensor modification process in a digital camera.

Fig. 24 is a flow chart showing the integration of optical and digital corrections with feedback.

Fig. 25 is a flow chart showing the interactive feedback mechanism of integrated corrections.

Fig. 26 is a flow chart describing the adaptive user pattern learning process to process images.

Fig. 27 is a flow chart describing the feedback process in filtering images.

Fig. 28 is a flow chart showing software privacy function in a digital imaging system.

Fig. 29 is a flow chart showing the dynamics of zoom lens corrections in digital imaging.

Fig. 30 is a diagram illustrating object tracking in dynamic changes in video corrections.

Fig. 31 is a flow chart showing objecting tracking of a digital imaging system.

Fig. 32 is a flow chart showing the caching process of an object in motion in a stationary scene.

Fig. 33 is a diagram showing network coordination of fixed sensor grid tracking multiple objects.

Fig. 34 is a diagram showing the wireless communication features of the digital imaging system.

Fig. 35 is a flow chart showing an image organization system.

Detailed Description of the Drawings

Fig. 1 illustrates the overall structure of the system. Object data (100) in the domain of objects being photographed by the camera constantly change. In some cases, the lighting changes, while in other cases, the positions of the objects change. At 120 the flash will artificially light the objects. Flashes may be either on the camera or remote from the camera. A camera sensor (130) will detect external data changes. An optical lens (110) feeds analogue imaging data to the digital sensor(s) (175 and 180). In some cases, a mirror (170) will swivel in order to directly input imaging data to the digital sensor after the shutter (150) is fired. In some cases, a filter (160) stands between the lens and the digital sensor(s). A digital signal processor (DSP) (195) is connected to at least one sensor (A or B). A database (190) is connected to at least one sensor (A or B) as well. The digital sensors are connected to an ASIC (195) and/or a microprocessor (193) in order to process the image and control the camera. The digital image data is passed from the digital sensor to either the ASIC or microprocessor and then stored in memory (197). The presence or absence of specific elements of this mechanism is not required for the correct functioning of this system. Consequently, a number of the drawings contained herein will focus only on specific sub-assemblies of the overall digital imaging system mechanism.

The present invention is intended to operate with a spectrum of camera types. These camera categories include digital still cameras without a mirror mechanism or without an optical interface. The present system applies to cameras with single lens reflex mechanisms. In addition, the present system applies to video cameras, both with or without mirror mechanisms, including camcorders. Finally, many of the functions disclosed in the present system are integrated into specific imaging sensors. The system applies to image sensors that are integrated with complex system functions, including those described herein, with "system on a chip" (SoC) capabilities in a single microelectronic integrated circuit. The invention also applies to networks of sensors, networks of cameras or integrated networks of both sensors and cameras.

Fig. 2 describes digital image signal processing. After an analog signal (200) is captured, it is converted to a digital signal by an analog-to-digital converter (210). The signal is then forwarded to the digital signal processor (220) and filtered (230). The digital signal is then stored in memory (240).

In fig. 3, the correction to the optical vignetting problem is shown. In vignetting, the lens (300) makes the edges of the image significantly darker as the light falls off, a phenomenon particularly prominent on wide angle lenses. As represented here, the concentric circles of filtration correction are darker in the middle (310) of the image in order to counteract the vignetting effect. The overall image aperture is reduced from one half to two stops in order to compensate for the maximum light fall off depending on the amount of vignetting effect from each lens type.

Fig. 4 shows a list of several different wide angle lenses in a database. In the 35mm domain, the 14mm (400), 20mm (410), 24mm (420), 28mm (430) and 35mm (440) lenses, each with f/2.8 apertures are listed in the database. Each lens type presents a distinct formulation involving different sets of optical data that require different aberration corrections.

The digital corrective process is described in fig. 5. After a specific lens type is identified (500) and a database is referenced (510), the lens type is matched with the specific optical aberrations (520). The digital filter then applies a correction to specific optical aberrations (530). As an example, the vignetting effect is corrected by gradually darkening the center of the image in concentric rings (540).

Fig. 6 shows the database configuration of several different types of 24mm f/2.8 lenses (600 to 630) with different optical configurations. Each lens type has a different set of manifestations of optical aberrations including vignetting (640), spherical aberration (650), pin cushion distortion (660), barrel distortion (670) and comatic aberration (680). For each lens, there will be a unique combination of optical aberrations compared to each lens type from different optical configurations. The database is accessed to provide the multi-objective optimization solution for correcting several different optical aberrations for each specific lens formula.

In fig. 7, after a camera captures an image (700) and uses a digital sensor to create a digital file (710), the digital file is forwarded to the digital signal processor semiconductor (720). The DSP applies the filtration (730) to correct the optical aberrations from the lenses. The revised digital file is then sent to storage (740).

Digital filtration is performed by employing the DSP hardware as well as specific software in order to attain specific aberration corrections. In an optical filter, which typically sits at the front of a lens and performs a single function of modifying the optical characteristics of the

lens, the electronic filter will process the image after it is converted from an analogue representation to a digital signal. Common digital filters include a low pass filter or anti-aliasing filter. In most cases digital imaging filtration is a discrete time application and is processed in a time-signal sequence.

One example of a digital filtration process is a fast Fourier transform (FFT). The digital signal is modified by applying an algorithm to extract the frequency spectrum. The original function is then reconstructed by an inverse transformation of the original signal. The signal can be manipulated to perform various conversions. This process is used to sharpen or soften an image. For instance, by differentiating the frequency spectrum, the high frequency can be emphasized by limiting the low frequency, as in a high pass filter. Digital filtration is typically performed by the DSP after the image is captured and before the image file is stored. However, in the present system, there is some filtration before the digital sensor that captures the image as well as some filtration processing after the sensor sends the file to the DSP.

In order to accelerate the filtration process, the digital file will be broken into parts, with each part processed simultaneously. Filtering a one-dimensional image will treat data from each column of a digital sensor separately. When the data is treated like a two dimensional image, the data file may be treated with different techniques. For instance, different quadrants of the image may be analyzed and filtered separately. In addition, the highlights and the shadows in the varied frequency range may be analyzed and filtered separately as well. Similarly, a two dimensional image file may be analyzed by starting in a corner and working in each contiguous quadrant in a circular (clockwise or counterclockwise) order. Further, the filtration process may begin in the corners and work inwards or begin in the center of the image and work outwards. For instance, in wide angle lens filtration to correct optical aberrations, the outer edges will be the most prominent distortions that will require the most corrections; therefore, the filtration process will work by starting on the corners first.

The present invention also addresses the multi-functional corrections in an image by applying multiple simultaneous techniques. This is done either by performing a sequential filtration process or a simultaneous filtration process. In either case, the image is re-filtered to make more than one pass in order to correct different types of aberrations.

Different types of aberrations require different types of filtration. In the case of pin cushion distortion and barrel distortion, which are inverse appearing aberrations, the filtration

process will adjust the edges of affected digital files captured with wide-angle lenses. The optimized images will be accessed by the database and compared to the actual image files. The filtration will be applied to each image file to closely correct the distortions bit by bit. In effect, the corrected digital images will be reverse engineered to discover the unique distortions as they establish a pattern by comparing the input digital images and the database of optimized images. The digital image correction will be applied once the aberration is assessed.

Each lens provides data to the camera microprocessor and DSP about its unique characteristics. The lens is pre-programmed with aberration data pertaining to that lens type and even to each particular lens (ascertained through a testing process). The lens then provides this specific data to the camera for processing of optical aberrations. In one additional embodiment, the lens will also contain software to correct its aberrations that will also be sent to the camera processors in order to be applied to specific digital file filtration. As information and techniques are made available, new software to ascertain and correct each lens's unique optical aberrations will be forwarded to the camera and stored in the lens, thereby providing an upgrade path to continuously improve the optical qualities of lenses by employing a sort of after-manufacture digital correction.

Fig. 8 shows the process of selecting filtration settings. After the user selects the specific filtration settings (800), the user marks the specific filtration setting and accepts the setting (810). The user may continue to select multiple settings. When the user has selected all preferences (820) and accepts the settings the user returns to the main menu.

In Fig. 9 varied depth of field optimization at different apertures is described. In the first drawing, the object (930) has a depth of field (940) that has a broad range of clarity around the object. The camera (900) evaluates the distance data (920) and the object to establish an optimal depth of field range between f/8 and f/11. In the second drawing, the object (980) has a narrower depth of field range (990) based on distance data (970) and object data from the camera (950) to determine an optimal depth of field range between f/2.8 and f/5.6. The camera's automatic alteration of the aperture to narrow the depth of field is based on a range of factors, including the focus on the object, the object's motion, the distance to the camera, shutter speed constraints and the light on the object. Modulating aperture automatically in the camera provides a blurring of the background and the foreground so that the object can stand out without distraction.

Exposure optimization using digital correction is shown in fig. 10. After the camera assesses an object's distance from the camera (1000) and identifies the optimal aperture of the image to maximize the dynamic range (1010), the aperture is either increased (1020) or decreased (1030) and the correction applied (1040).

In-camera special effects filtration is illustrated in fig. 11. Once the image exposure is assessed by using the camera exposure meter (1100), the camera corrects the image by either underexposing the image by one third stops to one stop if the image is overexposed (1110) or overexposing the image by one third stops to one stop if the image is underexposed (1120). The camera finally takes a picture and stores the image (1130).

Fig. 12 shows the selective in-camera filtration of specific objects. After the camera identifies specific objects (1200), the camera assesses distance to the objects (1210). This is done by sending out an infrared light signal, bouncing it off the object, and measuring the distance data from the camera to the object. The camera isolates the objects on a one-dimensional Euclidian plane (1220) and then selects the optimum aperture to isolate objects and to blur the background and foreground (1230). The camera tracks the motion of objects (1240) and activates a digital sensor (1250) thereby capturing the image. The image data is sent to a post-sensor processor (1260) where the camera applies specific filtration only to the designated objects (1265) and stores the file in memory (1270). Alternatively, the camera will apply specific filtration only to the background (not to the objects) (1275) and then stores the file in memory (1280). The effect of only applying filtration to an object or to its background is to isolate the subject. The type and degree of special effects, which are selected by user-adjustable in-camera software, will be determined by the user's palate of filtration choices.

Image exposure adjustment using in-camera filtration is described in fig. 13. Once the camera assesses a two stop difference in parts of the image (1300), the camera's microprocessor accesses the database of similar scenes (1310) and then selects the optimal metering for the image and the user activates the digital sensor (1320), capturing an image. The camera provides the filtration to part of the image by adjusting the exposure in the processor (1330) and then stores the image (1340). In scenes such as sky on top, a neutral density filter is often required to remove the two stop difference between the bright top of the image and the darker bottom of the image. By reducing the brightness at the top, the exposure is evened out. By using the present system, this process is accomplished in the camera.

In-camera special effects filtration is described in fig. 14. After a user selects a special effects filtration technique (1400), the camera assesses image meta-data (1410), analyzes image data (1420) and the user captures the image (1430). The camera's post-capture processor applies special effects filtration technique to part of the image (1440) and the camera stores the image in memory (1450).

Digital correction for sensor dust is described in fig. 15. The pattern of dust on the pixels of a digital sensor (1500) is assessed. The specific pixels that are obscured by the dust are identified (1510) and a map is built of a digital sensor pixel frame by comparing information from at least two image samples to identify obscured pixels (1520) and the camera takes an image (1530). Information from pixels that are adjacent to dust-affected pixels are used to interpolate data on affected pixels (1540) and image data is processed and stored in memory (1550).

Fig. 16 shows an ASIC array in a digital imaging system. Once the digital sensor (1620) captures an image, the digital file is sent to multiple application specific integrated circuits (1630, 1640, 1650 and 1660) for processing of several digital signals simultaneously. In one embodiment of the invention, each ASIC corrects a single optical aberration. In another embodiment, the ASICs will divide the digital file and perform specific functions on parts of the image file and reunite the file before storing the completed image in memory (1670).

In fig. 17, the camera is illustrated with multiple interchangeable digital sensors. The CCD (1720) is shown in the forward position capturing the digital image in this drawing. However, the CMOS (1730) digital imaging sensor may swivel around (1740) to replace the position of the CCD in order to be used to capture the image. The image is then processed (1750) and stored in memory (1760). The advantages of interchanging the digital sensors are to have the opportunity to benefit from the strengths of each sensor type without sacrificing the weaknesses of either. In some cases, the scene will be optimized for the exposure range of a CMOS digital sensor, while at other times, the scene will be optimized for the detail of the CCD.

In fig. 18, the nano-grid (1820) appears in front of the digital sensor (1830). The lens will send analog image data to the sensor through the nano-grid. Once the digital data from the sensor is processed (1840) it is sent to memory (1850). Fig. 19 shows a nano-grid (1900). Nanofilaments are shown at 1920. The modulation effects of the nanofilaments are shown at 1910. Nanofilaments will change their position in order to allow more or less light through the

system. Nano-grids fit before, or in some cases, adjacent to and on top of the digital sensor. Nano-grids behave as adjustable screens and may be used to polarize light between the lens and the digital sensor. Nano-grids are activated by electrical charge pulses sent to nanofilaments.

In fig. 20, the feedback loop connecting the processor and the nano-grid is shown. Analog optical data passes through the nano-grid (2020) to the digital sensor (2030) to the processor (DSP) (2040). A feedback loop (2050) is created by analyzing the data at the processor and modulating the performance of the nano-grid. For example, the image may be very bright initially, but the DSP will require that the image needs to be darker in order to be properly exposed. In this case, it will activate the nano-grid to modulate its grid structure in order to darken the image so as to let less light through the filaments by adjusting the filament structure. Once properly exposed, the camera will capture a digital image and send the file to memory (2060) for storage.

In fig. 21, a tri-pixel architecture is described. The large (deeper) oval bucket in the center (2110) will capture highlight exposure, the medium sized oval bucket at the right (2120) will capture a normal exposure range and the small (shallower) oval bucket at the left (2130) will capture the shadow exposure range. These three separate wells are contained within each pixel. In most cases, a pixel well is like a bucket, capturing light data and passing the data sets to the digital processor. By splitting the exposure range into three distinct wells within each pixel, the data is more accurately captured and organized in order to accommodate the broader range of exposure data. This system will be able to increase the range of digital imaging up to four stops, from the typical two stops. By maximizing the range of exposure data, the image collection will display more tonal range that is more associated with films' broader exposure range.

Fig. 22 shows the pre-programmed module for in-camera functionality. After the camera detects the lens type and the sensor type (2200), the camera focuses on an object (2210) and the processor accesses the library of scene and filter types (2220). The user pre-selects specific in-camera modifications (2230) and activates the camera to capture an image (2240). The processor makes filtration adjustments after the sensor takes the image (2250) and the image file is stored (2260) in memory.

Much like the nano-grid that is present before the digital image sensor, the pre-sensor modification to an image is shown in fig. 23. An optical filter (2320) such as a polarizer filter is shown in a position between the lens and the digital sensor (2340). The image is captured and

the optical filter is activated by the processor (2350), which determines whether to activate the filter after analyzing a particular scene. Other filtration (2330), such as the use of the nano-grid, is also interchangeable with the optical filter in a position before the digital sensor. In another embodiment of the present invention, the filter assembly is sequential, with both, or multiple, filters being activated in order so as to obtain the maximum filtration effect. The DSP will compute the optimal combination of filtration resources based on the available resources in the camera. In another embodiment, the optical filter assembly will fit out of the line of sight between the lens and the digital sensor and will be activated by the DSP on-demand to swing into the optical image path much like a mirror mechanism.

Fig. 24 shows the integration of optical and digital corrections with feedback. Once the camera meters a scene (2400), the camera auto-focuses and obtains distance data to the object (2410), analyzes the lens data, the aperture data and the shutter speed data and accesses the library of images (2420). The camera assesses the optical aberrations (2430), activates the digital filters to correct aberrations (2440) and takes the picture (2450). The camera analyzes the image and optimizes the image using the processor (2460). This is performed by comparing the image data to the library of images and assessing the needed filtration required to optimize the image. The image is then stored in memory (2470).

The interactive feedback mechanism of integrated correction is described in fig. 25. After an analysis of the initial image (2500), the identification of optical aberrations (2510) is made. The camera's database is accessed to retrieve the corrections (2520) and the interactive feedback mechanism is activated (2530). Corrections to filters are applied before the sensor captures the next image (2540). In addition, correction to the image signal via the DSP is made after the sensor data is captured (2550) and the image is stored in memory (2560).

The adaptive user pattern learning process is shown as images are processed in fig. 26. A batch of images (2600, 2610, 2620 and 2630) is shown. The first image is processed (2640) and data from image 1 is analyzed and metadata is mapped (2650). Image 2 is then analyzed and its metadata is compared to the image 1 metadata (2660). Similar metadata in images 1 and 2 programmed in the processor (2670) and image 2 is rapidly processed by using similar metadata from image 1 (2680). Images 3 and 4 are analyzed and their metadata are compared to image 1 and rapidly processed (2690).

In fig. 27, the feedback process of filtering images is shown. After the camera analyzes the user behaviors, user preferences and subject behaviors (2700), the camera's processor analyzes trends in the pattern of user behavior and preferences and creates a map (2710). The camera's processor anticipates the user behavior and subject behavior (2720) by applying evolutionary computation and fuzzy logic algorithms. The camera's processor then applies a collaborative filtering process to a new image (2730) and the user takes and optimizes the image (2740).

Fig. 28 shows a software privacy function in a digital imaging system. The camera automatically downloads software as it enters a building or specified area (2800). The camera's features are deactivated in specific locations by the software (2810) while allowing the camera to perform specific camera functions by accessing software keys (2820). The camera then performs specific functions (2830) that are available in the restricted area while other specific functions are disabled (2850).

In fig. 29, the dynamics of zoom lens corrections are described. After a lens detects a zoom lens type (2900), the camera detects a particular focal length setting of the zoom lens (2910) and accesses a data library in the database to modify aberrations to optimize the zoom lens at a specific focal setting (2920). The camera applies a correction to a lens setting (2930) and continuously tracks the lens changes in the lens focal length (2940). The camera then applies the changed corrections to the changed focal lengths in the zoom lens (2950) and analyzes patterns of the user and subject behaviors (2960). Using fuzzy logic and evolutionary computation, the camera anticipates behaviors and rapidly optimizes image corrections by applying digital filtration (2970).

Fig. 30 shows object tracking in the dynamic changes of video corrections. An object moves from position 1 (3010) to position 6 (3060) in sequence. The camera (3000) is stationary, yet it records the object's motion as it is moving within the field of vision.

In fig. 31, object tracking is described. Once the camera tracks an object with auto-focus mechanisms and supplies distance information (3100), it tracks the user's zoom lens use patterns, anticipates the focal length changes (3110) and, using evolutionary computation and fuzzy logic algorithms, predicts optimal exposures (3120) and captures images in real time, continuously tracking the object (3130).

Fig. 32 shows the caching process of a moving object in a stationary scene. After the main objects are tracked by the camera (3200), the background of a stationary scene is cached in the camera (3210). The camera subtracts the data about objects from the background of the scene (3220). The background scene is then "blanked out" and cached in memory (3230) and the main objects are optimized by applying digital filters.

Fig. 33 describes the network coordination of a fixed sensor grid tracking multiple objects. The object in motion is represented in positions A through D (3370, 3380, 3390 and 3395). The fixed sensors are at positions 1-6 (3300, 3310, 3320, 3330, 3340 and 3350). The image data is fed remotely into the central imager (3360). The sensors track the object by taking image data at each fixed sensor position in the network. As the object moves through the field of the network, each sensor records the object.

In fig. 34, wireless communication features of the digital imaging system are described. The camera (3400) sends digital image data files wirelessly to a computer (3410). Files are also uploaded from the camera to the Internet in accessible locations (3450), while software files are downloaded from the Internet to the camera, both automatically and through manual intervention. Files are automatically downloaded if the user sets the camera to receive automated software updates. One advantage of loading files automatically to the Internet is that the images are then automatically published (3460) at a remote location, or locations, for viewing.

Fig. 35 describes an image organization system. After images are captured by the camera (3500), the image files are organized according to metadata in an external computer database (3510). The image files are then sorted by category and sent to the database of a distributed network (3520) for off-site storage.

Reference to the remaining portions of the specification, including the drawings and claims, will realize other features and advantages of the present invention. Further features and advantages of the present invention, as well as the structure and operation of various embodiments of the present invention, are described in detail below with respect to accompanying drawings.

It is understood that the examples and embodiments described herein are for illustrative purposes only and that various modifications or changes in light thereof will be suggested to

persons skilled in the art and are to be included within the spirit and purview of this application and scope of the appended claims. All publications, patents, and patent applications cited herein are hereby incorporated by reference for all purposes in their entirety.

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DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

[X] Declaration Submitted With Initial Filing OR [ ] Declaration Submitted After Initial Filing (surcharge (37 CFR 1.16(f)) required)

Attorney Docket Number	
First Named Inventor	Neal Solomon
COMPLETE IF KNOWN	
Application Number	
Filing Date	
Art Unit	
Examiner Name	

I hereby declare that: (1) Each inventor's residence, mailing address, and citizenship are as stated below next to their name; and (2) I believe the inventor(s) named below to be the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention titled:

Digital imaging system for correcting video image aberrations

(Title of the invention)

the application of which

[X] is attached hereto

OR

[ ] was filed on (MM/DD/YYYY) _____ as United States Application Number or PCT International Application Number _____ and was amended on (MM/DD/YYYY) _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified application, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

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NAME OF SOLE OR FIRST INVENTOR:		A petition has been filed for this unsigned inventor
Given Name (first and middle [if any])	Family Name or Surname	
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☐ Additional inventors or a legal representative are being named on the _____ supplemental sheet(s) PTO/SB/02A or 02LR attached herein

WHAT IS CLAIMED IS:

1. A digital imaging system for correcting optical image aberrations comprising:

a digital video camera mechanism, an optical lens mechanism, at least one digital sensor, an integrated circuit, a digital signal processor, system software, a database management system and a memory storage sub-system;

wherein the optical lens mechanism is a fixed focal length lens;

wherein an integrated circuit uses system software to identify at least one optical aberration by accessing the database;

wherein the integrated circuit uses the database to identify at least one algorithm to use to correct the at least one optical and/or digital aberration in at least one frame of the digital video;

wherein when the video image file is captured by the at least one digital sensor the digital file is forwarded to the digital signal processor;

wherein the video image file with the at least one optical or digital aberration is corrected by applying digital filtration by using at least one algorithm in the digital signal processor; and

wherein the modified digital file consisting of the digital data optimized from the at least one optical or digital aberration that are corrected from the original video image is stored in memory.

2. The system of claim 1:

wherein the optical aberrations include at least one of spherical, comatic, lens distortion, astigmatism, curvature of field, pin cushion, barrel distortion, chromatic aberrations, scattered light, red eye, dust and/or flare types of optical aberrations.

3. The system of claim 1:

wherein the optical aberration is vignetting;

wherein the digital signal processor applies neutral density filtration from one third of a stop to three stops in the center of the image and/or wherein the digital signal processor applies an algorithm to lighten the corners of the image or the digital signal processor applies both neutral density filtration in the image center and/or an algorithm to lighten the corners of the image; and

wherein the image exposure is optimized to correct the vignetting.

4. The system of claim 1:

wherein the digital signal processor applies at least one fast Fourier transform (FFT) algorithm to correct the at least one optical aberration.

5. The system of claim 1:

wherein each lens type is registered in the camera database;

wherein the multiple optical aberrations of each lens is listed in the database;

wherein the filtration solutions to the lens optical aberrations are listed in the database;

wherein the filtration of each lens optical aberration is applied by the digital signal processor; and

wherein after the digital signal processor applies the filtration to correct the optical aberrations the corrected digital file is forwarded to storage in memory.

6. A digital imaging system for correcting image aberrations comprising:

a digital video camera mechanism, an optical lens mechanism, at least one digital sensor, an integrated circuit, a digital signal processor, system software, a database management system and a memory storage sub-system;

wherein the optical lens mechanism is a zoom lens or a fixed focal length lens;

wherein the video image data file is forwarded from the at least one digital sensor to storage in memory;

wherein at least one optical and/or digital aberration in at least two frames of the digital video image file are identified by comparing image files in the database management system by using the system software and the integrated circuit;

wherein the at least one filtration algorithms required to correct the at least one optical and/or digital aberration of at least two frames of the digital video file are sent from the integrated circuit to the digital signal processor;

wherein the at least one optical and/or digital aberration from the optical lens mechanism of at least two frames of the digital video file are corrected by using the digital signal processor to apply at least one digital filtration algorithm; and

wherein the modified digital video file consisting of the digital data optimized from the at least one aberration that are corrected from the original video images is stored in memory.

7. The system of claim 6:

wherein the optical aberrations include spherical, comatic, lens distortion, astigmatism, chromatic aberrations, curvature of field, pin cushion, barrel distortion, scattered light, red eye, dust and/or flare types of optical aberrations.

8. The system of claim 6:

wherein the digital aberrations include moiré and/or aliasing.

9. The system of claim 6:

wherein the digital signal processor applies a fast Fourier transform (FFT) algorithm to correct optical and/or digital aberrations of at least two frames in the digital video file.

10. The system of claim 6:

wherein the digital signal processor applies color filtration to at least two frames of the digital video image file.

11. The system of claim 6:

wherein the digital video image file is filtered to correct at least one optical and/or digital aberrations after initial capture and before the image file is initially sent to storage.

12. The system of claim 6:

wherein the integrated circuit may be a microprocessor, an application specific integrated circuit or a system on a chip.

13. The system of claim 6:

wherein the optical aberration is vignetting;

wherein the digital signal processor applies neutral density filtration from one third of a stop to three stops in the center of the image and/or wherein the digital signal processor applies an algorithm to lighten the corners of the at least two image frames or the digital signal processor applies both neutral density filtration in the image center and/or an algorithm to lighten the corners of the image of at least two image frames; and

wherein the image exposure for at least two frames in the digital video file is optimized to correct the vignetting.

14. A digital imaging system for correcting image aberrations comprising:

a digital video camera mechanism, an optical lens mechanism, at least one digital sensor, an integrated circuit, a digital signal processor, system software, a database management system and a memory storage sub-system;

wherein the optical lens mechanism is a zoom lens;

wherein the zoom lens changes focal length positions;

wherein when the digital image file is captured by the at least one digital sensor the file is forwarded to the digital signal processor and to memory;

wherein the integrated circuit uses system software to access the database to identify at least one optical and/or digital aberrations in at least one frame of the video file at any focal length of a zoom lens configuration;

wherein the integrated circuit accesses the database to obtain at least one filtration correction algorithm to the optical and/or digital aberrations of at least one frame in the video file and forwards the at least one filtration algorithms to the digital signal processor;

wherein the digital video image file is forwarded to the digital signal processor which applies at least one filtration algorithm to optimize the digital video file and corrects the at least one optical and/or digital aberrations in at least one video frame for the at least one focal length in the zoom lens configuration; and

wherein the modified digital video image file consisting of the digital data optimized from the at least one optical and/or digital aberrations in at least one frame of the video file of at least one focal length of the zoom lens that are corrected from the original video image is stored in memory.

15. The system of claim 14:

wherein the optical aberrations include vignetting, spherical, comatic, lens distortion, chromatic aberrations, curvature of field, pin cushion, barrel distortion, scattered light, red eye, dust and/or flare types of optical aberrations.

16. The system of claim 14:

wherein the digital signal processor applies a fast Fourier transform (FFT) algorithm to correct optical and/or digital aberrations in the digital video file.

17. The system of claim 14:

wherein each focal length of a zoom lens in at least one video image frame is analyzed for a different set of optical aberrations.

18. The system of claim 14:

wherein the digital signal processor applies color filtration to at least one frame of the digital video image file.

18. The system of claim 14:

wherein the optical aberration is vignetting;

wherein the digital signal processor applies neutral density filtration from one third of a stop to three stops in the center of the image and/or wherein the digital signal processor applies an algorithm to lighten the corners of at least one image frame or the digital signal processor applies both neutral density filtration in the image center and/or an algorithm to lighten the corners of the image of at least one image frame; and

wherein the image exposure for at least one frame in the digital video file is optimized to correct the vignetting.

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NONPUBLICATION REQUEST UNDER 35 U.S.C. 122(b)(2)(B)(i)

First Named Inventor	Neal Solomon
Title	Digital imaging system for correcting video image aberrations
Attorney Docket Number	

I hereby certify that the invention disclosed in the attached application **has not and will not be** the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

I hereby request that the attached application not be published under 35 U.S.C. 122(b).

Neal Solomon — Signature

12/2/12 — Date

Neal Solomon — Typed or printed name

Registration Number, if applicable

Telephone Number

This request must be signed in compliance with 37 CFR 1.33(b) and submitted with the application **upon filing.**

Applicant may rescind this nonpublication request at any time. If applicant rescinds a request that an application not be published under 35 U.S.C. 122(b), the application will be scheduled for publication at eighteen months from the earliest claimed filing date for which a benefit is claimed.

If applicant subsequently files an application directed to the invention disclosed in the attached application in another country, or under a multilateral international agreement, that requires publication of applications eighteen months after filing, the applicant **must** notify the United States Patent and Trademark Office of such filing within forty-five (45) days after the date of the filing of such foreign or international application. **Failure to do so will result in abandonment of this application (35 U.S.C. 122(b)(2)(B)(iii)).**

This collection of information is required by 37 CFR 1.213(a). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 6 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 (1-800-786-9199) and select option 2.

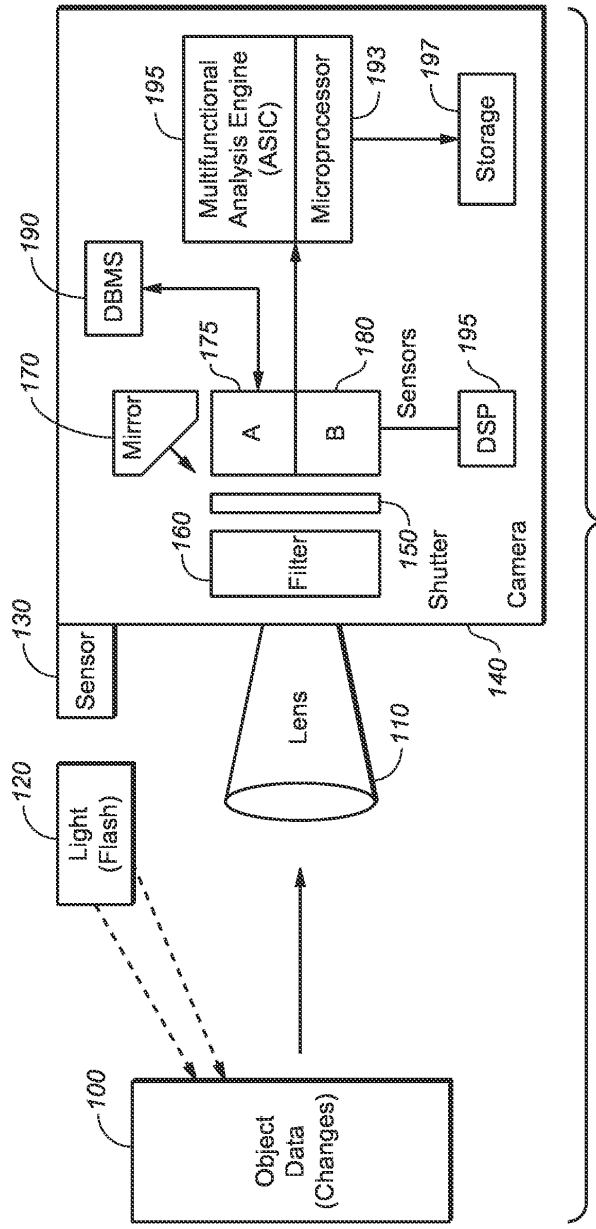

Object Data (Changes)
100
Light (Flash)
120
Lens
110
Sensor
130
Camera
140
Shutter
150
Filter
160
Mirror
170
A
175
B
180
Sensors
DSP
185
DBMS
190
Multifunctional Analysis Engine (ASIC)
195
Microprocessor
193
Storage
197

FIG. 1

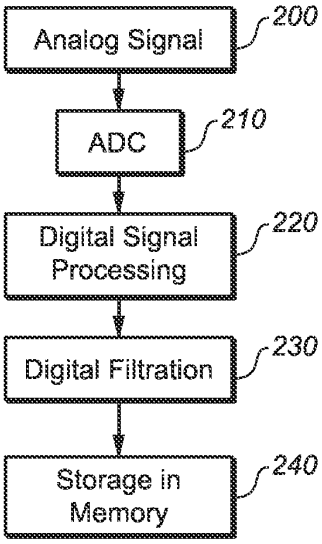


FIG. 2

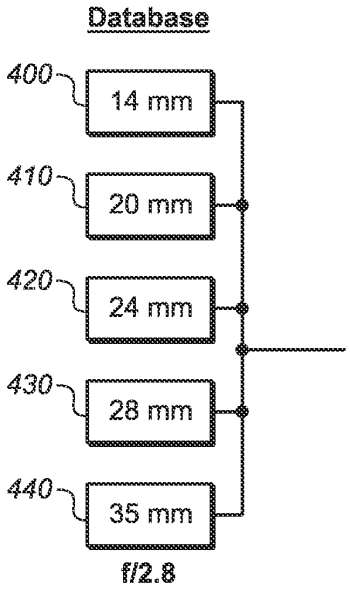


FIG. 4

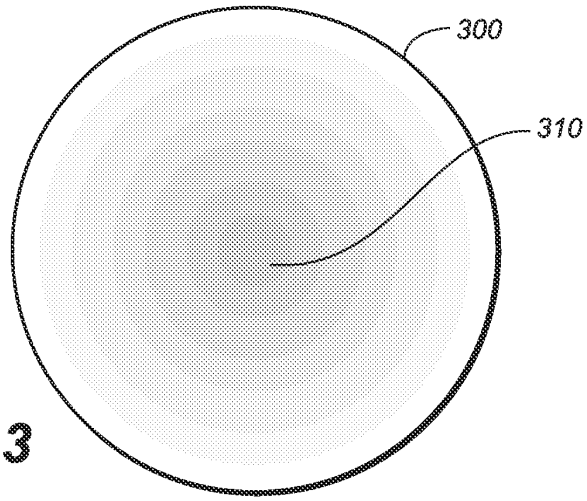


FIG. 3

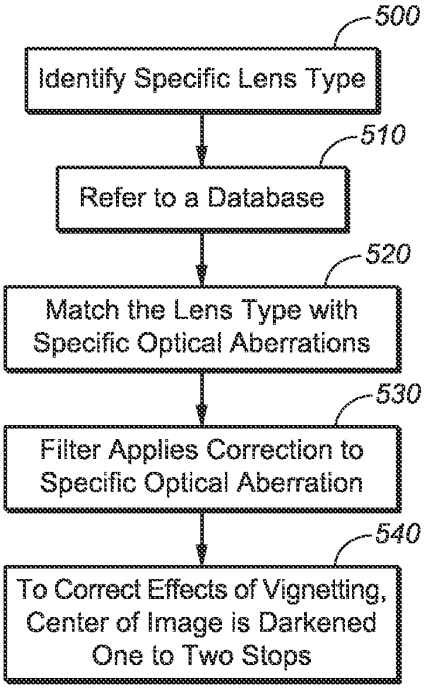


FIG. 5

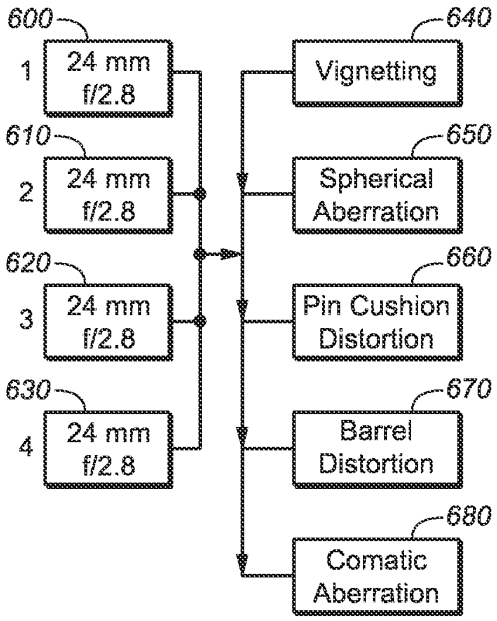


FIG. 6

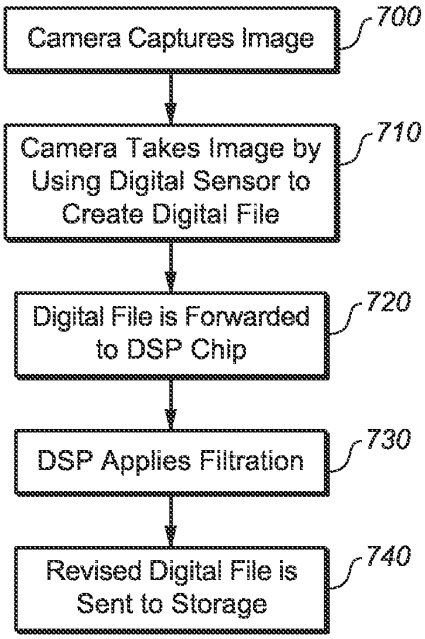


FIG. 7

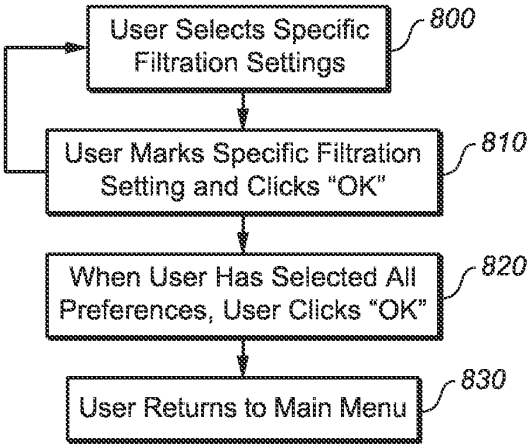

User Selects Specific Filtration Settings
800
User Marks Specific Filtration Setting and Clicks "OK"
810
When User Has Selected All Preferences, User Clicks "OK"
820
User Returns to Main Menu
830

FIG. 8

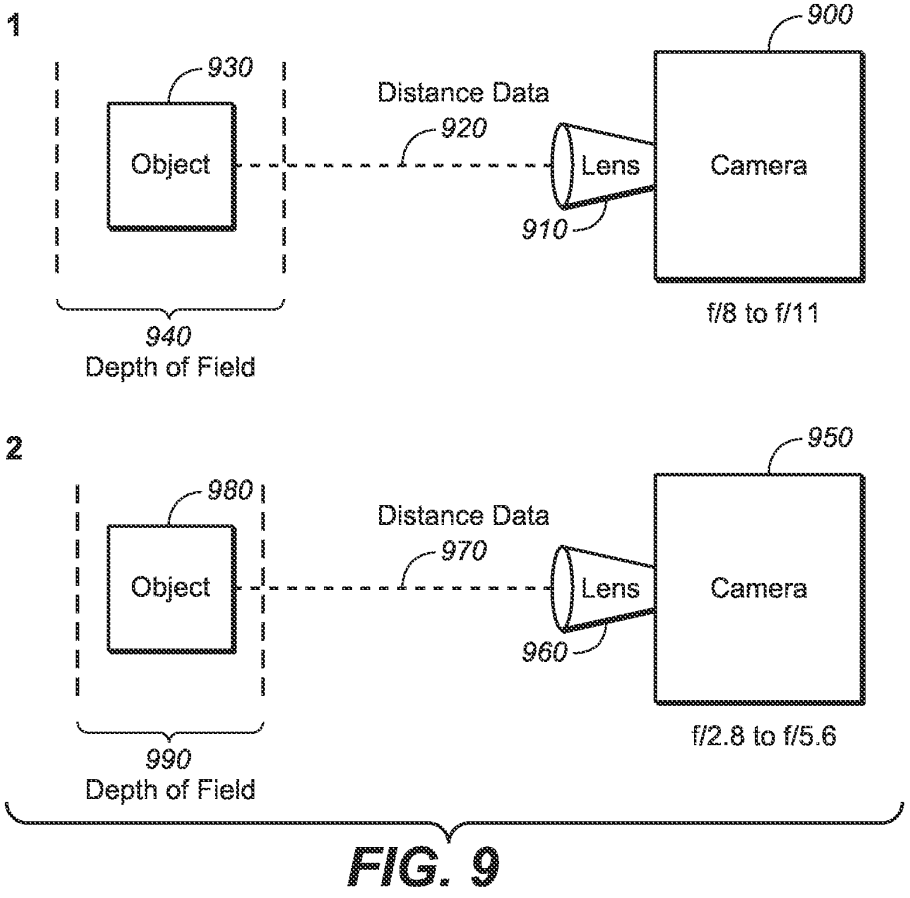

1
900
930
Distance Data
920
Object
Lens
Camera
910
940
Depth of Field
f/8 to f/11
2
950
980
Distance Data
970
Object
Lens
Camera
960
990
Depth of Field
f/2.8 to f/5.6

FIG. 9

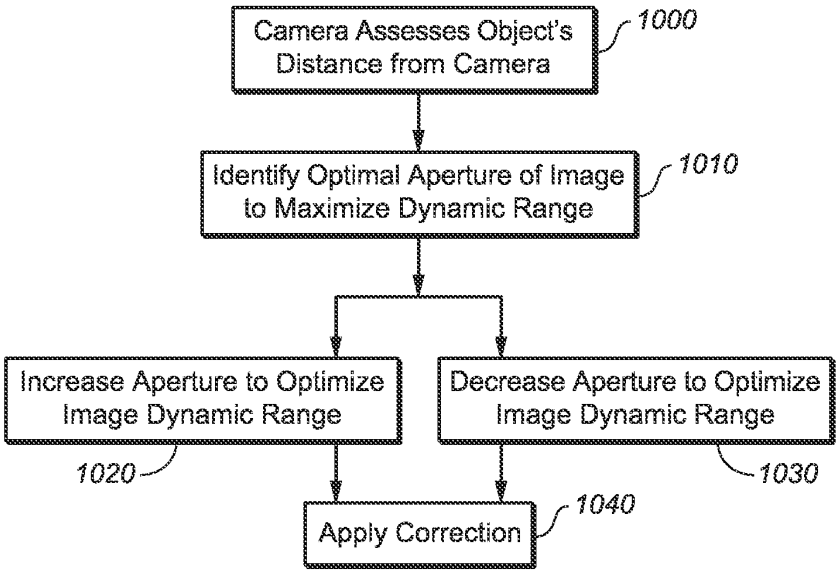

Camera Assesses Object's Distance from Camera
1000
Identify Optimal Aperture of Image to Maximize Dynamic Range
1010
Increase Aperture to Optimize Image Dynamic Range
1020
Decrease Aperture to Optimize Image Dynamic Range
1030
Apply Correction
1040

FIG. 10

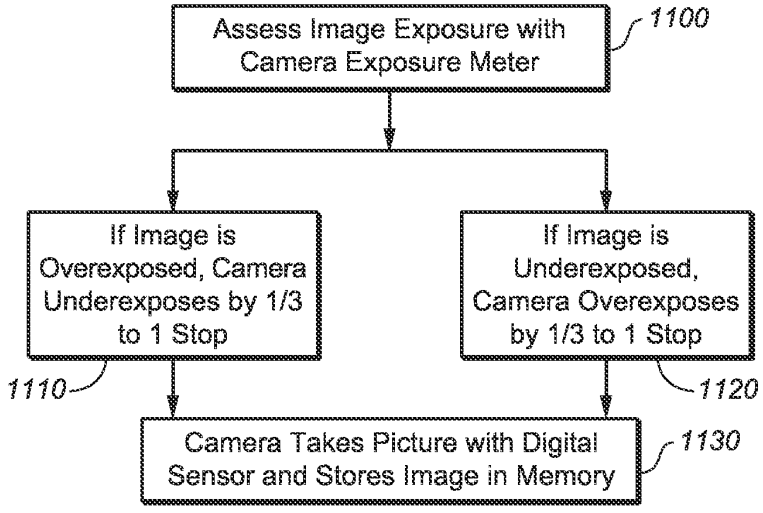

Assess Image Exposure with Camera Exposure Meter
1100
If Image is Overexposed, Camera Underexposes by 1/3 to 1 Stop
1110
If Image is Underexposed, Camera Overexposes by 1/3 to 1 Stop
1120
Camera Takes Picture with Digital Sensor and Stores Image in Memory
1130

FIG. 11

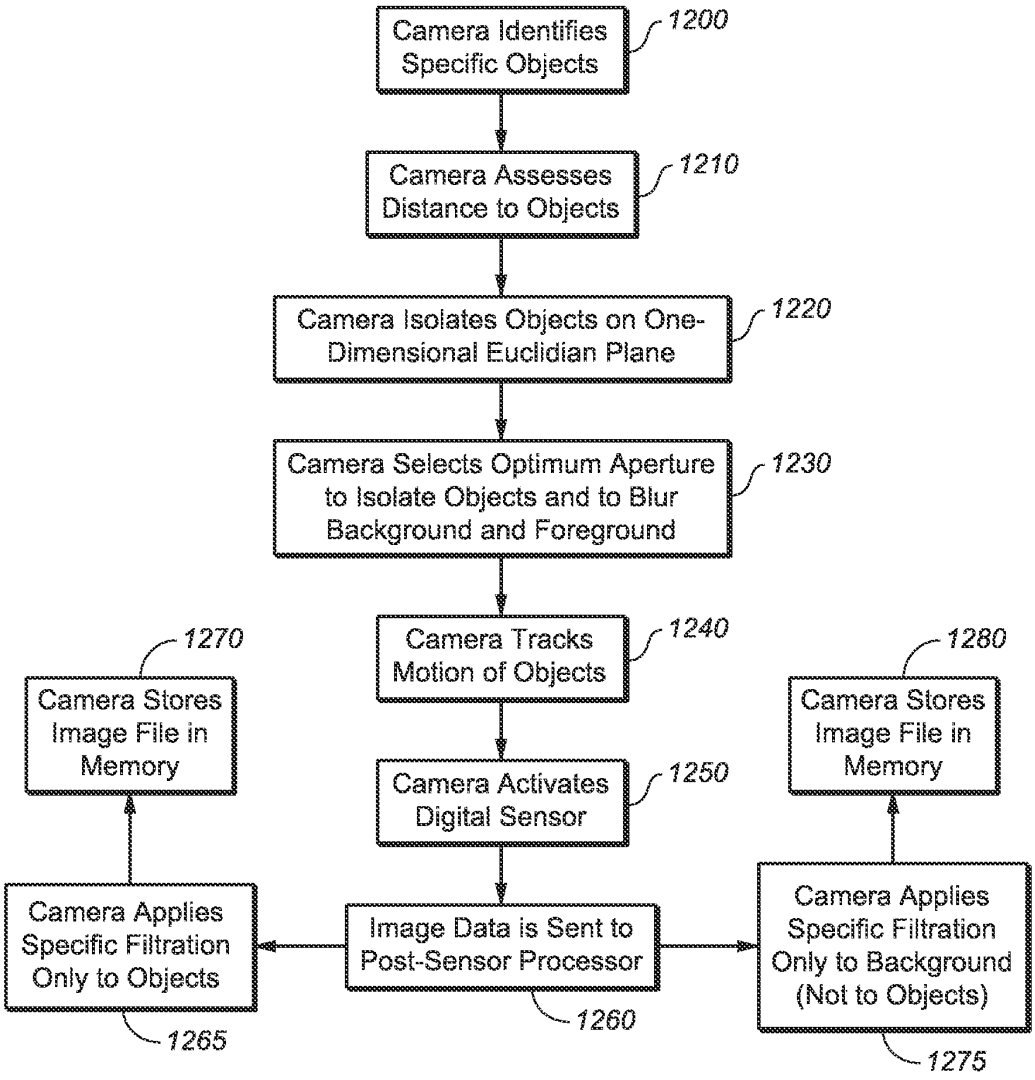

Camera Identifies Specific Objects
1200
Camera Assesses Distance to Objects
1210
Camera Isolates Objects on One-Dimensional Euclidian Plane
1220
Camera Selects Optimum Aperture to Isolate Objects and to Blur Background and Foreground
1230
Camera Tracks Motion of Objects
1240
Camera Activates Digital Sensor
1250
Image Data is Sent to Post-Sensor Processor
1260
Camera Applies Specific Filtration Only to Objects
1265
Camera Stores Image File in Memory
1270
Camera Applies Specific Filtration Only to Background (Not to Objects)
1275
Camera Stores Image File in Memory
1280

FIG. 12

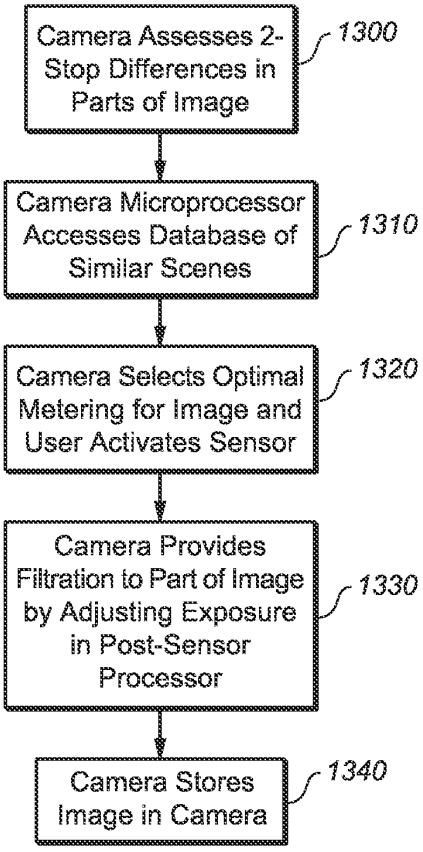

Camera Assesses 2-Stop Differences in Parts of Image
1300
Camera Microprocessor Accesses Database of Similar Scenes
1310
Camera Selects Optimal Metering for Image and User Activates Sensor
1320
Camera Provides Filtration to Part of Image by Adjusting Exposure in Post-Sensor Processor
1330
Camera Stores Image in Camera
1340

FIG. 13

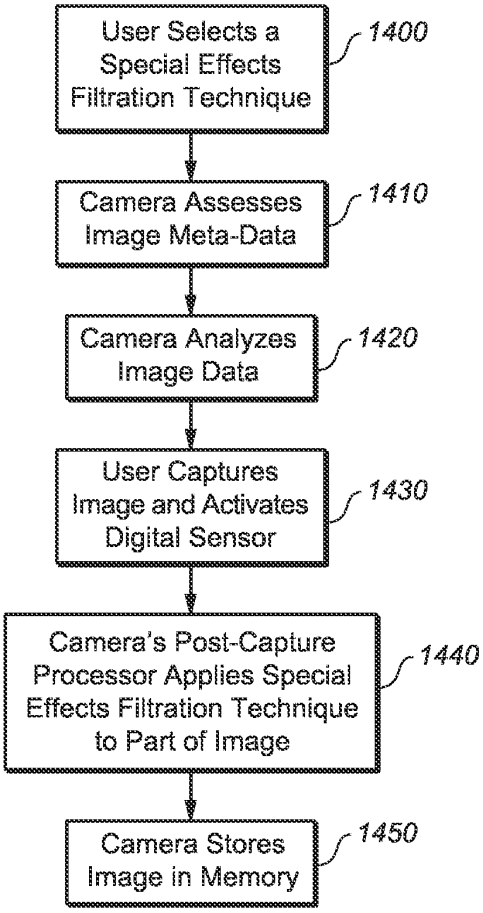

User Selects a Special Effects Filtration Technique
1400
Camera Assesses Image Meta-Data
1410
Camera Analyzes Image Data
1420
User Captures Image and Activates Digital Sensor
1430
Camera's Post-Capture Processor Applies Special Effects Filtration Technique to Part of Image
1440
Camera Stores Image in Memory
1450

FIG. 14

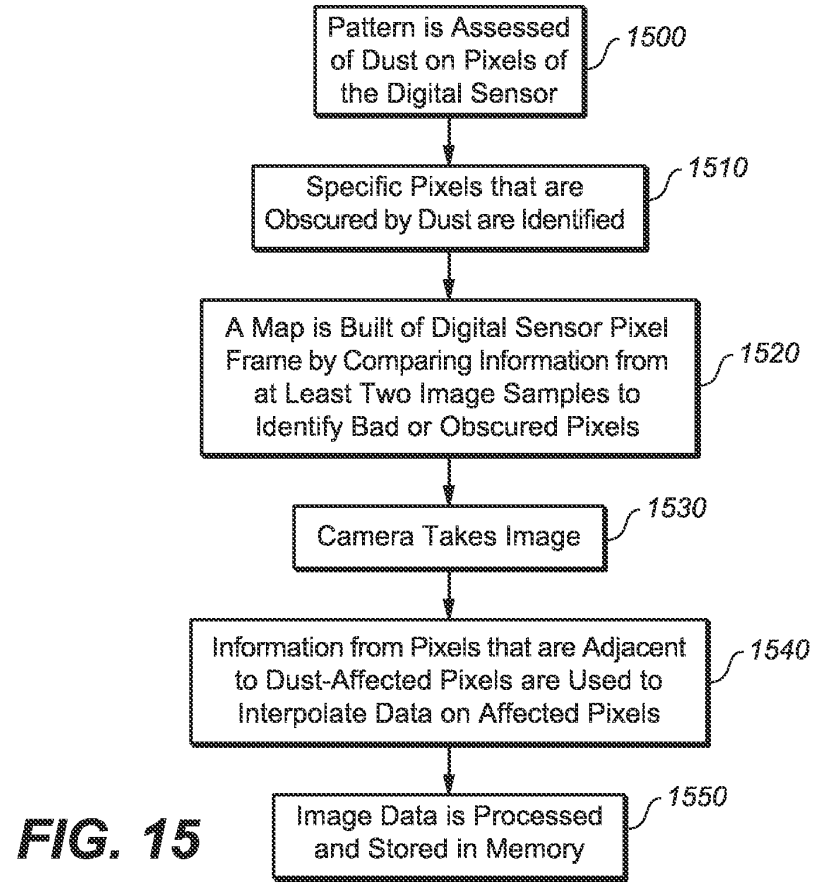

Pattern is Assessed of Dust on Pixels of the Digital Sensor
1500
Specific Pixels that are Obscured by Dust are Identified
1510
A Map is Built of Digital Sensor Pixel Frame by Comparing Information from at Least Two Image Samples to Identify Bad or Obscured Pixels
1520
Camera Takes Image
1530
Information from Pixels that are Adjacent to Dust-Affected Pixels are Used to Interpolate Data on Affected Pixels
1540
Image Data is Processed and Stored in Memory
1550

FIG. 15

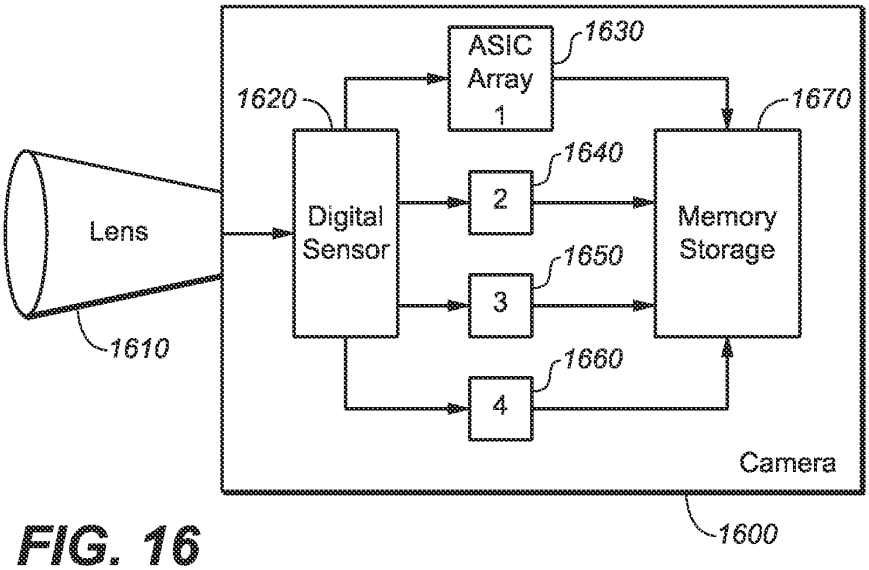

ASIC Array 1
1630
1620
1670
Lens
Digital Sensor
2
1640
Memory Storage
1650
3
1660
4
1610
Camera
1600

FIG. 16

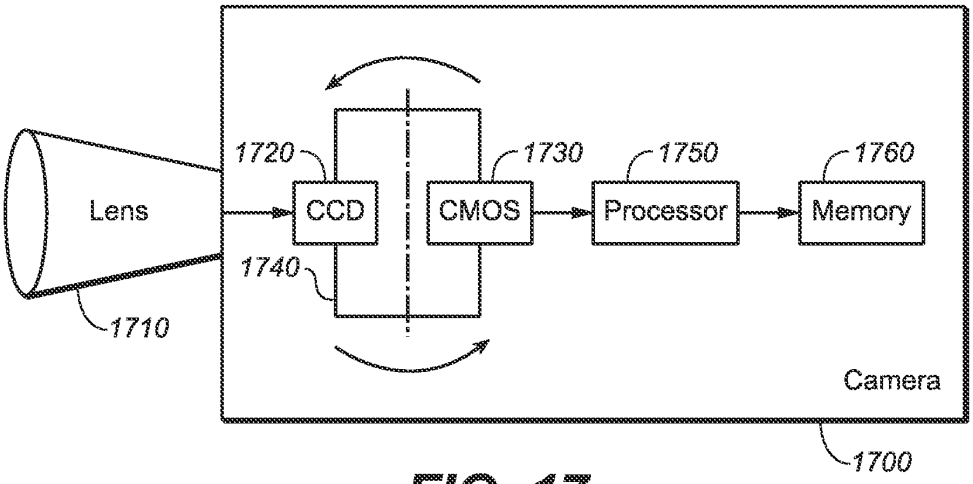

1720
1730
1750
1760
Lens
CCD
CMOS
Processor
Memory
1740
1710
Camera
1700

FIG. 17

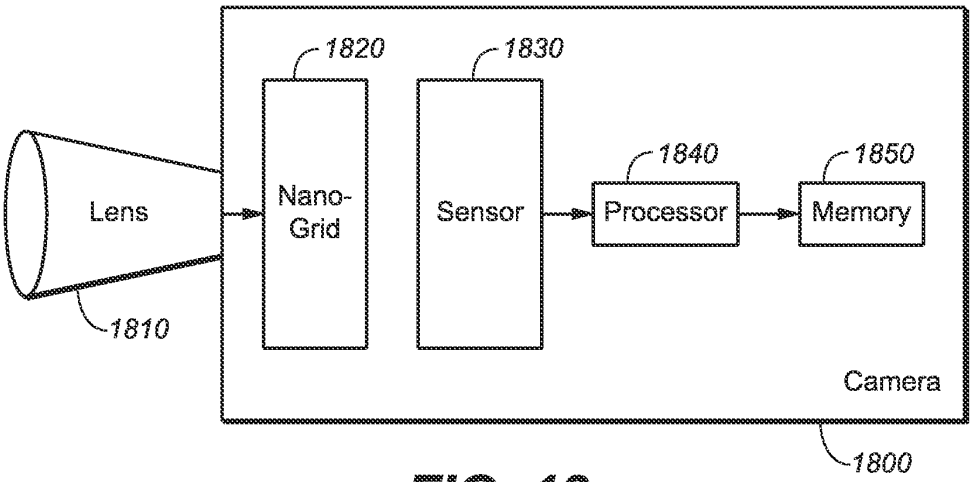

1820
1830
1840
1850
Lens
Nano-
Grid
Sensor
Processor
Memory
1810
Camera
1800

FIG. 18

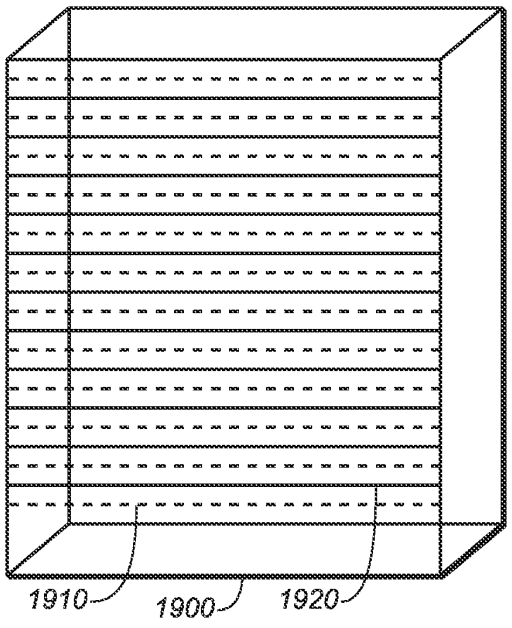

1910
1900
1920

FIG. 19

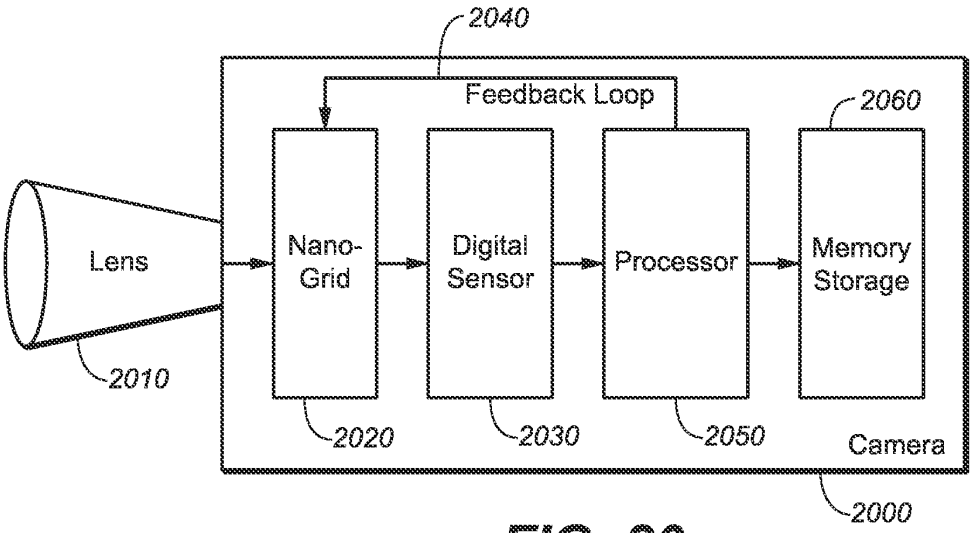

2040
Feedback Loop
2060
Lens
Nano-Grid
Digital Sensor
Processor
Memory Storage
2010
2020
2030
2050
Camera
2000

FIG. 20

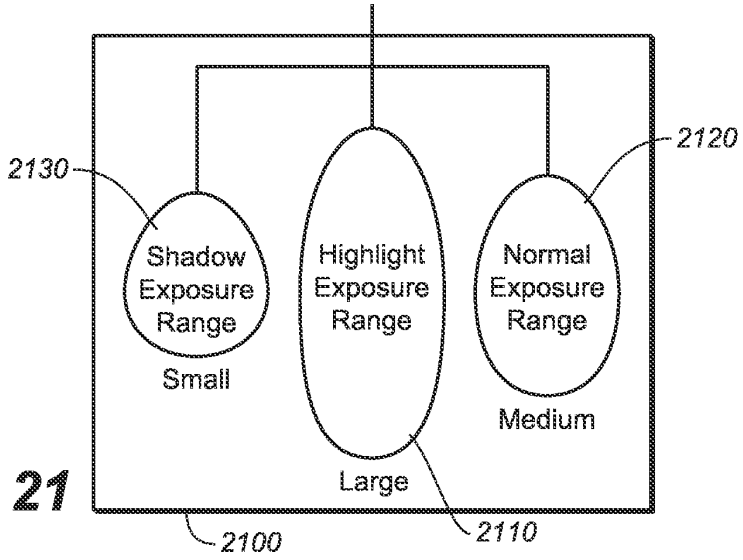

2130
2120
Shadow Exposure Range
Small
Highlight Exposure Range
Large
Normal Exposure Range
Medium
2100
2110

FIG. 21

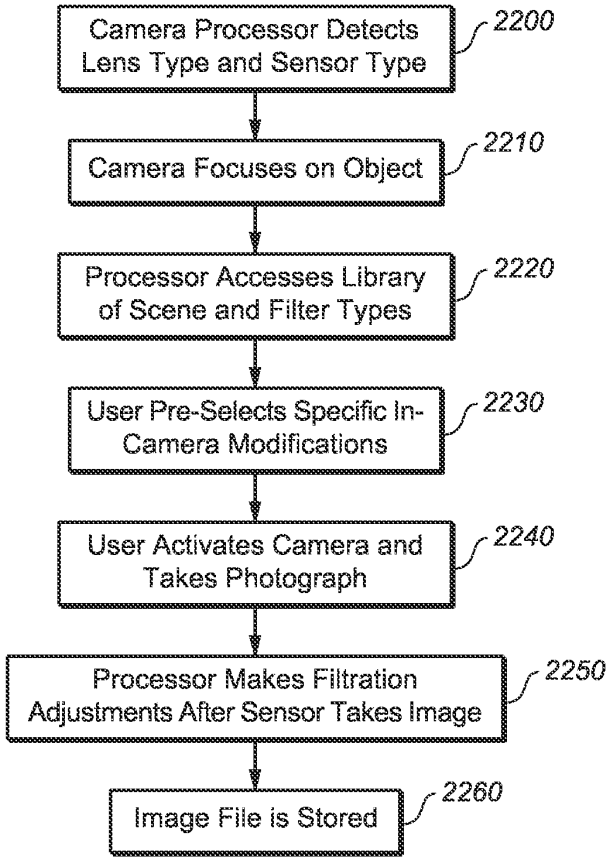

Camera Processor Detects Lens Type and Sensor Type
2200
Camera Focuses on Object
2210
Processor Accesses Library of Scene and Filter Types
2220
User Pre-Selects Specific In-Camera Modifications
2230
User Activates Camera and Takes Photograph
2240
Processor Makes Filtration Adjustments After Sensor Takes Image
2250
Image File is Stored
2260

FIG. 22

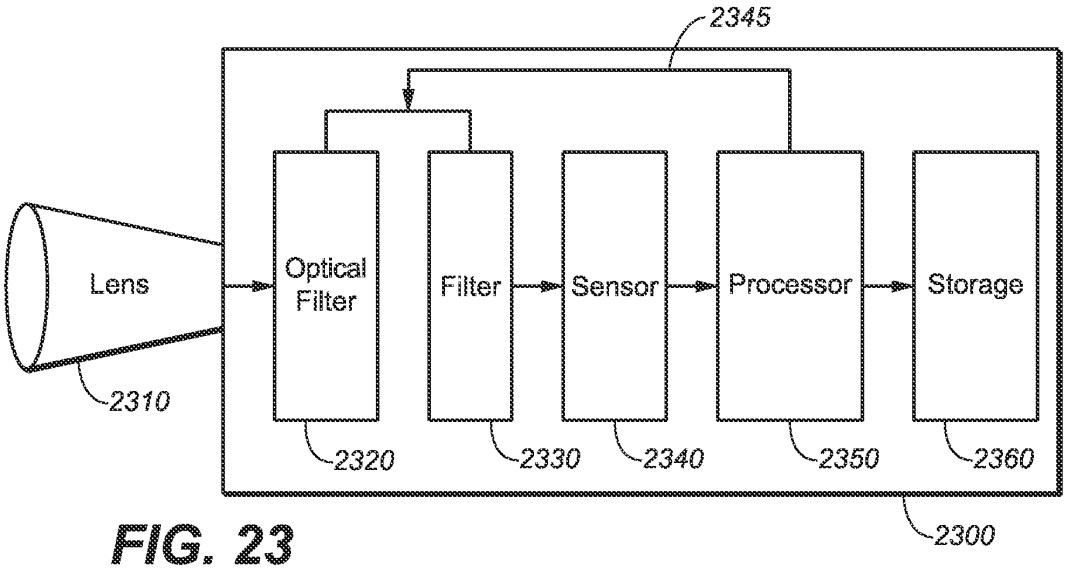

2345
Lens
Optical Filter
Filter
Sensor
Processor
Storage
2310
2320
2330
2340
2350
2360
2300

FIG. 23

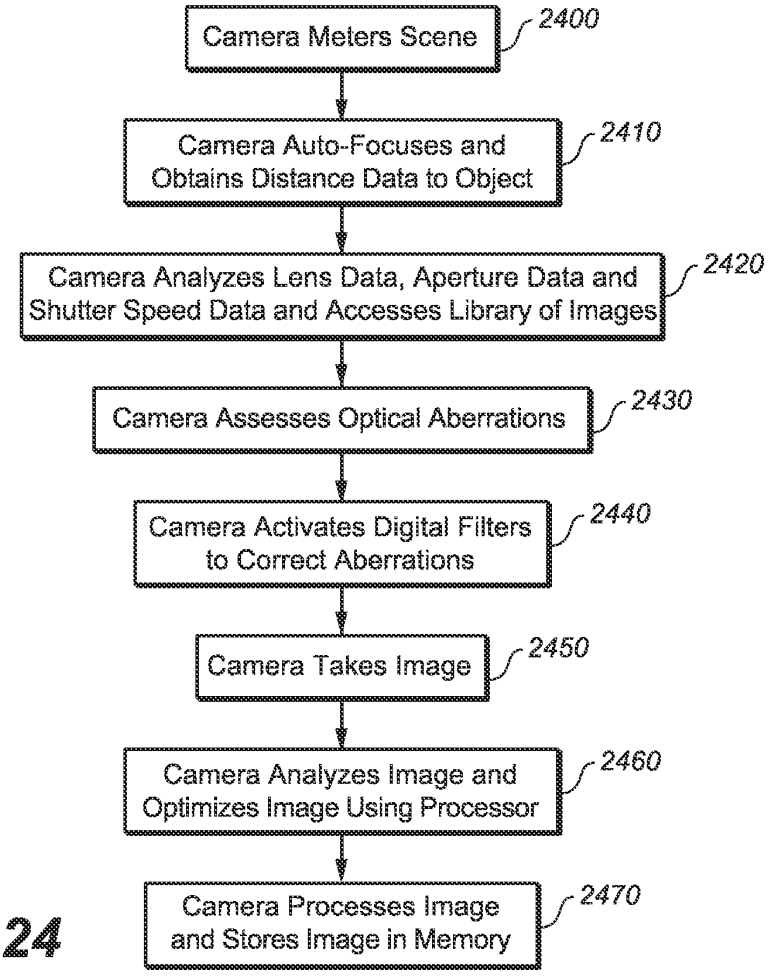

Camera Meters Scene
2400
Camera Auto-Focuses and Obtains Distance Data to Object
2410
Camera Analyzes Lens Data, Aperture Data and Shutter Speed Data and Accesses Library of Images
2420
Camera Assesses Optical Aberrations
2430
Camera Activates Digital Filters to Correct Aberrations
2440
Camera Takes Image
2450
Camera Analyzes Image and Optimizes Image Using Processor
2460
Camera Processes Image and Stores Image in Memory
2470

FIG. 24

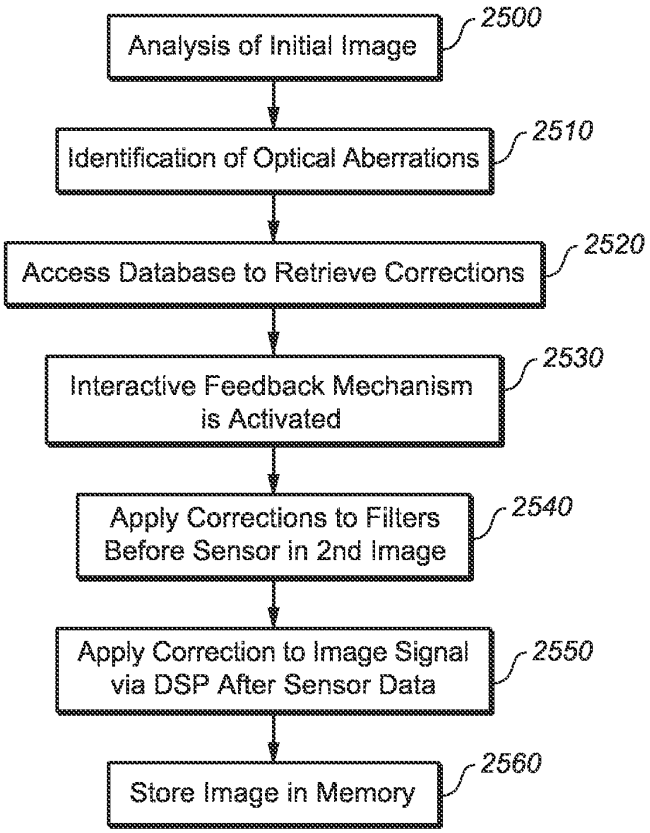

Analysis of Initial Image
2500
Identification of Optical Aberrations
2510
Access Database to Retrieve Corrections
2520
Interactive Feedback Mechanism is Activated
2530
Apply Corrections to Filters Before Sensor in 2nd Image
2540
Apply Correction to Image Signal via DSP After Sensor Data
2550
Store Image in Memory
2560

FIG. 25

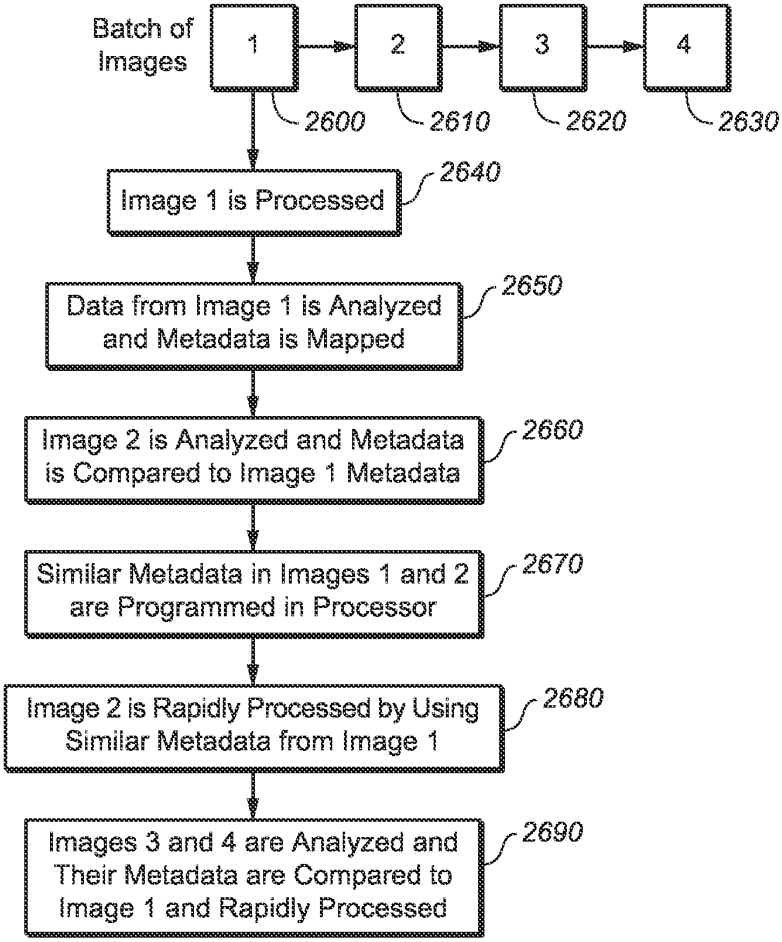

Batch of Images
1
2
3
4
2600
2610
2620
2630
Image 1 is Processed
2640
Data from Image 1 is Analyzed and Metadata is Mapped
2650
Image 2 is Analyzed and Metadata is Compared to Image 1 Metadata
2660
Similar Metadata in Images 1 and 2 are Programmed in Processor
2670
Image 2 is Rapidly Processed by Using Similar Metadata from Image 1
2680
Images 3 and 4 are Analyzed and Their Metadata are Compared to Image 1 and Rapidly Processed
2690

FIG. 26

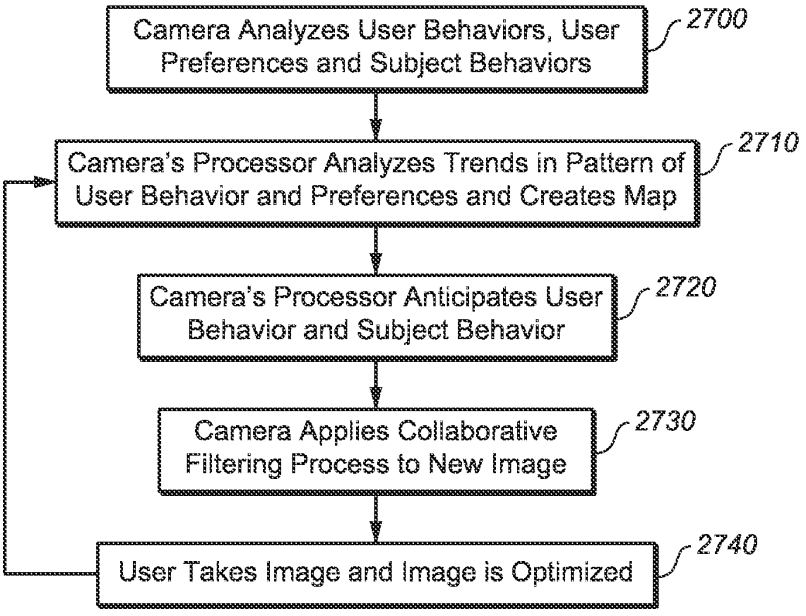

Camera Analyzes User Behaviors, User Preferences and Subject Behaviors
2700
Camera's Processor Analyzes Trends in Pattern of User Behavior and Preferences and Creates Map
2710
Camera's Processor Anticipates User Behavior and Subject Behavior
2720
Camera Applies Collaborative Filtering Process to New Image
2730
User Takes Image and Image is Optimized
2740

FIG. 27

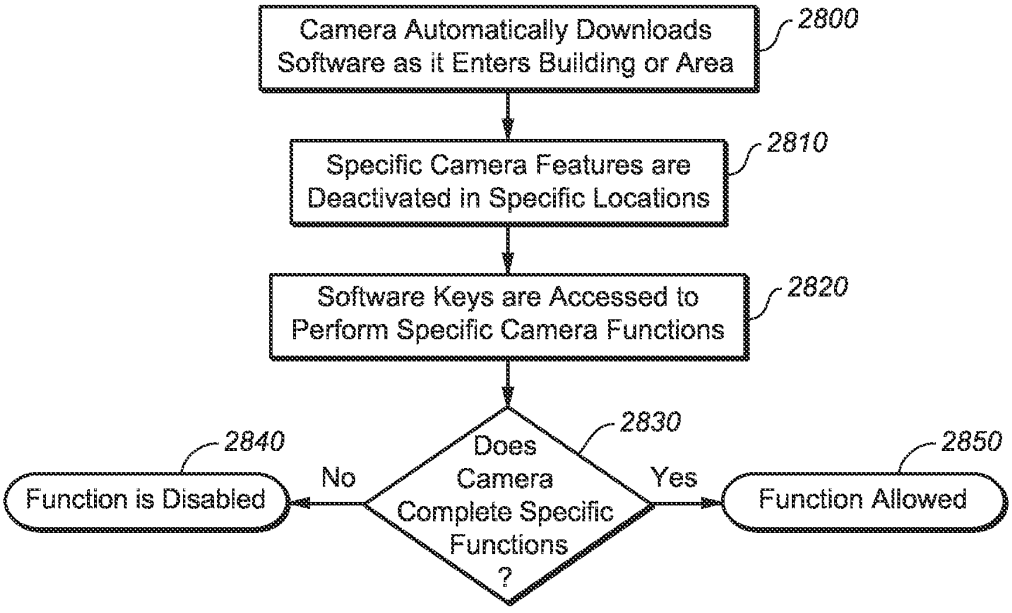

Camera Automatically Downloads Software as it Enters Building or Area
2800
Specific Camera Features are Deactivated in Specific Locations
2810
Software Keys are Accessed to Perform Specific Camera Functions
2820
Does Camera Complete Specific Functions ?
2830
No
Yes
Function is Disabled
2840
Function Allowed
2850

FIG. 28

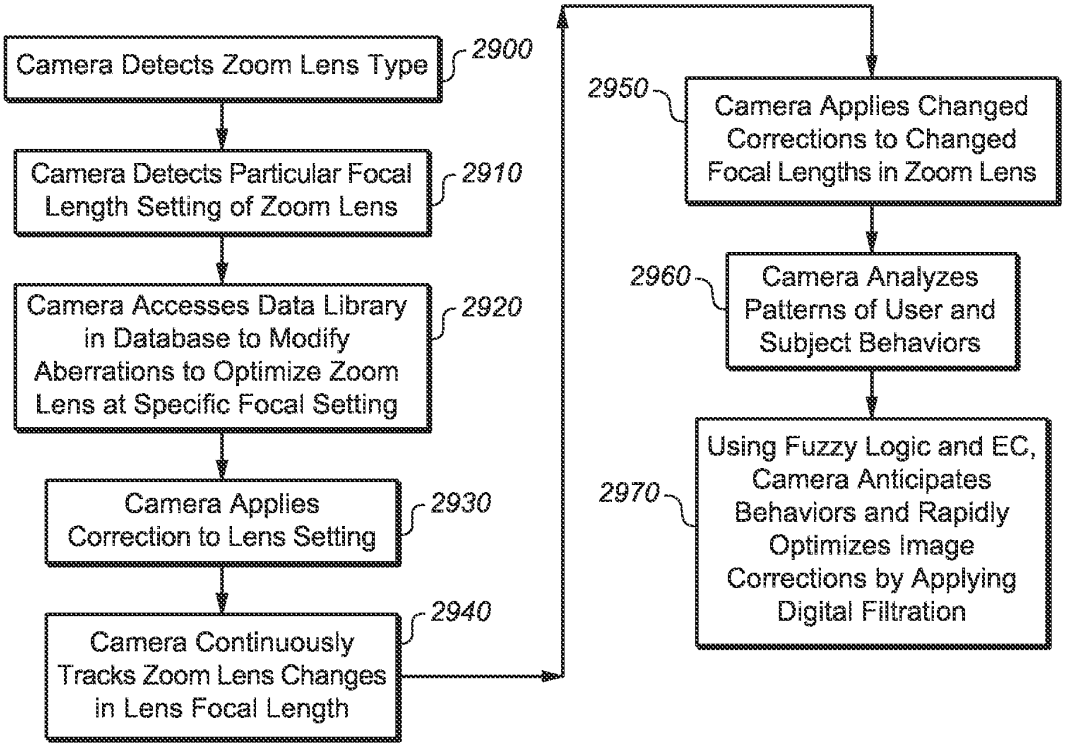

Camera Detects Zoom Lens Type
2900
Camera Detects Particular Focal Length Setting of Zoom Lens
2910
Camera Accesses Data Library in Database to Modify Aberrations to Optimize Zoom Lens at Specific Focal Setting
2920
Camera Applies Correction to Lens Setting
2930
Camera Continuously Tracks Zoom Lens Changes in Lens Focal Length
2940
2950
Camera Applies Changed Corrections to Changed Focal Lengths in Zoom Lens
2960
Camera Analyzes Patterns of User and Subject Behaviors
2970
Using Fuzzy Logic and EC, Camera Anticipates Behaviors and Rapidly Optimizes Image Corrections by Applying Digital Filtration

FIG. 29

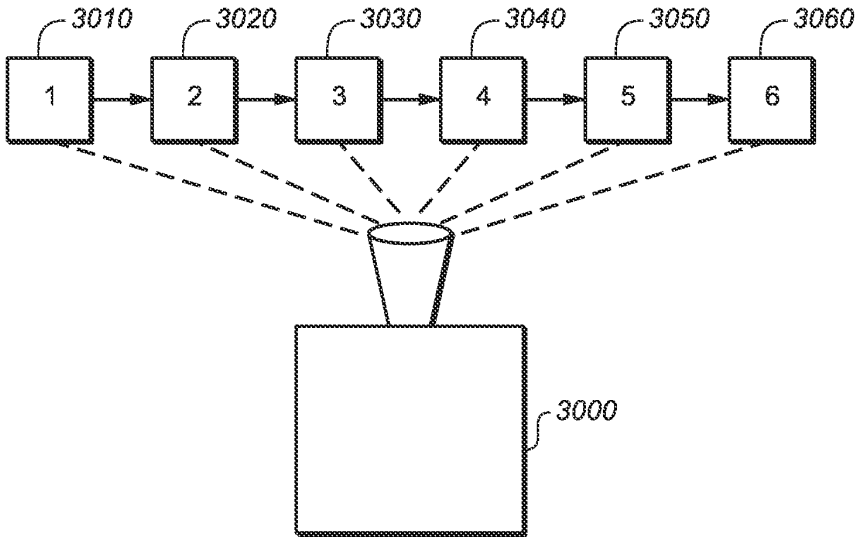

3010
3020
3030
3040
3050
3060
1
2
3
4
5
6
3000

FIG. 30

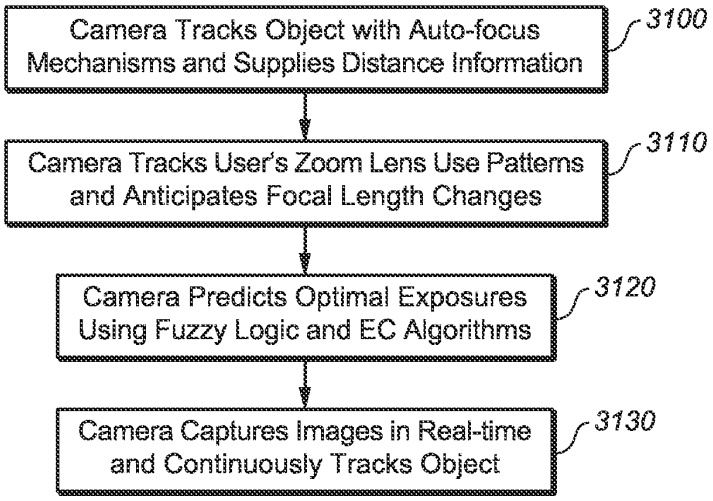

Camera Tracks Object with Auto-focus Mechanisms and Supplies Distance Information
3100
Camera Tracks User's Zoom Lens Use Patterns and Anticipates Focal Length Changes
3110
Camera Predicts Optimal Exposures Using Fuzzy Logic and EC Algorithms
3120
Camera Captures Images in Real-time and Continuously Tracks Object
3130

FIG. 31

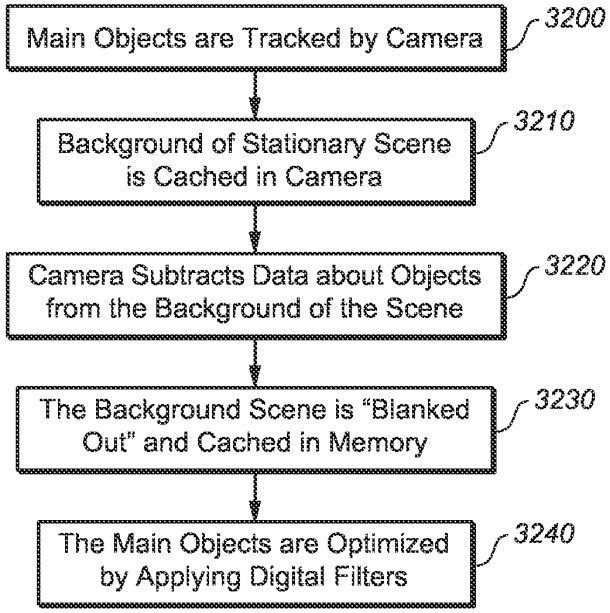

Main Objects are Tracked by Camera
3200
Background of Stationary Scene is Cached in Camera
3210
Camera Subtracts Data about Objects from the Background of the Scene
3220
The Background Scene is "Blanked Out" and Cached in Memory
3230
The Main Objects are Optimized by Applying Digital Filters
3240

FIG. 32

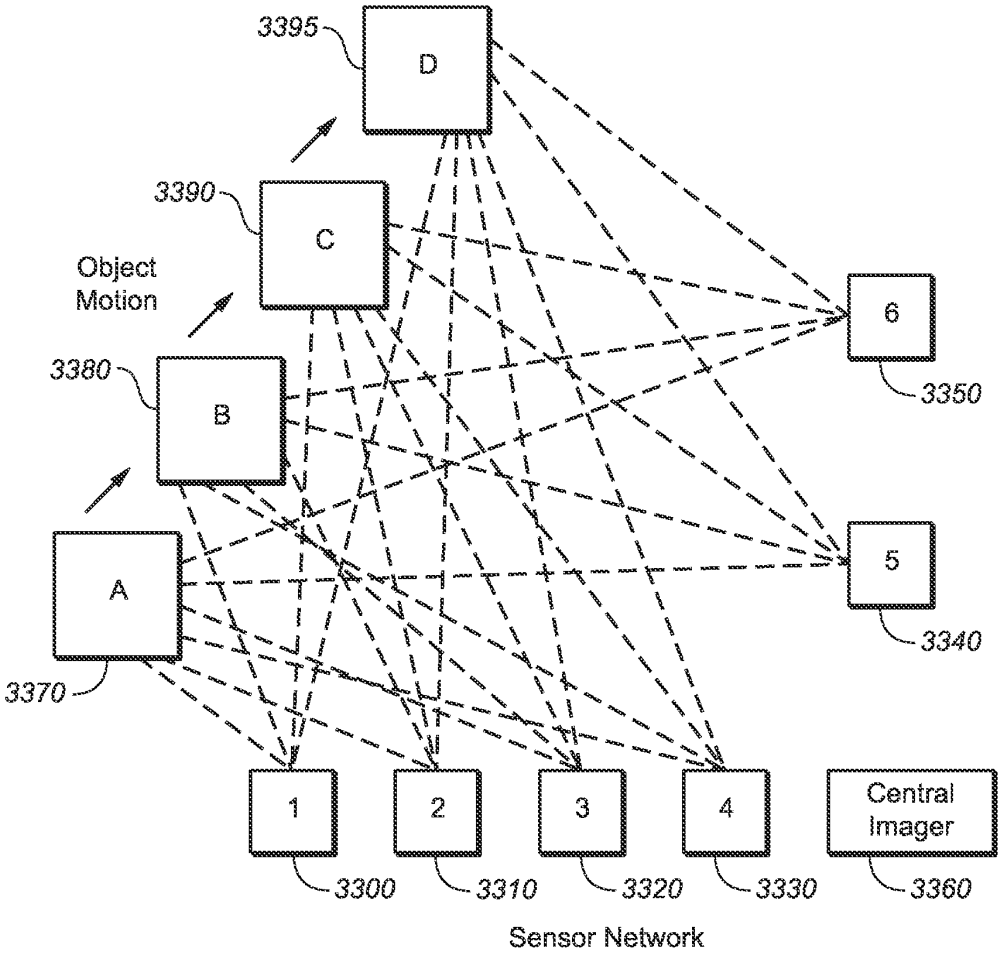

3395
D
3390
C
Object
Motion
3380
B
A
3370
6
3350
5
3340
1
2
3
4
Central
Imager
3300
3310
3320
3330
3360
Sensor Network

FIG. 33

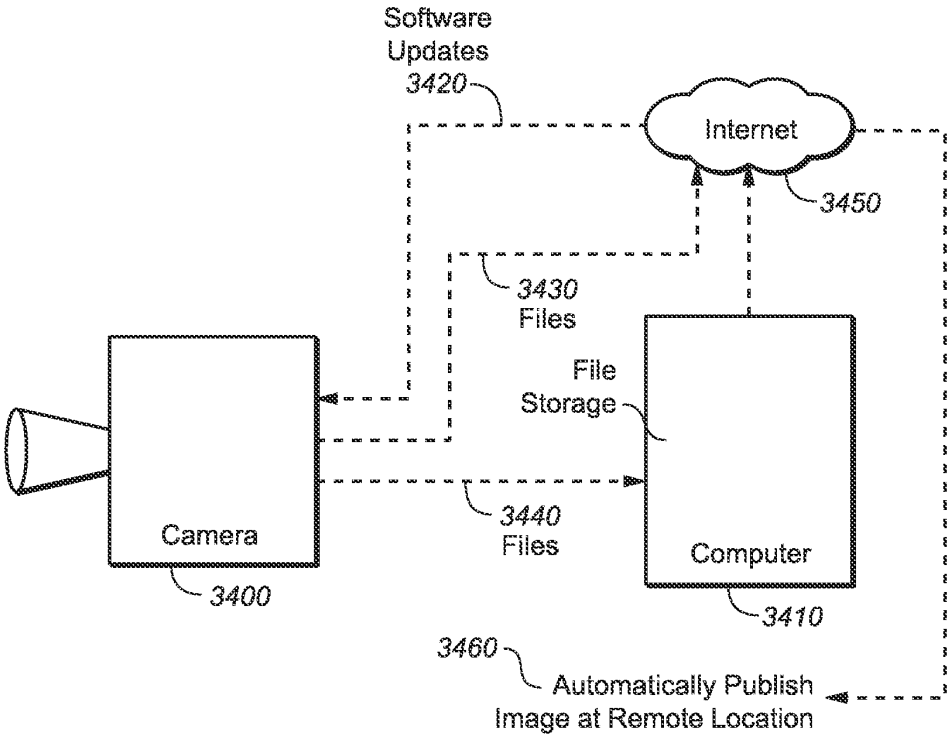

Software
Updates
3420
Internet
3450
3430
Files
File
Storage
3440
Files
Camera
3400
Computer
3410
3460
Automatically Publish
Image at Remote Location

FIG. 34

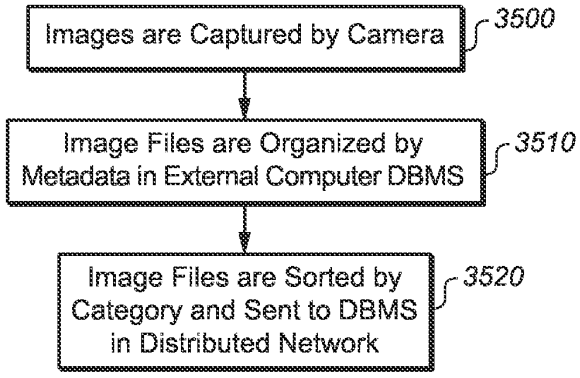

Images are Captured by Camera
3500
Image Files are Organized by
Metadata in External Computer DBMS
3510
Image Files are Sorted by
Category and Sent to DBMS
in Distributed Network
3520

FIG. 35

SCORE Placeholder Sheet for IFW Content

Application Number: 13691805 Document Date: 12/02/2012

The presence of this form in the IFW record indicates that the following document type was received in electronic format on the date identified above. This content is stored in the SCORE database.

- Drawings – Other than Black and White Line Drawings

Since this was an electronic submission, there is no physical artifact folder, no artifact folder is recorded in PALM, and no paper documents or physical media exist. The TIFF images in the IFW record were created from the original documents that are stored in SCORE.

To access the documents in the SCORE database, refer to instructions developed by SIRA.

At the time of document entry (noted above):

- Examiners may access SCORE content via the eDAN interface.
- Other USPTO employees can bookmark the current SCORE URL (http://es/ScoreAccessWeb/).
- External customers may access SCORE content via the Public and Private PAIR interfaces.

Form Revision Date: February 8, 2006

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/691,805	12/02/2012	2661	0.00		18	3

CONFIRMATION NO. 6244

103468
Neal Solomon
P.O. Box 21297
Oakland, CA 94620

FILING RECEIPT

OC000000058365729

Date Mailed: 01/03/2013

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Neal Solomon, Oakland, CA;

Applicant(s)

Neal Solomon, Oakland, CA;

Power of Attorney: None

Domestic Applications for which benefit is claimed - None.
A proper domestic benefit claim must be provided in an Application Data Sheet in order to constitute a claim for domestic benefit. See 37 CFR 1.76 and 1.78.

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

If Required, Foreign Filing License Granted: 12/27/2012

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/691,805**

Projected Publication Date: Request for Non-Publication Acknowledged

Non-Publication Request: Yes

Early Publication Request: No
** **SMALL ENTITY** **

Title

Digital imaging system for correcting video image aberrations

Preliminary Class

348

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as

set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

SelectUSA

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage, facilitate, and accelerate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/691,805	12/02/2012	Neal Solomon	

CONFIRMATION NO. 6244

103468
Neal Solomon
P.O. Box 21297
Oakland, CA 94620

FORMALITIES LETTER

OC000000058365730

Date Mailed: 01/03/2013

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is missing.
  *Applicant must submit $***390** *to complete the basic filing fee for a small entity.*

The applicant needs to satisfy supplemental fees problems indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- A surcharge (for late submission of the basic filing fee, search fee, examination fee or inventor's oath or declaration) as set forth in 37 CFR 1.16(f) of $ **130** for a small entity in compliance with 37 CFR 1.27, must be submitted.

SUMMARY OF FEES DUE:

Total fee(s) required within **TWO MONTHS** from the date of this Notice is $ **1390** for a small entity
- $ **390** Statutory basic filing fee.
- $ **130** Surcharge.
- The application search fee has not been paid. Applicant must submit $ **620** to complete the search fee.
- The application examination fee has not been paid. Applicant must submit $ **250** to complete the examination fee for a small entity in compliance with 37 CFR 1.27.

Items Required To Avoid Processing Delays:

Applicant is notified that the above-identified application contains the deficiencies noted below. No period for reply is set forth in this notice for correction of these deficiencies. However, if a deficiency relates to the inventor's oath or declaration, the applicant must file an oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each actual inventor no later than the expiration of the time period set in the "Notice of Allowability" to avoid abandonment. See 37 CFR 1.53(f).

A new inventor's oath or declaration that identifies this application (e.g., by Application Number and filing date) is required. The inventor's oath or declaration does not comply with 37 CFR 1.63 in that it:

- does not state that the above-identified application was made or authorized to be made by the person executing the oath or declaration.

Replies must be received in the USPTO within the set time period or must include a proper Certificate of Mailing or Transmission under 37 CFR 1.8 with a mailing or transmission date within the set time period. For more information and a suggested format, see Form PTO/SB/92 and MPEP 512.

Replies should be mailed to:

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web.
https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html

For more information about EFS-Web please call the USPTO Electronic Business Center at **1-866-217-9197** or visit our website at http://www.uspto.gov/ebc.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

/tnegash/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 13/691,805

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	98		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	310		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	125		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	18 minus 20 =	*	x 31 =	0.00	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*	x 125 =	0.00			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	533		TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)	OR	RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

UNITED STATES PATENT AND TRADEMARK OFFICE

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P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/691,805	12/02/2012	Neal Solomon	

CONFIRMATION NO. 6244

103468
Neal Solomon
P.O. Box 21297
Oakland, CA 94620

ABANDONMENT/TERMINATION LETTER

OC000000063588825

Date Mailed: 09/06/2013

NOTICE OF ABANDONMENT UNDER 37 CFR 1.53 (f) OR (g)

The above-identified application is abandoned for failure to timely or properly reply to the Notice to File Missing Parts (Notice) mailed on 01/03/2013.

- No reply was received.

If a complete reply to the notice was previously filed by applicant within the time period set forth in the notice, applicant may request for reconsideration of the holding of abandonment within 2 months from the mailing of this notice of abandonment by filing a petition to withdraw the holding of abandonment under 37 CFR 1.181(a). No petition fee is required. The petition must be accompanied by a true copy of the originally filed reply and the item(s) identified in one of the following:

1. A properly itemized date-stamped postcard receipt (see MPEP § 503);

2. If the originally filed reply included a certificate of mailing or transmission in compliance with 37 CFR 1.8(a), a copy of the certificate of mailing or transmission and a statement in compliance with 37 CFR 1.8(b) (see MPEP § 512); or

3. If the reply was filed via "Express Mail," a submission satisfying the requirements of 37 CFR 1.10(e) including, for example, a copy of the "Express Mail" mailing label showing the "date-in" (see MPEP § 513).

Any petition to withdraw the holding of abandonment should be directed to OPAP.

If applicant did not previously file a complete reply within the time period set forth in the notice, applicant may file a petition to revive the application under 37 CFR 1.137.

Under 37 CFR 1.137(a), a petition requesting the application be revived on the grounds of **UNAVOIDABLE DELAY** must be filed promptly after the applicant becomes aware of the abandonment and such petition must be accompanied by: (1) an adequate showing of the cause of unavoidable delay; (2) the required reply to the above-identified Notice; (3) the petition fee set forth in 37 CFR 1.17(l); and (4) a terminal disclaimer if required by 37 CFR 1.137(d). See MPEP § 711.03(c) and Form PTO/SB/61.

Under 37 CFR 1.137(b), a petition requesting the application be revived on the grounds of **UNINTENTIONAL DELAY** must be filed promptly after applicant becomes aware of the abandonment and such petition must be accompanied by: (1) a statement that the entire delay was unintentional; (2) the required reply to the above-identified Notice; (3) the petition fee set forth in 37 CFR 1.17(m); and (4) a terminal disclaimer if required by 37 CFR 1.137(d). See MPEP § 711.03(c) and Form PTO/SB/64.

Any questions concerning petitions to revive should be directed to the "Office of Petitions" at (571) 272-3282.

A copy of this notice MUST be returned with the reply.

/ylueng/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

Document code: WFEE

United States Patent and Trademark Office
Sales Receipt for Accounting Date: 03/27/2019

CVORACHA ADJ #00000001 Mailroom Dt: 02/11/2019
Seq No: 15 Sales Acctg Dt: 02/12/2019 13691805
03 FC : 2011 -150.00 OP

Document code: WFEE

United States Patent and Trademark Office
Sales Receipt for Accounting Date: 03/27/2019

CVORACHA SALE #00000002 Mailroom Dt: 02/11/2019 13691805
01 FC : 4011 75.00 OP

OPAP
FEB 11 2019
PATENT & TRADEMARK OFFICE

Doc Code: PET.OP
Document Description: Petition for Review by the Office of Petitions

PTO/SB/64 (07-09)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PETITION FOR REVIVAL OF AN APPLICATION FOR PATENT ABANDONED UNINTENTIONALLY UNDER 37 CFR 1.137(b)	Docket Number (Optional)

First named inventor: Neal Solomon

Application No.: 13/691,805 Art Unit: 2622

Filed: December 12, 2012 Examiner: Usman Khan

Title: Digital Imaging System for Correcting Video Image Aberrations

Attention: Office of Petitions
Mail Stop Petition
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450
FAX (571) 273-8300

NOTE: If information or assistance is needed in completing this form, please contact Petitions Information at (571) 272-3282.

The above-identified application became abandoned for failure to file a timely and proper reply to a notice or action by the United States Patent and Trademark Office. The date of abandonment is the day after the expiration date of the period set for reply in the office notice or action plus any extensions of time actually obtained.

APPLICANT HEREBY PETITIONS FOR REVIVAL OF THIS APPLICATION

NOTE: A grantable petition requires the following items:
(1) Petition fee;
(2) Reply and/or issue fee;
(3) Terminal disclaimer with disclaimer fee - required for all utility and plant applications filed before June 8, 1995; and for all design applications; and
(4) Statement that the entire delay was unintentional

1. Petition Fee

☒ Small entity-fee $ 1,000 (37 CFR 1.17(m)). Application claims small entity status. See 37 CFR 1.27.

☐ Other than small entity-fee $ _____ (37 CFR 1.17(m))

2. Reply and/or fee

A. The reply and/or fee to the above-noted Office action in the form of _____ (identify type of reply):

☐ has been filed previously on _____.

☒ is enclosed herewith.

B. The issue fee and publication fee (if applicable) of $_____.

☐ has been paid previously on _____.

☐ is enclosed herewith.

This collection of information is required by 37 CFR 1.137(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1.0 hour to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Mail Stop Petition, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

3. Terminal disclaimer with disclaimer fee

☒ Since this utility/plant application was filed on or after June 8, 1995, no terminal disclaimer is required.

☐ A terminal disclaimer (and disclaimer fee (37 CFR 1.20(d)) of $_____ for a small entity or $_____ for other than a small entity) disclaiming the required period of time is enclosed herewith (see PTO/SB/63).

4. STATEMENT: The entire delay in filing the required reply from the due date for the required reply until the filing of a grantable petition under 37 CFR 1.137(b) was unintentional. [NOTE: The United States Patent and Trademark Office may require additional information if there is a question as to whether either the abandonment or the delay in filing a petition under 37 CFR 1.137(b) was unintentional (MPEP 711.03(c), subsections (III)(C) and (D)).]

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

Neal Solomon — Signature

2/7/19 — Date

Neal Solomon — Type or Printed name

Registration Number, If applicable

PO Box 21297, Oakland, CA 94620 — Address

Telephone Number

Address

Enclosures:

☐ Fee Payment

☐ Reply

☐ Terminal Disclaimer Form

☐ Additional sheets containing statements establishing unintentional delay

☐ Other: _____

CERTIFICATE OF MAILING OR TRANSMISSION [37 CFR 1.8(a)]

I hereby certify that this correspondence is being:

☒ Deposited with the United States Postal Service on the date shown below with sufficient postage as first class mail in an envelope addressed to: Mail Stop Petition, Commissioner for Patents, P. O. Box 1450, Alexandria, VA 22313-1450.

☐ Transmitted by facsimile on the date shown below to the United States Patent and Trademark Office at (571) 273-8300.

2/7/19 — Date

Neal Solomon — Signature

Neal Solomon — Typed or printed name of person signing certificate

OPAP AKIMA-15
FEB 1 1 2019
PATENT & TRADEMARK OFFICE

February 7, 2019

Office of Petitions

Patent and Trademark Office

P.O. Box 1450

Alexandria, VA 22313-1450

Re: Petition to Revive Abandoned U.S. Patent Application 13/691,805

Dear Office of Petitions:

On December 12, 2012, I filed patent application 13/691,805 entitled "Digital Imaging System for Correcting Video Image Aberrations" with the U.S. PTO [confirmation number 6244]. However, this application was abandoned for lack of payment of application fees.

I am requesting revival of this abandoned patent application. Enclosed is completed Form 64 (Petition for Revival of an Application for Patent Abandoned Unintentionally under 37 CFR 1.137(b)), indicating the abandonment was unintentional. The reason for the non-payment was economic constraints.

Also enclosed is a petition to expedite the request to revive the abandoned patent application.

I am paying the $785 for the patent application fee (for electronic filing), $1,000 for the Office of Petitions fee and $200 for the petition to expedite. I am enclosing a check for $1985. Please refer to the accompanying petition to expedite.

I appreciate your assistance is processing this request.

If you have any questions, you may reach me at the address and number below.

Yours very truly,

Neal Z Solomon

Neal Solomon

P.O. Box 21297

Oakland, CA 94620

(415) 334-5600



Petition to Expedite

February 7, 2019

Office of Petitions

Patent and Trademark Office

P.O. Box 1450

Alexandria, VA 22313-1450

Re: U.S. Patent Application 13/691,805

Dear Office of Petitions:

Please expedite the petition for revival of U.S. patent application 13/691,805 [confirmation number 6244]. I am the inventor and owner of '805.

I am enclosing a letter requesting revival of the patent application and appropriate fees. In addition, I am enclosing a completed Form 64 (Petition for Revival of an Application for Patent Abandoned Unintentionally under 37 CFR 1.137(b)).

I am paying a fee of $200 for the petition to expedite.

Please expedite the processing of the request as soon as possible. Note that I am a small entity.

Feel free to call if you have any questions. I appreciate your assistance in processing this request.

Respectfully submitted,

Neal Z. Solomon

Neal Solomon

(415) 334-5600

United States Patent and Trademark Office

- Sales Receipt -

02/12/2019 HVUONG1 00000015 13691805

01 FC:2453	1000.00	OP
02 FC:2462	200.00	OP
03 FC:2011	150.00	OP
04 FC:2311	380.00	OP
05 FC:2051	80.00	OP
06 FC:2622	175.00	OP

Document Code: IMIS

Notice of Fee Due

Application Number: 13691805 Date: 02-12-19

Fees are due for the application or document dated 02/11/19. The payment was not collectable for the reason indicated below.

Note: If the fee due is for any of the filing fees, the surcharge for late payment of the filing fees is now due as well.

- ☑ Insufficient payment by check or money order.
- ☑ No authorization to charge a deposit account.
- ☐ Invalid deposit account number.
- ☐ User name not listed in deposit account _____ at _____(time).
- ☐ Insufficient funds in deposit account _____ at _____ (time).
- ☐ Insufficient payment by credit card.
- ☐ Declined credit card _____(time).

Fee code(s) to be applied:	2111	$ 330
		$
		$
		$
		$
Amount in holding fee code:	1506	$
	1622/2622	$ 175
	1206/2206	$
	1999	$
		$ 155

RAM Operator: Huong

Rev. 04/10/2013



FL
DAC

February 26, 2019

Office of Petitions
U.S. PTO
P.O. Box 1450
Alexandria, VA 22313-1450

Re: Application 13/691,805

Dear Petitions:

I recently paid $1985 to revive application 13/691,805. However, according to a recent calculation of fees due, the amount I paid was deficient by $155.

Enclosed please find a check for $155 in order to process my request to revive – and expedite – the patent application.

If you have questions, please contact me at the number below.

Sincerely,

Neal Solomon

(415) 334-5600

United States Patent and Trademark Office

- Sales Receipt -

Adjustment date: 03/01/2019 CCHAU1

02/12/2019 HVUONG1 00000015 13691805

06 FC:2622 -175.00 OP

United States Patent and Trademark Office

- Sales Receipt -

03/01/2019 CCHAU1 00000021 13691805

01 FC:2111 330.00 OP

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/691,805	12/02/2012	Neal Solomon		6244

103468 7590 03/22/2019

Neal Solomon
P.O. Box 21297
Oakland, CA 94620

EXAMINER	
ART UNIT	PAPER NUMBER
2661	
MAIL DATE	DELIVERY MODE
03/22/2019	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450
www.uspto.gov

In re Application of	:	
Solomon, Neal	:	
Application No. 13/691,805	:	DECISION ON PETITION
Filed: December 02, 2012	:	
For: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS	:	

This is a decision on the petition under 37 CFR 1.182, filed February 11, 2019, to expedite consideration of the petition under the unintentional provisions of 37 CFR 1.137(b), filed February 11, 2019 and supplemented on February 28, 2019, which is being treated as a petition under the unintentional provisions of 37 CFR 1.137(a), to revive the above-identified application. The requisite $200 petition fee to expedite consideration has been received.

The petition under 37 CFR 1.182 is **GRANTED**.

The petition under 37 CFR 1.137(a) is **GRANTED**.

The application became abandoned for failure to reply in a timely manner to the Notice to File Missing Parts of Nonprovisional Application (Notice), mailed January 03, 2013. The Notice set a period for reply of two (2) months from the mail date of the Notice. No extensions of time under the provisions of 37 CFR 1.136(a) were obtained. Accordingly, the application became abandoned by operation of law on March 04, 2013. A courtesy Notice of Abandonment was mailed on September 06, 2013.

The petition satisfies the requirements of 37 CFR 1.137(a) in that petitioner has supplied (1) the reply in the form of the basic filing fee of $150, the search fee of $330, the examination fee of $380, the surcharge fee $80, (2) the petition fee of $1,000 and (3) a proper statement of unintentional delay.

37 CFR 1.137(b)(4) requires a statement that the entire delay in filing the required reply from the due date for the reply until the filing of a grantable petition pursuant to 37 CFR 1.137(a) was unintentional. Since the statement appearing in the petition varies from the language required by 37 CFR 1.137(b)(4), the statement is being construed as the required statement. Petitioner must notify the Office if this is **not** a correct reading of the statement appearing in the petition.

This application has been abandoned for an extended period of time. The U.S. Patent and Trademark Office is relying on petitioner's duty of candor and good faith and accepting the statement that "the entire delay in filing the required reply from the due date for the reply until the filing of a grantable petition pursuant to 37 CFR 1.137 was unintentional." *See* Changes to Representation of Others Before the United States Patent and Trademark Office, 73 Fed. Reg. 47650 (August 14, 2008), 1334 Off. Gaz. Pat. Office 338 (September 9, 2008) (applicant obligated under 37 CFR 11.18 to inquire into the underlying facts and circumstances when providing the statement required by 37 CFR 1.137 to the U.S. Patent and Trademark Office).

This application is being referred to the Office of Patent Application Processing (OPAP) for further pre-examination processing in the normal course of business on the reply received February 11, 2019 and February 28, 2019.

Telephone inquiries concerning this decision should be directed to Jonya Smalls, Paralegal Specialist at (571) 272-1619.

/JONYA SMALLS/
Jonya Smalls
Paralegal Specialist, OPET

Document code: WFEE

United States Patent and Trademark Office
Sales Receipt for Accounting Date: 03/27/2019

CVORACHA RF #00192489 Mailroom Dt: 03/27/2019 13691805

CHECK Refund Total: $75.00

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/691,805	12/02/2012	Neal Solomon	

CONFIRMATION NO. 6244

103468
Neal Solomon
P.O. Box 21297
Oakland, CA 94620

INFORMAL NOTICE

OC000000106975050

Date Mailed: 03/29/2019

INFORMATIONAL NOTICE TO APPLICANT

Applicant is notified that the above-identified application contains the deficiencies noted below. No period for reply is set forth in this notice for correction of these deficiencies. However, if a deficiency relates to the inventor's oath or declaration, the applicant must file an oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each actual inventor no later than the expiration of the time period set in the "Notice of Allowability" to avoid abandonment. See 37 CFR 1.53(f).

The item(s) indicated below are also required and should be submitted with any reply to this notice to avoid further processing delays.

A new inventor's oath or declaration that identifies this application (e.g., by Application Number and filing date) is required. The inventor's oath or declaration does not comply with 37 CFR 1.63 in that it:

- does not state that the above-identified application was made or authorized to be made by the person executing the oath or declaration.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/sareebuddin/

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/691,805		Neal Solomon	

CONFIRMATION NO. 6244

103468
Neal Solomon
P.O. Box 21297
Oakland, CA 94620

WITHDRAWAL NOTICE

OC000000106885876

Date Mailed: 03/29/2019

Letter Regarding a New Notice and/or the Status of the Application

If a new notice or Filing Receipt is enclosed, applicant may disregard the previous notice mailed on 09/06/2013. The time period for reply runs from the mail date of the new notice. Within the time period for reply, applicant is required to file a reply in compliance with the requirements set forth in the new notice to avoid abandonment of the application.

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web. https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html

For more information about EFS-Web please call the USPTO Electronic Business Center at **1-866-217-9197** or visit our website at http://www.uspto.gov/ebc.

If the reply is not filed electronically via EFS-Web, the reply must be accompanied by a copy of the new notice.

If the Office previously granted a petition to withdraw the holding of abandonment or a petition to revive under 37 CFR 1.137, the status of the application has been returned to pending status.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/sareebuddin/

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 13/691,805

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	75		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	330		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	380		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	18 minus 20 =	*	x 50 =	0.00	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*	x 230 =	0.00			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	785		TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)	OR	RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/691,805	12/02/2012	2661	865		18	3

CONFIRMATION NO. 6244

UPDATED FILING RECEIPT

103468
Neal Solomon
P.O. Box 21297
Oakland, CA 94620

OC000000108975049

Date Mailed: 03/29/2019

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Neal Solomon, Oakland, CA;

Applicant(s)

Neal Solomon, Oakland, CA;

Power of Attorney: None

Domestic Applications for which benefit is claimed - None.
A proper domestic benefit claim must be provided in an Application Data Sheet in order to constitute a claim for domestic benefit. See 37 CFR 1.76 and 1.78.

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: No

Permission to Access Search Results: No

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 12/27/2012

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/691,805**

Projected Publication Date: Request for Non-Publication Acknowledged

Non-Publication Request: Yes

Early Publication Request: No
**** SMALL ENTITY ****
Title

Digital imaging system for correcting video image aberrations

Preliminary Class

348

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications:

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

SelectUSA

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The U.S. offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to promote and facilitate business investment. SelectUSA provides information assistance to the international investor community; serves as an ombudsman for existing and potential investors; advocates on behalf of U.S. cities, states, and regions competing for global investment; and counsels U.S. economic development organizations on investment attraction best practices. To learn more about why the United States is the best country in the world to develop technology, manufacture products, deliver services, and grow your business, visit http://www.SelectUSA.gov or call +1-202-482-6800.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s): Neal Solomon
Title: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

Docket No.:	5311.001US3	Serial No.:	13/691,805
Filed:	December 2, 2012	Due Date:	N/A
Examiner:	Unknown	Group Art Unit:	2661
Customer No.:	21186	Confirmation No.:	6244

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

We are transmitting herewith the following attached items (as indicated with an "X"):

X Power of Attorney to Prosecute Applications before the USPTO (PTO/AIA/82B) (1 pg.)

If not provided for in a separate paper filed herewith, please consider this a PETITION FOR EXTENSION OF TIME for sufficient number of months to enter these papers and please charge any additional fees or credit overpayment to Deposit Account No. 19-0743. If applicable, any papers or fees supplied herewith are considered to be timely filed pursuant to 37 C.F.R. § 1.7(a), the response period falling on a Federal Holiday, Saturday or Sunday being extended to the next succeeding business day.

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
Customer No.: 21186

By: /Timothy E. Bianchi/
Timothy E. Bianchi
Reg. No. 39,610

Electronic Acknowledgement Receipt

EFS ID:	35861224
Application Number:	13691805
International Application Number:	
Confirmation Number:	6244
Title of Invention:	Digital imaging system for correcting video image aberrations
First Named Inventor/Applicant Name:	Neal Solomon
Customer Number:	103468
Filer:	Timothy J. Christman/Mandy Brown
Filer Authorized By:	Timothy J. Christman
Attorney Docket Number:	
Receipt Date:	29-APR-2019
Filing Date:	02-DEC-2012
Time Stamp:	15:40:48
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		5311_001US3_RPOA_signed.pdf	182753 e440a36af30be973952ff5a131f5d78d56d7d446	yes	2

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Power of Attorney	2	2
	Miscellaneous Incoming Letter	1	1
Warnings:			
Information:			
	Total Files Size (in bytes):	182753	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Amended PTO/AIA/82B(07-13)
Approved for use through 03/31/2021. OMB 0651-0035
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

POWER OF ATTORNEY BY APPLICANT

I hereby revoke all previous powers of attorney given in the application identified in either the attached transmittal letter or the boxes below.

Application Number	Filing Date

(Note: The boxes above may be left blank if information is provided on form PTO/AIA/82A.)

☒ I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above: 21186

OR

☐ I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

Please recognize or change the correspondence address for the application identified in the attached transmittal letter or the boxes above to:

☒ The address associated with the above-mentioned Customer Number.

OR

☐ The address associated with Customer Number:

OR

☐ Firm or Individual Name					
Address					
City		State		Zip	
Country					
Telephone		Email			

I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

☒ Inventor or Joint Inventor (title not required below)

☐ Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)

☐ Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)

☐ Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

SIGNATURE of Applicant for Patent

The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

Signature	/Neal J Solomon/	Date (Optional)	
Name	**Neal Solomon**		
Title			

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.

☒ *Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/691,805	12/02/2012	Neal Solomon	5311.001US3

CONFIRMATION NO. 6244

21186
SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402

POA ACCEPTANCE LETTER

OC000000107829002

Date Mailed: 05/02/2019

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 04/29/2019.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/mabebe/

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13/691,805	Solomon, Neal
	Examiner	Art Unit
	MARLY S CAMARGO	2699

CPC - Searched*		
Symbol	**Date**	**Examiner**
(H04N5/357 | H04N5/217 | H04N5/2253 | H04N5/2254 | H04N5/228 | H04N5/238 | H04N5/76 | H04N5/225 | H04N5/374 | G06K9/36 | G06K9/40 | G01J1/20).CPC.	05/10/2019	

CPC Combination Sets - Searched*		
Symbol	**Date**	**Examiner**

US Classification - Searched*			
Class	**Subclass**	**Date**	**Examiner**
348	241,231.99,222.1,335,240.99,240.1,240.3,333.08,340,342,208.11,345,346-350,355,349	05/10/2019	
382	254,255,264,263,266,275	05/10/2019	
359	16,637,666,665,207.2,354,676	05/10/2019	

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	**Date**	**Examiner**
(H04N5/357 | H04N5/217 | H04N5/2253 | H04N5/2254 | H04N5/228 | H04N5/238 | H04N5/76 | H04N5/225 | H04N5/374 | G06K9/36 | G06K9/40 | G01J1/20).CPC. and the results teaxt limited - see attached search history printout.	05/10/2019	
EAST as BRS	05/10/2019	
inventor	05/10/2019	
assignee	05/10/2019	
Google and Google Patents	05/01-10/2019	

/MARLY S CAMARGO/ Examiner, Art Unit 2699	

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13/691,805	Solomon, Neal
	Examiner	Art Unit
	MARLY S CAMARGO	2699

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner

/MARLY S CAMARGO/ Examiner, Art Unit 2699	

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13/691,805	Solomon, Neal
	Examiner	Art Unit
	MARLY S CAMARGO	2699

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

CLAIMS

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	05/11/2019								
	1	✓								
	2	✓								
	3	✓								
	4	✓								
	5	✓								
	6	✓								
	7	✓								
	8	✓								
	9	✓								
	10	✓								
	11	✓								
	12	✓								
	13	✓								
	14	✓								
	15	✓								
	16	✓								
	17	✓								
	18	✓								

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/691,805	12/02/2012	Neal Solomon	5311.001US3	6244

21186 7590 05/15/2019

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402

EXAMINER
CAMARGO, MARLY S.B.

ART UNIT	PAPER NUMBER
2699	

NOTIFICATION DATE	DELIVERY MODE
05/15/2019	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

SLW@blackhillsip.com
uspto@slwip.com

Office Action Summary	**Application No.** 13/691,805	**Applicant(s)** Solomon, Neal	
	Examiner MARLY S CAMARGO	**Art Unit** 2699	**AIA (FITF) Status** No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☑ Responsive to communication(s) filed on application revival filed on 02/11/2019, granted on 03/22/2019..

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☐ This action is **FINAL.** 2b) ☑ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5) ☑ Claim(s) 1-18 is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6) ☐ Claim(s) _____ is/are allowed.

7) ☑ Claim(s) 1-18 is/are rejected.

8) ☐ Claim(s) _____ is/are objected to.

9) ☐ Claim(s) _____ are subject to restriction and/or election requirement

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to **PPHfeedback@uspto.gov.**

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☑ The drawing(s) filed on 12/2/2012 is/are: a)☑ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☑ Notice of References Cited (PTO-892)

2) ☐ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date _____.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date _____.

4) ☐ Other: _____.

Notice of Pre-AIA or AIA Status

The present application is being examined under the pre-AIA first to invent provisions.

Note: The present application was abandoned by Applicant on 09/06/2013 and Applicant file a petition for revival on 02/11/2019. The petition was granted by the office on 03/22/2019; therefore, the current application is being examined under the pre- AIA provisions.

Change in Art Unit Designation for Your Application

1. The Art Unit designation of your application in the USPTO has changed from 2664 to 2699. The examiner assigned to this application remains the same. To aid in correlating any papers for this application, all further correspondence regarding this application should be directed to Art Unit 2699.

DETAILED ACTION

2. This is the initial Office Action based on the revival of application filed 02/11/2019 and granted on 03/22/2019, which was previously abandoned on 09/06/2013. This application is a Continuation of application 12/586221, which is a continuation of 11/825521. The Examiner acknowledges the following:

3. The drawings filed on 12/02/2012 are accepted by the Examiner.

4. Currently claims 1 - 18 are pending and are being considered for examination.

Claim Objections

5. Claim set includes two claims numbered 18. Correction to the claim disclosure is required.

Double Patenting

6. The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the "right to exclude" granted by a patent and to prevent possible harassment by multiple assignees. A nonstatutory obviousness-type double patenting rejection is appropriate where the conflicting claims are not identical, but at least one examined application claim is not patentably distinct from the reference claim(s) because the examined application claim is either anticipated by, or would have been obvious over, the reference claim(s). See, e.g., In re Berg, 140 F.3d 1428, 46 USPQ2d 1226 (Fed. Cir. 1998); In re Goodman, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993); In re Longi, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); In re Van Omum, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); In re Vogel, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); and In re Thorington, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321 (c) or 1.321(d) may be used to overcome an actual or provisional rejection based on a nonstatutory double patenting ground provided the conflicting application or patent either is shown to be commonly owned with this application, or claims an invention made as a result of activities undertaken within the scope of a joint research agreement.

Effective January 1, 1994, a registered attorney or agent of record may sign a terminal disclaimer. A terminal disclaimer signed by the assignee must fully comply with 37 CFR 3.73(b).

5. Instant Application and parent application 12/586221(US 8,451,339 B2) allowed on May 28, 2013.

Claims 1 - 18 are rejected on the ground of nonstatutory obviousness-type double patenting as being unpatentable over claims 1 – 18 of parent Application No. 12/586221(US 8,451,339 B2) allowed on May 28,2013, which is now allowed in view of Havens (US 2007/0080280 A1) and in further view of Alon (US 2007/0236574 A1).

Note: Please, see Table I for the comparison between the claims of the parent patent US 8,451,339 B2 (1st column) and the present application as the apparatus claims (2nd column). That is not a complete list of all the current claims, but it indicates the most relevant limitations of claims that were already patented in the parent US 8,451,339 B2.

Regarding Claim 1:

As seen in Table I, parent case claim 1 has the same limitations as the current application and underlined portions represent the limitations that are common to both. The only difference is that the child claims “an integrated circuit” instead “a microprocessor”; however, a microprocessor is generally part of the integrated circuit of a digital camera as claimed. On the other hand, claim 6 of the parent already claims the integrated circuit as well. As for the “video”, a digital imaging system as disclosed in the parent is capable of doing that. As for “at least at least one frame” limitation, in the parent the images or image frames or video image frames are interpreted as the same limitation in both the parent and the child. Therefore, there is nothing new or different in relation to what was already disclosed in the parent.

Therefore, claim 1 is rejected under nonstatutory obviousness-type double patenting in view of the references cited, and it is anticipated and fully encompassed by claim 1 of the parent issued patent US 8,451,339 B2.

Regarding claims 2 – 5:

Even though the text of the aforementioned claims was not included in Table I; their disclosure is pretty much the same which was already disclosed in parent patent and they are rejected under non-statutory double patent as fully encompassed by claims 2 – 5 of parent patent US 8,451,339 B2.

Regarding Claim 6:

As seen in Table I, parent case claim 6 has the same limitations as the current application and underlined portions represent the limitations that are common to both. The only difference is that the child claims "an integrated circuit" instead "a microprocessor"; however, a microprocessor is generally part of the integrated circuit of a digital camera as claimed. As for the "video", a digital imaging system as disclosed in the parent is capable of doing that. As for "at least at least one frame" limitation, in the parent the images or image frames or video image frames are interpreted as the same limitation in both the parent and the child. Therefore, there is nothing new or different in relation to what was already disclosed in the parent.

Therefore, claim 6 is rejected under nonstatutory obviousness-type double patenting in view of the references cited, and it is anticipated and fully encompassed by claim 6 of the parent issued patent US 8,451,339 B2.

Regarding claims 7 – 13:

Even though the text of the aforementioned claims was not included in Table I; their disclosure is pretty much the same which was already disclosed in parent patent and they are rejected under non-statutory double patent as fully encompassed by claims 7 – 13 of parent patent US 8,451,339 B2.

Regarding Claim 14:

As seen in Table I, parent case claim 14 has the same limitations as the current application and underlined portions represent the limitations that are common to both. The only difference is that the child claims "an integrated circuit" instead "a microprocessor"; however, a microprocessor is generally part of the integrated circuit of a digital camera as claimed. On the other hand, claim 6 of the parent already claims the integrated circuit as well. As for the "video", a digital imaging system as disclosed in the parent is capable of doing that. As for "at least at least one frame" limitation, in the parent the images or image frames or video image frames are interpreted as the same limitation in both the parent and the child. Therefore, there is nothing new or different in relation to what was already disclosed in the parent.

Therefore, claim 14 is rejected under nonstatutory obviousness-type double patenting in view of the references cited, and it is anticipated and fully encompassed by claim 14 of the parent issued patent US 8,451,339 B2.

Regarding claims 15 – 18:

Even though the text of the aforementioned claims was not included in Table I; their disclosure is pretty much the same which was already disclosed in parent patent and they are rejected under non-statutory double patent as fully encompassed by claims 15 – 18 of parent patent US 8,451,339 B2.

Note: the extra claim 18 (the first one) is rejected under the non-statutory double patent based on its dependence on claim 14.

In conclusion, claims 1 – 18 of the current application are rejected under non-statutory obviousness-type double patent as related to grandparent claims 1 – 18 of the parent issued patent US 8,451,339 B2.

TABLE I: Comparison between the parent claims and the child or present application claims.

Parent 12/586221 – now US 8,451,339 B2	Child 13/691805
1. A digital imaging system for correcting optical image aberrations comprising:	**1. A digital imaging system for correcting optical image aberrations comprising:**
a digital camera mechanism, **an optical lens mechanism**, **a digital sensor**, a microprocessor, **a digital signal processor**, **system software**, **a database management system and a memory storage sub-system;**	**a digital** video **camera mechanism**, **an optical lens mechanism,** at least one **digital sensor**, an integrated circuit, **a digital signal processor**, **system software**, **a database management system and a memory storage sub-system;**
wherein the optical lens mechanism is a fixed focal length lens;	**wherein the optical lens mechanism is a fixed focal length lens;**
wherein a microprocessor **uses system software to identify at least one optical aberration by accessing the database;**	**wherein** an integrated circuit **uses system software to identify at least one optical aberration by accessing the database;**
wherein the microprocessor **uses the database to identify at least one algorithm to use to correct the at least one optical aberration**;	**wherein the** integrated circuit **uses the database to identify at least one algorithm to use to correct the at least one optical** and/or digital

wherein when the image file is captured by the digital sensor the digital file is forwarded to the digital signal processor; **wherein the image file with the at least one optical aberration is corrected by applying digital filtration by using at least one algorithm in the digital signal processor; and** **wherein the modified digital file consisting of the digital data optimized from the at least one optical aberration that are corrected from the original optical image is stored in memory.**	**aberration** in at least one frame of the digital video; **wherein when the video image file is captured by the** at least one **digital sensor the digital file is forwarded to the digital signal processor**; **wherein the** video **image file with the at least one optical** or digital **aberration is corrected by applying digital filtration by using at least one algorithm in the digital signal processor; and** **wherein the modified digital file consisting of the digital data optimized from the at least one optical** or digital **aberration that are corrected from the original video image is stored in memory**. Note: i) the microprocessor in the parent is part of an integrated circuit of the digital imaging system; ii) at least one frame limitation: in the parent the images or image frames or video image frames are interpreted as the same limitation in both the parent and the child; iii) note that claim 6 of parent also include the integrated circuit.
6. A digital imaging system for correcting image aberrations comprising: **a digital camera mechanism, an optical lens mechanism, a digital sensor, an integrated circuit, a digital signal processor, system software, a database management system and a memory storage sub-system;** **wherein the optical lens mechanism is a zoom lens or a fixed focal length lens;** **wherein the image data file is forwarded from the digital sensor to storage in memory;** **wherein at least one optical and/or digital aberration in the image file are identified by comparing image files in the database management system by using the system software and the integrated circuit;** **wherein the at least one filtration algorithms required to correct the at least one optical and/or digital aberration are sent from the integrated circuit to the digital signal processor;**	**6. A digital imaging system for correcting image aberrations comprising:** **a digital video camera mechanism, an optical lens mechanism**, at least **one digital sensor, an integrated circuit, a digital signal processor, system software, a database management system and a memory storage sub-system;** **wherein the optical lens mechanism is a zoom lens or a fixed focal length lens;** **wherein the video image data file is forwarded from the** at least one **digital sensor to storage in memory**; **wherein at least one optical and/or digital aberration in** at least two frames of **the digital video image file are identified by comparing image files in the database management system by using the system software and the integrated circuit;** **wherein the at least one filtration algorithms required to correct the at least one optical and/or digital aberration** of at least two frames of the digital video file **are sent from the integrated circuit to the digital signal processor**;

wherein the at least one optical and/or digital aberration from the optical lens mechanism are corrected by using the digital signal processor to apply digital filtration algorithm; and **wherein the modified digital file consisting of the digital data optimized from the at least one aberration that are corrected from the original optical image is stored in memory.**	**wherein the at least one optical and/or digital aberration from the optical lens mechanism** of at least two frames of the digital video file **are corrected by using the digital signal processor to apply at least one digital filtration algorithm;** and **wherein the modified digital video file consisting of the digital data optimized from the at least one aberration that are corrected from the original video images is stored in memory.**
14. A digital imaging system for correcting image aberrations comprising: **a digital camera mechanism, an optical lens mechanism, a digital sensor**, a microprocessor, **a digital signal processor, system software, a database management system and a memory storage sub-system;** **wherein the optical lens mechanism is a zoom lens;** **wherein the zoom lens changes focal length positions;** **wherein when the image file is captured by the digital sensor the file is forwarded to the digital signal processor and to memory;** **wherein** the microprocessor **uses system software to access the database to identify at least one optical aberration in the image file at any focal length of a zoom lens configuration;** **wherein** the microprocessor **accesses the database to obtain at least one filtration correction algorithm to the optical aberrations and forwards the at least one filtration algorithms to the digital signal processor;** **wherein the image file is forwarded to the digital signal processor which applies at least one filtration algorithm to optimize the image and corrects the at least one optical**	14. A digital imaging system for correcting image aberrations comprising: **a digital video camera mechanism, an optical lens mechanism**, at least one **digital sensor**, an integrated circuit, **a digital signal processor, system software, a database management system and a memory storage sub-system;** **wherein the optical lens mechanism is a zoom lens;** **wherein the zoom lens changes focal length positions;** **wherein when the** digital **image file is captured by the** at least one **digital sensor the file is forwarded to the digital signal processor and to memory;** **wherein** the integrated circuit **uses system software to access the database to identify at least one optical** and/or digital **aberrations in** at least one frame of the video **file at any focal length of a zoom lens configuration;** **wherein** the integrated circuit **accesses the database to obtain at least one filtration correction algorithm to the optical** and/or digital **aberrations** of at least one frame in the video file **and forwards the at least one filtration algorithms to the digital signal processor;**

aberration at the specific focal length in the zoom lens configuration; and **wherein the modified image file consisting of the digital data optimized from the at least one optical aberration of a specific focal length of the zoom lens that are corrected from the original optical image is stored in memory.**	**wherein** the digital video **image file is forwarded to the digital signal processor which applies at least one filtration algorithm to optimize** the digital video **file and corrects the at least one optical** and/or digital **aberrations** in at least one video frame for the **at least one focal length in the zoom lens configuration; and** **wherein the modified** digital video **image file consisting of the digital data optimized from the at least one optical** and/or digital **aberrations** in at least one frame of the video file of at least one **focal length of the zoom lens that are corrected from the original video image is stored in memory.** Note: : i) the microprocessor in the parent is part of an integrated circuit of the digital imaging system; ii) at least one frame limitation: in the parent the images or image frames or video image frames are interpreted as the same limitation in both the parent and the child; iii) note that claim 6 of parent also include the integrated circuit.

Conclusion

7. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure:

1. N. Solomon, US 8,451,339 B2 – it belongs to the same inventor and it claims the same invention limitations as the current invention. There is a double patent issue with the current application.

2. W. Havens, US 2007/0080280 A1 – it teaches an imager for use in a data collection device, said imager comprising a fluid lens system for focusing light received by said data collection device from a target image, said fluid lens system comprising: an optically clear front window, a fluid lens having a front surface and a rear surface, a first volume bounded by said front window and said front surface of said fluid lens, said first volume having a

first fluid disposed therein; an optically clear rear window; a second volume bounded by the front surface of said fluid lens and said rear window, said second volume having a second fluid disposed therein; and a sealed system comprising a pump, a first channel connecting said first volume to said pump, and a second channel connecting said second volume to said pump, wherein said pump comprises a seal that separates said first fluid and said second fluid, and wherein operation of said pump to effect a first change in the quantity of fluid in either of said first volume or said second volume results in a corresponding second change in the quantity of fluid in the other of said first volume or said second volume, wherein the front surface of said fluid lens defines a meniscus, and wherein the fluid lens system is operative so that curvature of the meniscus is changed responsively to change in the quantity of fluid in either of said first volume or said second volume.

3. A. Alon et al., US 2007/0236574 A1 – it teaches a method for producing a camera, which includes objective optics for forming an image on an electronic image sensor and a digital filter for filtering an output of the image sensor, the method comprising: defining a maximum permissible value of a noise gain; determining one or more aberrations due to the objective optics; calculating coefficients of the digital filter so as to compensate for the one or more aberrations while preventing the noise gain of the digital filter from exceeding the maximum permissible value; and filtering the output of the image sensor using the computed coefficients so as to generate an enhanced output image.

4. H. Hamano et al., US 9,998,652 B2 – it teaches a focusing adjustment apparatus includes a focusing unit, a first acquisition unit, a second acquisition unit, and a control unit. The focusing unit outputs a first signal for a focusing operation. The first acquisition

unit acquires first information, which is related to characteristics of a signal used for outputting the first signal, and second information, which is related to characteristics of a captured image and is predetermined. The second acquisition unit acquires third information on aberrations of an imaging optical system. The control unit calculates a correction value based on the first information, the second information, and the third information. By using the correction value, the control unit changes the first signal, output from the focusing unit, to a second signal used in the focusing operation.

5. N. Koishi, US 10,237,485 B2 – it teaches an image processing apparatus includes a vibration-proof optical system driving amount acquiring section, a distortion aberration correcting section, and a deviation amount converting section. The vibration-proof optical system driving amount acquiring section acquires a driving amount of the vibration-proof optical system. The distortion aberration correcting section corrects a distortion aberration on based on a deviation amount to a captured image. The deviation amount converting section calculates the deviation amount corresponding to the driving amount on the basis of a correlation between a shape of the distortion aberration corresponding to the driving amount of the vibration-proof optical system and a shape of the distortion aberration corresponding to the deviation amount.

Contact

8. Any inquiry concerning this communication or earlier communications from the examiner should be directed to MARLY CAMARGO whose telephone number is (571)270-3729. The examiner can normally be reached on 6:00AM - 10PM, M-F, EST.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Lin Ye can be reached on (571)272-7372. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/MARLY S CAMARGO/
Examiner, Art Unit 2699

Notice of References Cited	Application/Control No. 13/691,805	Applicant(s)/Patent Under Reexamination Solomon, Neal	
	Examiner MARLY S CAMARGO	Art Unit 2699	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-8,451,339-B2	05-2013	Solomon; N.	H04N5/228	348/222.1
*	B	US-2007/0080280-A1	04-2007	Havens; W.	G01J1/20	250/201.1
*	C	US-2007/0236574-A1	10-2007	Alon; A.	H04N5/225	348/207.99
*	D	US-9,998,652-B2	06-2018	Hamano; H.	H04N5/357	348/349
*	E	US-10,237,485-B2	03-2019	Koishi; N.	H04N5/23287	348/208.5
	F					
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FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
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	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	33470	348/241,231.99,222.1,335,240.99,240.1,240.3,333.08,340,342,208.11,345,346-350,355,349.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(17:32
L2	15928	382/254,255,264,263,266,275.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(17:32
L3	5250	359/16,637,666,665,207.2,354,676.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(17:33
L4	119424	(H04N5/357 | H04N5/217 | H04N5/2253 | H04N5/2254 | H04N5/228 | H04N5/238 | H04N5/76 | H04N5/225 | H04N5/374 | G06K9/36 | G06K9/40 | G01J1/20).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(18:20
L5	17	(aberration$1 with digital with database)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(18:21
L6	9	1 and 5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(18:21
L7	0	2 and 5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(18:21
L8	0	3 and 5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(18:21
L9	5	4 and 5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	ON	2019/05/1(18:22

			DERWENT; IBM_TDB			
L10	0	canon.as. and (aberration$1 with digital with database)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(18:22
L12	0	canon.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:23
L13	0	fuji.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:23
L14	0	microsoft.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:23
L15	0	panasoninc.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:24
L16	0	nikon.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:24
L17	0	omnivision.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:26
L19	0	olympus.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:29
L20	0	olympus.as. and ((aberration$1 with digital with database) and vignet$5)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:29
L21	0	pelican.as. and ((aberration$1 with digital with database) and vignet$5)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:29
L22	0	fotonation.as. and ((aberration$1 with digital with database) and vignet$5)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:30
L23	0	(carl with zeiss).as. and ((aberration$1 with digital with database) and vignet$5)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:30
S1	0	13/691805	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(12:06
S2	2	12/586221	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(12:06
S3	4	11/825521	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(12:08
S4	139	(neal with solomon).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(12:09

S5	17	(neal with solomon).in. and (correct$4 with aberration$1)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(12:10
S6	11	(neal with solomon).as.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(12:11
S7	6	("20070080280" | "20070236574").PN. OR ("8451339").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:19
S8	0	(11/278268).APP.	USPAT; USOCR	OR	ON	2019/05/1(12:25
S9	1	(11/546531).APP.	USPAT; USOCR	OR	ON	2019/05/1(12:26
S10	116	("1269422" | "20030098952" | "20040008853" | "20040218283" | "20040227063" | "20040228003" | "20050002113" | "20050014306" | "20050100270" | "20050212952" | "20050218231" | "20060072915" | "20060076540" | "20060086596" | "20070063048" | "20070080280" | "20070116858" | "20080144185" | "20080144186" | "20080245872" | "20090072037" | "2062468" | "2300251" | "3161718" | "3305294" | "3583790" | "3761157" | "3778170" | "4134393" | "4191594" | "4210121" | "4249516" | "4261655" | "4286839" | "4289379" | "4312709" | "4407567" | "4487659" | "4514048" | "4783153" | "4783155" | "4784479" | "4802746" | "5091801" | "5150234" | "5305356" | "5389222" | "5396144" | "5684637" | "5892625" | "5917657" | "5973852" | "6081388" | "6109852" | "6188526" | "6212015" | "6368954" | "6369954" | "6376971" | "6399954" | "6437925" | "6449081" | "6475639" | "6529620" | "6538823" | "6542309" | "6545815" | "6545816" | "6586859" | "6628040" | "6702483" | "6715876" | "6734903" | "6747806" | "6762210" | "6806621" | "6806988" | "6809462" | "6812624" | "6882086" | "6891317" | "6934090" | "6936809" | "7169822" | "7224106" | "7301708" | "7416125" | "RE39874").PN. OR ("8027095").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:27
S11	28	("20020176148" | "20040228003" | "5071229" | "5150234").PN. OR ("6934090").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:32
S12	480	(marly with camargo).xa,xp.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(12:36
S13	18	(marly with camargo).xa,xp. and (correct$4 with aberration$1)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(12:36
S14	5	("20060228097" | "8395677" | "9077842" | "9392176" | "9998652").PN. OR ("10237485").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:38
S15	9	("20080309771" | "20090256952" | "20100013947" | "20100194966" | "20120274837" | "20140036134" | "20140340567" | "6363220").PN. OR ("9998652").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:39
S16	12	(aberration$1 with digital with database)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:42
S17	10	(aberration$1 with digital with database) and vignet$5	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:43
S18	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:44
S19	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with	US-PGPUB;	OR	ON	2019/05/1(

		circuit) and (lens with mechanism)	USPAT; USOCR			12:46
S20	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:46
S21	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1)))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:49
S22	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1))) and (algorithm or procedure)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:49

EAST Search History (Interference)

< This search history is empty>

5/ 10/ 2019 6:31:26 PM
C:\ Users\ mcamargo\ Documents\ EAST\ Workspaces\ 13691805.wsp

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/691,805	12/02/2012	Neal Solomon	5311.001US3	6244

21186 7590 07/17/2019

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402

EXAMINER
CAMARGO, MARLY S.B.

ART UNIT	PAPER NUMBER
2699	

NOTIFICATION DATE	DELIVERY MODE
07/17/2019	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

SLW@blackhillsip.com
uspto@slwip.com

Applicant-Initiated Interview Summary	**Application No.** 13/691,805	**Applicant(s)** Solomon, Neal	
	Examiner MARLY S CAMARGO	**Art Unit** 2699	**AIA (FITF) Status** No

All participants (applicant, applicants representative, PTO personnel):

(1) MARLY S.B.. CAMARGO. (3) _____.

(2) Mr. Tim Bianchi (REG# 39610). (4) _____.

Date of Interview: 12 July 2019.

Type: ☐ Telephonic ☑ Video Conference
☐ Personal [copy given to: ☐ applicant ☐ applicant's representative]

Exhibit shown or demonstration conducted: ☐ Yes ☑ No.
If Yes, brief description: _____.

Issues Discussed ☐101 ☐112 ☐102 ☐103 ☑Others
(For each of the checked box(es) above, please describe below the issue and detailed description of the discussion)

Claim(s) discussed: n/a.

Identification of prior art discussed: n/a.

Substance of Interview
(For each issue discussed, provide a detailed description and indicate if agreement was reached. Some topics may include: identification or clarification of a reference or a portion thereof, claim interpretation, proposed amendments, arguments of any applied references etc...)

Mr. Bianchi called the Examiner to discuss some general problems related to the application: 1) filing a Terminal Disclaimer overcome the Double Patent rejection; 2) to file a petition to modify the ADS (Application Data Sheet) since Applicant made a mistake when filing it up; 3) file an amendment to claims to improve the claim language. Based on our conversation, Mr. Bianchi is filing the TD, the petition to correct the ADS and claim amendment with improved claim language..

Applicant recordation instructions: The formal written reply to the last Office action must include the substance of the interview. (See MPEP section 713.04). If a reply to the last Office action has already been filed, applicant is given a non-extendable period of the longer of one month or thirty days from this interview date, or the mailing date of this interview summary form, whichever is later, to file a statement of the substance of the interview.

Examiner recordation instructions: Examiners must summarize the substance of any interview of record. A complete and proper recordation of the substance of an interview should include the items listed in MPEP 713.04 for complete and proper recordation including the identification of the general thrust of each argument or issue discussed, a general indication of any other pertinent matters discussed regarding patentability and the general results or outcome of the interview, to include an indication as to whether or not agreement was reached on the issues raised.

☐ Attachment

/MARLY S CAMARGO/ Examiner, Art Unit 2699	

Summary of Record of Interview Requirements

Manual of Patent Examining Procedure (MPEP), Section 713.04, Substance of Interview Must be Made of Record
A complete written statement as to the substance of any face-to-face, video conference, or telephone interview with regard to an application must be made of record in the application whether or not an agreement with the examiner was reached at the interview.

Title 37 Code of Federal Regulations (CFR) 1.133 Interviews
Paragraph (b)

In every instance where reconsideration is requested in view of an interview with an examiner, a complete written statement of the reasons presented at the interview as warranting favorable action must be filed by the applicant. An interview does not remove the necessity for reply to Office action as specified in §§ 1.111, 1.135. (35 U.S.C. 132)

37 CFR §1.2 Business to be transacted in writing.
All business with the Patent or Trademark Office should be transacted in writing. The personal attendance of applicants or their attorneys or agents at the Patent and Trademark Office is unnecessary. The action of the Patent and Trademark Office will be based exclusively on the written record in the Office. No attention will be paid to any alleged oral promise, stipulation, or understanding in relation to which there is disagreement or doubt.

The action of the Patent and Trademark Office cannot be based exclusively on the written record in the Office if that record is itself incomplete through the failure to record the substance of interviews.

It is the responsibility of the applicant or the attorney or agent to make the substance of an interview of record in the application file, unless the examiner indicates he or she will do so. It is the examiners responsibility to see that such a record is made and to correct material inaccuracies which bear directly on the question of patentability.

Examiners must complete an Interview Summary Form for each interview held where a matter of substance has been discussed during the interview by checking the appropriate boxes and filling in the blanks. Discussions regarding only procedural matters, directed solely to restriction requirements for which interview recordation is otherwise provided for in Section 812.01 of the Manual of Patent Examining Procedure, or pointing out typographical errors or unreadable script in Office actions or the like, are excluded from the interview recordation procedures below. Where the substance of an interview is completely recorded in an Examiners Amendment, no separate Interview Summary Record is required.

The Interview Summary Form shall be given an appropriate Paper No., placed in the right hand portion of the file, and listed on the "Contents" section of the file wrapper. In a personal interview, a duplicate of the Form is given to the applicant (or attorney or agent) at the conclusion of the interview. In the case of a telephone or video-conference interview, the copy is mailed to the applicants correspondence address either with or prior to the next official communication. If additional correspondence from the examiner is not likely before an allowance or if other circumstances dictate, the Form should be mailed promptly after the interview rather than with the next official communication.

The Form provides for recordation of the following information:
- Application Number (Series Code and Serial Number)
- Name of applicant
- Name of examiner
- Date of interview
- Type of interview (telephonic, video-conference, or personal)
- Name of participant(s) (applicant, attorney or agent, examiner, other PTO personnel, etc.)
- An indication whether or not an exhibit was shown or a demonstration conducted
- An identification of the specific prior art discussed
- An indication whether an agreement was reached and if so, a description of the general nature of the agreement (may be by attachment of a copy of amendments or claims agreed as being allowable). Note: Agreement as to allowability is tentative and does not restrict further action by the examiner to the contrary.
- The signature of the examiner who conducted the interview (if Form is not an attachment to a signed Office action)

It is desirable that the examiner orally remind the applicant of his or her obligation to record the substance of the interview of each case. It should be noted, however, that the Interview Summary Form will not normally be considered a complete and proper recordation of the interview unless it includes, or is supplemented by the applicant or the examiner to include, all of the applicable items required below concerning the substance of the interview.

A complete and proper recordation of the substance of any interview should include at least the following applicable items:
1) A brief description of the nature of any exhibit shown or any demonstration conducted,-
2) an identification of the claims discussed,
3) an identification of the specific prior art discussed,
4) an identification of the principal proposed amendments of a substantive nature discussed, unless these are already described on the Interview Summary Form completed by the Examiner,
5) a brief identification of the general thrust of the principal arguments presented to the examiner,
(The identification of arguments need not be lengthy or elaborate. A verbatim or highly detailed description of the arguments is not required. The identification of the arguments is sufficient if the general nature or thrust of the principal arguments made to the examiner can be understood in the context of the application file. Of course, the applicant may desire to emphasize and fully describe those arguments which he or she feels were or might be persuasive to the examiner.)
6) a general indication of any other pertinent matters discussed, and
7) if appropriate, the general results or outcome of the interview unless already described in the Interview Summary Form completed by the examiner.

Examiners are expected to carefully review the applicants record of the substance of an interview. If the record is not complete and accurate, the examiner will give the applicant an extendable one month time period to correct the record.

Examiner to Check for Accuracy

If the claims are allowable for other reasons of record, the examiner should send a letter setting forth the examiners version of the statement attributed to him or her. If the record is complete and accurate, the examiner should place the indication, Interview Record OK on the paper recording the substance of the interview along with the date and the examiners initials.

Electronic Acknowledgement Receipt

EFS ID:	36809420
Application Number:	13691805
International Application Number:	
Confirmation Number:	6244
Title of Invention:	Digital imaging system for correcting video image aberrations
First Named Inventor/Applicant Name:	Neal Solomon
Customer Number:	21186
Filer:	Jose M. Nunez/Farah O'Sullivan
Filer Authorized By:	Jose M. Nunez
Attorney Docket Number:	5311.001US3
Receipt Date:	07-AUG-2019
Filing Date:	02-DEC-2012
Time Stamp:	14:33:15
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		InterviewAgenda13691805.pdf	724792 eb1bbe75392b99c414f41e85f8146d19584853b6	yes	3

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Letter Requesting Interview with Examiner	1	1
	Miscellaneous Incoming Letter	2	3
Warnings:			
Information:			
	Total Files Size (in bytes):	724792	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Applicant Initiated Interview Request Form

Application No.: 13/691,805 First Named Applicant: Neal Solomon
Examiner: M. Camargo Art Unit: 2699 Status of Application: Pending

Tentative Participants:
(1) T. Bianchi **(2)** _____

(3) _____ **(4)** _____

Proposed Date of Interview: open **Proposed Time:** open **(◎AM◎PM)**

Type of Interview Requested:
(1) ☑ **Telephonic** **(2)** ☐ **Personal** **(3)** ☐ **Video Conference**

Exhibit To Be Shown or Demonstrated: ☑ **YES** ☐ **NO**
If yes, provide brief description: Proposed amended claim 1.

Issues To Be Discussed

Issues (Rej., Obj., etc)	Claims/ Fig. #s	Prior Art	Discussed	Agreed	Not Agreed
(1) text of claim 1	1		☐	☐	☐
(2)			☐	☐	☐
(3)			☐	☐	☐
(4)			☐	☐	☐

☐ Continuation Sheet Attached ☑ Proposed Amendment or Arguments Attached

Brief Description of Arguments to be Presented: Discuss amended claim.

An interview was conducted on the above-identified application on _____

NOTE: This form should be completed and filed by applicant in advance of the interview (see MPEP § 713.01). If this form is signed by a registered practitioner not of record, the Office will accept this as an indication that he or she is authorized to conduct an interview on behalf of the principal (37 CFR 1.32(a)(3)) pursuant to 37 CFR 1.34. This is not a power of attorney to any above named practitioner. See the Instruction Sheet for this form, which is incorporated by reference. By signing this form, applicant or practitioner is certifying that he or she has read the Instruction Sheet. After the interview is conducted, applicant is advised to file a statement of the substance of this interview (37 CFR 1.133(b)) as soon as possible. This application will not be delayed from issue because of applicant's failure to submit a written record of this interview.

/Timothy E. Bianchi/
Applicant/Applicant's Representative Signature

Examiner/SPE Signature

Timothy E. Bianchi
Typed/Printed Name of Applicant or Representative

office 612 373-6912 / mobile 612 743-5431
Applicant's/Applicant's Representative's Telephone Number

39,610
Registration Number, if applicable

This collection of information is required by 37 CFR 1.133. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 24 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

1. [Proposed Amendments] A digital imaging system for correcting optical image aberrations in a digital video, comprising:

a digital video camera ~~mechanism~~including in-camera software, an optical lens mechanism, at least one digital sensor for capturing the digital video, an integrated circuit including: a digital signal processor ~~;system software~~,configured to access a database management system including a plurality of optical image aberration corrections and a memory storage sub-system;

wherein the optical lens mechanism is a fixed focal length lens;

wherein ~~an~~ the integrated circuit uses ~~system~~ the in-camera software to identify at least one optical aberration and ~~by accessing the database;~~

~~wherein the integrated circuit uses the database to identify at least one algorithm to use~~ to correct the at least one optical ~~and/or digital~~image aberration in at least one frame of the digital video using at least one of the plurality of optical image aberration corrections in the database;

wherein when the video ~~image file~~ is captured by the at least one digital sensor ~~the digital file~~ and is forwarded to the digital signal processor;

wherein the video ~~image file~~ with the at least one optical or digital aberration is corrected by applying digital filtration ~~by~~ using ~~at least one algorithm in~~ the digital signal processor; and

wherein the ~~modified~~ corrected ~~digital file~~ video consisting of the digital data optimized from the at least one optical or digital aberration that are corrected from the original video image is stored in the memory storage sub-system.

1. [Clean Copy With Proposed Amendments] A digital imaging system for correcting optical image aberrations in a digital video, comprising:

a digital video camera including in-camera software, an optical lens mechanism, at least one digital sensor for capturing the digital video, an integrated circuit including a digital signal processor configured to access a database management system including a plurality of optical image aberration corrections and a memory storage sub-system;

wherein the optical lens mechanism is a fixed focal length lens;

wherein the integrated circuit uses the in-camera software to identify at least one optical aberration and to correct the at least one optical image aberration in at least one frame of the digital video using at least one of the plurality of optical image aberration corrections in the database;

wherein when the video is captured by the at least one digital sensor and is forwarded to the digital signal processor;

wherein the video with the at least one optical or digital aberration is corrected by applying digital filtration using the digital signal processor; and

wherein the corrected video consisting of the digital data optimized from the at least one optical or digital aberration that are corrected from the original video image is stored in the memory storage sub-system.

Modified PTO/AIA/14 (12-13)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor:

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix

Residence Information (Select One) ☐ US Residency ☐ Non US Residency ☐ Active US Military Service

City		State/Province		Country of Residence	

Mailing Address of Inventor:

Address 1	
Address 2	

City		State/Province	
Postal Code		Country	

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ An Address is being provided for the correspondence information of this application.

Customer Number	
Email Address	

Application Information:

Title of the Invention			
Attorney Docket Number		Small Entity Status Claimed ☐	
Application Type			
Subject Matter			
Suggested Class (if any)		Sub Class (if any)	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)		Suggested Figure for Publication (if any)	

Modified PTO/AIA/14 (12-13)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country Publication

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ Request Not to Publish. I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application has not and will not be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Enter either Customer Number or complete the Representative Name section below. If both sections are completed the Customer Number will be used for the Representative Information during processing.

Please Select One:	☐ Customer	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)
Customer Number			

EX1002 - Page 156

Modified PTO/AIA/14 (12-13)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78(a)(2) or CFR 1.78(a)(4), and need not otherwise be made part of the specification.

Prior Application Status	Patented		
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
This application	continuation of	12/586,221	2009-09-18
Prior Application Status	Patented		
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
This application	continuation of	11/825,521	2007-07-06
Prior Application Status	Expired		
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
11/825,521	Claims benefit of provisional	60/807,065	2006-07-11

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(d). When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)i the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(h)(1) and (2). Under the POX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Application Number	Country	Parent Filing Date (YYYY-MM-DD)	Access Code (if applicable)

EX1002 - Page 157

Modified PTO/AIA/14 (12-13)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant must opt-out of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is ONLY reviewed and processed with the INITIAL filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby grants the USPTO authority to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant DOES NOT authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant DOES NOT authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

☐ Assignee	☐ Legal Representative under 35 U.S.C. 117	☐ Joint Inventor
☐ Person to whom the inventor is obligated to assign	☐ Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

☐ Deceased	☐ Legally incapacitated

Name of the Deceased or Legally Incapacitated Inventor :

If the Applicant is an Organization check here: ☐

Organization Name:

Prefix	Given Name	Middle Name	Family Name	Suffix

Mailing Address Information:

Address 1			
Address 2			
City		State/Province	
Country		Postal Code	
Phone Number			
Email Address			

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	Given Name	Middle Name	Family Name	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		State/Province	
Country		Postal Code	
Phone Number		Fax Number	
Email Address			

Signature:

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, all joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of all joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Ryan J. Connell/			Date (YYYY-MM-DD)	2019-08-20
First Name	Ryan	Last Name	Connell	Registration Number	74,611

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-14**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s):	Neal Solomon	Examiner: Marly Camargo	
Serial No.:	13/691,805	Group Art Unit: 2699	
Filed:	December 2, 2012	Docket No.: 5311.001US3	
Customer No.:	21186	Confirmation No.: 6244	
Title:	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS		

PETITION TO EXPEDITE CONSIDERATION UNDER 37 C.F.R. § 1.182

Director, Office of Petitions
Attention: Christina Tartera Donnell
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Patentee respectfully requests accelerated consideration of Patentee's Petition under 37 CFR §1.78(c) and 1.78(e) and all accompanying documents that outline accurate claims of priority. The delayed claims of priority were unintentional and Patentee submits this Petition requesting expedited review.

The Commissioner is hereby authorized to charge Deposit Account 19-0743 in the amount of $200.00, which is the required fee due under 37 C.F.R. § 1.17(f). Please charge any additional fees deemed necessary for the consideration of this Petition to Deposit Account 19-0743.

CONCLUSION

Applicant respectfully submits that the claims are in condition for allowance and notification to that effect is earnestly requested. The Examiner is invited to telephone Applicant's representative at (612) 305-2704 to facilitate prosecution of this application.

If necessary, please charge any additional fees or credit overpayment to Deposit Account 19-0743.

Respectfully submitted,

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. Box 2938
Minneapolis, MN 55402
(612) 373-6912

Date 8/20/2019

By /Ryan J. Connell/
Ryan J. Connell
Reg. No. 74,611

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s):	Neal Solomon	Examiner: Marly Camargo	
Serial No.:	13/691,805	Group Art Unit: 2699	
Filed:	December 2, 2012	Docket No.: 5311.001US3	
Customer No.:	21186	Confirmation No.: 6244	
Title:	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS		

PETITION UNDER 37 CFR 1.78(c) AND 1.78(e) TO ACCEPT AN UNINTENTIONALLY DELAYED PRIORITY CLAIM

Director, Office of Petitions
Attention: Christina Tartera Donnell
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Patentee respectfully requests that the priority claim for the above-identified patent be corrected to clarify that it is a continuation of U.S. Patent Application Ser. No. 12/586,221 filed on September 18, 2009, now issued as U.S. Patent 8,451,339, which is a continuation of U.S. Patent Application Ser. No. 11/825,521 filed on Jul. 11, 2007 now issued as U.S. Patent 7,612,805, which claims the benefit of Provisional Patent Application Ser. No. 60/807,065 filed on July 11, 2006.

Patentee has submitted herewith a Supplemental Application Data Sheet to reflect the correction of the priority claim.

Therefore, Patentee respectfully requests that the priority claim under 35 U.S.C. §120 be corrected for the above-referenced patent to clearly show that it (U.S. Application Serial No. 13/691,805) is a continuation of U.S. Patent Application Ser. No. 12/586,221 filed on September 18, 2009, now issued as U.S. Patent 8,451,339, which is a continuation of U.S. Patent Application Ser. No. 11/825,521 filed on Jul. 11, 2007 now issued as U.S. Patent 7,612,805. Patentee further requests that priority under 35 U.S.C. § 119(e) be corrected to clearly show that the above-referenced patent (U.S. Application Serial No. 13/691,805) further claims the benefit of priority of U.S. Provisional Patent Application Ser. No. 60/807,065 filed on July 11, 2006.

Accordingly, it is respectfully requested that this Petition be granted to accept Patentee's delayed claims of priority. Patentee certifies that the entire delay between the date the claims of priority were first made and the date of correction was unintentional.

The Commissioner is authorized to charge Deposit Account No. 19-0743 in the amount of $1000.00, which is the fee set forth under 37 C.F.R. § 1.17(m). Patentee submits

herewith a Certificate of Correction and a Petition to Expedite Consideration Under 37 C.F.R. § 1.182 with authorizations to pay the requisite fees for each, respectively. The Commissioner is further authorized to charge any fees deemed necessary for the consideration and grant of this Petition and its supporting documents to Deposit Account 19-0743.

CONCLUSION

Applicant respectfully submits that the claims are in condition for allowance and notification to that effect is earnestly requested. The Examiner is invited to telephone Applicant's representative at (612) 305-2704 to facilitate prosecution of this application.

If necessary, please charge any additional fees or credit overpayment to Deposit Account 19-0743.

Respectfully submitted,

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. Box 2938
Minneapolis, MN 55402
(612) 373-6912

Date 8/20/2019

By /Ryan J. Connell/
Ryan J. Connell
Reg. No. 74,611

S/N 13/691,805 **PATENT**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s):	Neal Solomon	Examiner: Marly Camargo	
Serial No.:	13/691,805	Group Art Unit: 2699	
Filed:	December 2, 2012	Docket No.: 5311.001US3	
Customer No.: 21186		Confirmation No.: 6244	
Title:	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS		

PATENTEE CERTIFICATION OF PETITION UNDER 37 CFR 1.78(c) AND 1.78(e) TO ACCEPT AN UNINTENTIONALLY DELAYED PRIORITY CLAIM

Director, Office of Petitions
Attention: Christina Tartera Donnell
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Patentee has respectfully submitted a Petition under 37 CFR 1.78(c) and 37 CFR 1.78(e) to accept an unintentionally delayed priority claim. Patentee certifies that the entire delay between the date the claims of priority were first made and the date of correction was unintentional.

Respectfully submitted,

Date 8/14/19 By Neal J Solomon

Neal Solomon

Electronic Acknowledgement Receipt	
EFS ID:	36920617
Application Number:	13691805
International Application Number:	
Confirmation Number:	6244
Title of Invention:	Digital imaging system for correcting video image aberrations
First Named Inventor/Applicant Name:	Neal Solomon
Customer Number:	21186
Filer:	Timothy E. Bianchi/Amanda Brace
Filer Authorized By:	Timothy E. Bianchi
Attorney Docket Number:	5311.001US3
Receipt Date:	20-AUG-2019
Filing Date:	02-DEC-2012
Time Stamp:	10:21:49
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$1200
RAM confirmation Number	E20198JA22131635
Deposit Account	190743
Authorized User	Amanda Brace
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

37 CFR 1.19 (Document supply fees)

37 CFR 1.20 (Post Issuance fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		5311001US3_PetitionforFiling.pdf	293885 d40e97c877ccb5a4a7b73933024d98cf3d82b13b	yes	13

Multipart Description/PDF files in .zip description

Document Description	Start	End
Transmittal Letter	1	1
Miscellaneous Incoming Letter	2	4
Miscellaneous Incoming Letter	5	6
Application Data Sheet	7	12
Miscellaneous Incoming Letter	13	13

Warnings:

Information:

2	Fee Worksheet (SB06)	fee-info.pdf	32183 2fab3e62b3162824ff030334c722fccbf1fb38c5	no	2

Warnings:

Information:

Total Files Size (in bytes):	326068

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Electronic Patent Application Fee Transmittal

Application Number:	13691805
Filing Date:	02-Dec-2012
Title of Invention:	Digital imaging system for correcting video image aberrations
First Named Inventor/Applicant Name:	Neal Solomon
Filer:	Timothy E. Bianchi/Amanda Brace
Attorney Docket Number:	5311.001US3

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
PETITION FEE - 37 CFR 1.17(F)(GROUP I)	2462	1	200	200
PET. DELAY SUB OR RESTORE PRIORITY-CLAIM	2454	1	1000	1000
Patent-Appeals-and-Interference:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**1200**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Neal Solomon

Title: DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS

Docket No:	5311.001US3	Serial No.:	13/691,805
Filed:	December 2, 2012	Group Art Unit:	2699
Examiner:	Marly Camargo	Patent No.:	
Customer No.:	21186	Confirmation No.:	6244

Certificate of Corrections Branch
ATTN: Christina Tartera Donnell
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

We are transmitting herewith the attached:

X Updated Application Data Sheet (6 pgs).
X Petition to Expedite Consideration Under 37 C.F.R. § 1.182 (2 pgs).
X Petition under 37 CFR 1.78(c) and 1.78(e) to Accept an Unintentionally Delayed Claim of Priority (3 pgs).
X Patentee Certification Of Petition Under 37 Cfr 1.78(C) And 1.78(E) To Accept An Unintentionally Delayed Priority Claim (1 pg).
X **Authorization to Charge Deposit Account 19-0743 in the amount of $200.00 to cover the Petition to Expedite Consideration fee.**
X **Authorization to Charge Deposit Account 19-0743 in the amount of $1000.00 to cover the Petition to Accept an Unintentionally Delayed Claim of Priority fee.**

If necessary please charge any additional fees or credit overpayment to Deposit Account No. 19-0743.

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
Customer No: 21186

By: /Ryan J. Connell/
Ryan J. Connell
Reg. No. 74,611

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/691,805	12/02/2012	Neal Solomon	5311.001US3	6244

21186 7590 08/21/2019

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402

EXAMINER
CAMARGO, MARLY S.B.

ART UNIT	PAPER NUMBER
2699	

NOTIFICATION DATE	DELIVERY MODE
08/21/2019	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

SLW@blackhillsip.com
uspto@slwip.com

Applicant-Initiated Interview Summary	**Application No.** 13/691,805	**Applicant(s)** Solomon, Neal	
	Examiner MARLY S CAMARGO	**Art Unit** 2699	**AIA (FITF) Status** No

All participants (applicant, applicants representative, PTO personnel):

(1) MARLY S.B.. CAMARGO. (3) _____.

(2) Mr. Timothy Bianchi (REG# 39,610). (4) _____.

Date of Interview: 16 August 2019.

Type: ☑ Telephonic ☐ Video Conference
☐ Personal [copy given to: ☐ applicant ☐ applicant's representative]

Exhibit shown or demonstration conducted: ☐ Yes ☑ No.
If Yes, brief description: _____.

Issues Discussed ☐101 ☐112 ☐102 ☐103 ☑Others
(For each of the checked box(es) above, please describe below the issue and detailed description of the discussion)

Claim(s) discussed: 1.

Identification of prior art discussed: n/a.

Substance of Interview
(For each issue discussed, provide a detailed description and indicate if agreement was reached. Some topics may include: identification or clarification of a reference or a portion thereof, claim interpretation, proposed amendments, arguments of any applied references etc...)

Mr. Bianchi called the Examiner about a proposed amendment to be done to claim 1 as to make it more readable. He also pointed out that they need to amend the limitation "wherein when the video is captured by the at least ..." to remove the word "when" from it ,since they do not have it. They will add new claims to the application and to correct the previous ones. They will correct the priority claim which is wrong and will also file a Terminal Disclaimer in regards the previous Double Patent rejections. Agreement was achieved..

Applicant recordation instructions: The formal written reply to the last Office action must include the substance of the interview. (See MPEP section 713.04). If a reply to the last Office action has already been filed, applicant is given a non-extendable period of the longer of one month or thirty days from this interview date, or the mailing date of this interview summary form, whichever is later, to file a statement of the substance of the interview.

Examiner recordation instructions: Examiners must summarize the substance of any interview of record. A complete and proper recordation of the substance of an interview should include the items listed in MPEP 713.04 for complete and proper recordation including the identification of the general thrust of each argument or issue discussed, a general indication of any other pertinent matters discussed regarding patentability and the general results or outcome of the interview, to include an indication as to whether or not agreement was reached on the issues raised.

☐ Attachment

/MARLY S CAMARGO/ Examiner, Art Unit 2699	

Summary of Record of Interview Requirements

Manual of Patent Examining Procedure (MPEP), Section 713.04, Substance of Interview Must be Made of Record
A complete written statement as to the substance of any face-to-face, video conference, or telephone interview with regard to an application must be made of record in the application whether or not an agreement with the examiner was reached at the interview.

Title 37 Code of Federal Regulations (CFR) 1.133 Interviews
Paragraph (b)

In every instance where reconsideration is requested in view of an interview with an examiner, a complete written statement of the reasons presented at the interview as warranting favorable action must be filed by the applicant. An interview does not remove the necessity for reply to Office action as specified in §§ 1.111, 1.135. (35 U.S.C. 132)

37 CFR §1.2 Business to be transacted in writing.
All business with the Patent or Trademark Office should be transacted in writing. The personal attendance of applicants or their attorneys or agents at the Patent and Trademark Office is unnecessary. The action of the Patent and Trademark Office will be based exclusively on the written record in the Office. No attention will be paid to any alleged oral promise, stipulation, or understanding in relation to which there is disagreement or doubt.

The action of the Patent and Trademark Office cannot be based exclusively on the written record in the Office if that record is itself incomplete through the failure to record the substance of interviews.

It is the responsibility of the applicant or the attorney or agent to make the substance of an interview of record in the application file, unless the examiner indicates he or she will do so. It is the examiners responsibility to see that such a record is made and to correct material inaccuracies which bear directly on the question of patentability.

Examiners must complete an Interview Summary Form for each interview held where a matter of substance has been discussed during the interview by checking the appropriate boxes and filling in the blanks. Discussions regarding only procedural matters, directed solely to restriction requirements for which interview recordation is otherwise provided for in Section 812.01 of the Manual of Patent Examining Procedure, or pointing out typographical errors or unreadable script in Office actions or the like, are excluded from the interview recordation procedures below. Where the substance of an interview is completely recorded in an Examiners Amendment, no separate Interview Summary Record is required.

The Interview Summary Form shall be given an appropriate Paper No., placed in the right hand portion of the file, and listed on the "Contents" section of the file wrapper. In a personal interview, a duplicate of the Form is given to the applicant (or attorney or agent) at the conclusion of the interview. In the case of a telephone or video-conference interview, the copy is mailed to the applicants correspondence address either with or prior to the next official communication. If additional correspondence from the examiner is not likely before an allowance or if other circumstances dictate, the Form should be mailed promptly after the interview rather than with the next official communication.

The Form provides for recordation of the following information:
- Application Number (Series Code and Serial Number)
- Name of applicant
- Name of examiner
- Date of interview
- Type of interview (telephonic, video-conference, or personal)
- Name of participant(s) (applicant, attorney or agent, examiner, other PTO personnel, etc.)
- An indication whether or not an exhibit was shown or a demonstration conducted
- An identification of the specific prior art discussed
- An indication whether an agreement was reached and if so, a description of the general nature of the agreement (may be by attachment of a copy of amendments or claims agreed as being allowable). Note: Agreement as to allowability is tentative and does not restrict further action by the examiner to the contrary.
- The signature of the examiner who conducted the interview (if Form is not an attachment to a signed Office action)

It is desirable that the examiner orally remind the applicant of his or her obligation to record the substance of the interview of each case. It should be noted, however, that the Interview Summary Form will not normally be considered a complete and proper recordation of the interview unless it includes, or is supplemented by the applicant or the examiner to include, all of the applicable items required below concerning the substance of the interview.

A complete and proper recordation of the substance of any interview should include at least the following applicable items:
1) A brief description of the nature of any exhibit shown or any demonstration conducted,-
2) an identification of the claims discussed,
3) an identification of the specific prior art discussed,
4) an identification of the principal proposed amendments of a substantive nature discussed, unless these are already described on the Interview Summary Form completed by the Examiner,
5) a brief identification of the general thrust of the principal arguments presented to the examiner,
(The identification of arguments need not be lengthy or elaborate. A verbatim or highly detailed description of the arguments is not required. The identification of the arguments is sufficient if the general nature or thrust of the principal arguments made to the examiner can be understood in the context of the application file. Of course, the applicant may desire to emphasize and fully describe those arguments which he or she feels were or might be persuasive to the examiner.)
6) a general indication of any other pertinent matters discussed, and
7) if appropriate, the general results or outcome of the interview unless already described in the Interview Summary Form completed by the examiner.

Examiners are expected to carefully review the applicants record of the substance of an interview. If the record is not complete and accurate, the examiner will give the applicant an extendable one month time period to correct the record.

Examiner to Check for Accuracy

If the claims are allowable for other reasons of record, the examiner should send a letter setting forth the examiners version of the statement attributed to him or her. If the record is complete and accurate, the examiner should place the indication, Interview Record OK on the paper recording the substance of the interview along with the date and the examiners initials.

Applicant Initiated Interview Request Form

Application No.: 13/691,805 First Named Applicant: Neal Solomon
Examiner: M. Camargo Art Unit: 2699 Status of Application: Pending

Tentative Participants:
(1) T. Bianchi (2) _____

(3) _____ (4) _____

Proposed Date of Interview: open **Proposed Time:** open (○AM○PM)

Type of Interview Requested:
(1) ☑ Telephonic (2) ☐ Personal (3) ☐ Video Conference

Exhibit To Be Shown or Demonstrated: ☑ YES ☐ NO
If yes, provide brief description: Proposed amended claim 1.

Issues To Be Discussed

Issues (Rej., Obj., etc)	Claims/ Fig. #s	Prior Art	Discussed	Agreed	Not Agreed
(1) text of claim 1	1		☒	☒	☐
(2)			☐	☐	☐
(3)			☐	☐	☐
(4)			☐	☐	☐

☐ Continuation Sheet Attached ☑ Proposed Amendment or Arguments Attached
Brief Description of Arguments to be Presented: Discuss amended claim.

An interview was conducted on the above-identified application on _____

NOTE: This form should be completed and filed by applicant in advance of the interview (see MPEP § 713.01). If this form is signed by a registered practitioner not of record, the Office will accept this as an indication that he or she is authorized to conduct an interview on behalf of the principal (37 CFR 1.32(a)(3)) pursuant to 37 CFR 1.34. This is not a power of attorney to any above named practitioner. See the Instruction Sheet for this form, which is incorporated by reference. By signing this form, applicant or practitioner is certifying that he or she has read the Instruction Sheet. After the interview is conducted, applicant is advised to file a statement of the substance of this interview (37 CFR 1.133(b)) as soon as possible. This application will not be delayed from issue because of applicant's failure to submit a written record of this interview.

/Timothy E. Bianchi/
Applicant/Applicant's Representative Signature

/MARLY S CAMARGO/ 08/16/2019
Examiner/SPE Signature

Timothy E. Bianchi
Typed/Printed Name of Applicant or Representative

office 612 373-6912 / mobile 612 743-5431
Applicant's/Applicant's Representative's Telephone Number

39,610
Registration Number, if applicable

This collection of information is required by 37 CFR 1.133. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 24 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS.
If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

1. [Proposed Amendment] A digital imaging system for correcting optical image aberrations in a digital video, comprising:

a digital video camera ~~mechanism~~including in-camera software, an optical lens mechanism, at least one digital sensor for capturing the digital video, an integrated circuit including: a digital signal processor ~~, system software,~~configured to access a database management system including a plurality of optical image aberration corrections and a memory storage sub-system;

wherein the optical lens mechanism is a fixed focal length lens;

wherein ~~an~~ the integrated circuit uses ~~system~~ the in-camera software to identify at least one optical aberration and ~~by accessing the database;~~

~~wherein the integrated circuit uses the database to identify at least one algorithm to use~~ to correct the at least one optical ~~and/or digital~~image aberration in at least one frame of the digital video using at least one of the plurality of optical image aberration corrections in the database;

wherein when the video ~~image file~~ is captured by the at least one digital sensor ~~the digital file~~ and is forwarded to the digital signal processor;

wherein the video ~~image file~~ with the at least one optical or digital aberration is corrected by applying digital filtration ~~by~~ using ~~at least one algorithm in~~ the digital signal processor; and

wherein the ~~modified~~ corrected ~~digital file~~ video consisting of the digital data optimized from the at least one optical or digital aberration that are corrected from the original video image is stored in the memory storage sub-system.

/MARLY S CAMARGO/

08/16/2019

1. [Clean Copy With Proposed Amendments] A digital imaging system for correcting optical image aberrations in a digital video, comprising:

a digital video camera including in-camera software, an optical lens mechanism, at least one digital sensor for capturing the digital video, an integrated circuit including a digital signal processor configured to access a database management system including a plurality of optical image aberration corrections and a memory storage sub-system;

wherein the optical lens mechanism is a fixed focal length lens;

wherein the integrated circuit uses the in-camera software to identify at least one optical aberration and to correct the at least one optical image aberration in at least one frame of the digital video using at least one of the plurality of optical image aberration corrections in the database;

wherein when the video is captured by the at least one digital sensor and is forwarded to the digital signal processor;

wherein the video with the at least one optical or digital aberration is corrected by applying digital filtration using the digital signal processor; and

wherein the corrected video consisting of the digital data optimized from the at least one optical or digital aberration that are corrected from the original video image is stored in the memory storage sub-system.

/MARLY S CAMARGO/

08/16/2019

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450
www.uspto.gov

MAILED
OCT 16 2019
OFFICE OF PETITIONS

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402

Inventor: Neal Solomon
Application No. 13/691,805
Filing Date: December 2, 2012
Attorney Docket No. 5311.001US3

Decision on Petition under
37 C.F.R. §§ 1.78(c) and 1.78(e)

This is a decision on the petition under 37 C.F.R. §§ 1.78(c) and 1.78 (e) filed August 20, 2019, to accept unintentionally delayed claims under 35 U.S.C. §§ 119(e) and 120 for the benefit of priority to the prior-filed provisional and nonprovisional applications set forth in the concurrently filed application data sheet. This is also a decision on the petition under 37 C.F.R. § 1.182 filed August 20, 2019, requesting expedited consideration of the petition under 37 C.F.R. § 1.78.

The petition under 37 C.F.R. § 1.182 is **granted**.

The petition under 37 C.F.R. §§ 1.78(c) and 1.78(e) is **dismissed**.

A renewed petition under 37 C.F.R. §§ 1.78(c) and 1.78(e) correcting the deficiency identified in the instant decision may be filed. The instant petition includes the required petition fee. Therefore, the renewed petition does not need to include a petition fee. The issuance of the instant decision does **not** toll or reset any time periods for reply set forth in any notice, Office action, or other communication issued by the Office setting a period for reply.

The following benefit claims are relevant to this decision:

(1) This application is a continuation of Application No. 12/586,221;
(2) This application is a continuation of Application No. 11/825,521; and
(3) Application No. 11/825,521 claims the benefit of Application No. 60/807,065.

The petition requests acceptance of benefit claims (1)-(3) set forth above.

A petition under 37 C.F.R. §§ 1.78(c) and 1.78(e) must be accompanied by:

(1) The reference required by 35 U.S.C. § 119(e) and 37 C.F.R. § 1.78(a)(3) to the prior filed provisional application(s) and required by 35 U.S.C. § 120 and 37 C.F.R. § 1.78(d)(2) to the nonprovisional application(s);
(2) The petition fee set forth in 37 C.F.R. § 1.17(m); and

(3) A statement that the entire delay between the date the claims were due under 37 C.F.R. §§ 1.78(a)(4) and 1.78(d)(3) and the date the claims were filed was unintentional.[1]

The petition includes the required petition fee and an adequate statement of delay.[2]

The petition does not include an acceptable reference. Benefit claim (2) is improper because copendency does not exist between Application No. 11/825,521 and this application. Specifically, Application No. 11/825,521 issued as a patent on November 3, 2009, and this application was filed on December 2, 2012.

In view of the prior discussion, the petition under 37 C.F.R. §§ 1.78(c) and 1.78(e) is dismissed.

Application may wish to consider filing a renewed petition and a new corrected application data sheet listing the following benefit claims with the information for each benefit claim underlined:

(1) This application is a continuation of Application No. 12/586,221;
(2) Application No. 12/586,221 is a continuation of Application No. 11/825,521; and
(3) Application No. 11/825,521 claims the benefit of Application No. 60/807,065.

Information concerning the use of EFS-Web to automatically generate and attach a PDF version of a Corrected Web-based ADS can be found at:
http://www.uspto.gov/sites/default/files/documents/Corrected-WebADS-QSG.pdf.

Further correspondence with respect to this matter may be submitted as follows:

By Internet: A request for reconsideration may be filed electronically using EFS Web.[3] Document Code "PET.OP" should be used if the request is filed electronically.

By mail: Mail Stop Petition
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

By facsimile: (571) 273-8300
Attn: Office of Petitions

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[1] With respect to the statement of delay, the Office "may require additional information where there is a question whether the delay was unintentional." 37 C.F.R. § 1.78(e)(3).

[2] 37 C.F.R. § 1.78(c) requires the submission of a statement that the entire delay between the date the claim was due under 37 C.F.R. § 1.78(a)(4) and the date the claim was filed was unintentional. 37 C.F.R. § 1.78(e) requires the submission of a statement that the entire delay between the date the claim was due under 37 C.F.R. § 1.78(d)(3) and the date the claim was filed was unintentional. The statement of delay in the petition is being construed as the statements required under 37 C.F.R. §§ 1.78(c) and 1.78(e). If this is not a correct reading of the statement appearing in the petition, petitioner should promptly notify the Office.

[3] General Information concerning EFS Web can be found at http://www.uspto.gov/patents/process/file/efs/index.jsp.

By hand: U.S. Patent and Trademark Office
Customer Service Window
Randolph Building
401 Dulany Street
Alexandria, VA 22314

Telephone inquiries regarding this communication should be directed to Attorney Advisor Steven Brantley at (571) 272-3203.

Charles Steven Brantley
Attorney Advisor
Office of Petitions

Electronic Acknowledgement Receipt

EFS ID:	37481765
Application Number:	13691805
International Application Number:	
Confirmation Number:	6244
Title of Invention:	Digital imaging system for correcting video image aberrations
First Named Inventor/Applicant Name:	Neal Solomon
Customer Number:	21186
Filer:	Joseph P. Mehrle/Amanda Brace
Filer Authorized By:	Joseph P. Mehrle
Attorney Docket Number:	5311.001US3
Receipt Date:	17-OCT-2019
Filing Date:	02-DEC-2012
Time Stamp:	10:47:59
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		5311001US3_PetitionforFiling.pdf	230832 23223edaa6488387785238c30efe9ac4a192434a	yes	10

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Application Data Sheet	5	10
	Miscellaneous Incoming Letter	2	4
	Transmittal Letter	1	1
Warnings:			
Information:			
	Total Files Size (in bytes):	230832	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s): Neal Solomon
Title: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

Docket No.:	5311.001US3	Serial No.:	13/691,805
Filed:	December 2, 2012	Due Date:	N/A
Examiner:	Marly Camargo	Group Art Unit:	2699
Customer No.:	21186	Confirmation No.:	6244

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

We are transmitting herewith the following attached items (as indicated with an "X"):

X Updated Petition Under 37 CFR 1.78(c) AND 1.78(e) To Accept An Unintentionally Delayed Priority Claim (3 pgs.)
X Updated Application Data Sheet (6 pgs)

If not provided for in a separate paper filed herewith, please consider this a PETITION FOR EXTENSION OF TIME for sufficient number of months to enter these papers and please charge any additional fees or credit overpayment to Deposit Account No. 19-0743. If applicable, any papers or fees supplied herewith are considered to be timely filed pursuant to 37 C.F.R. § 1.7(a), the response period falling on a Federal Holiday, Saturday or Sunday being extended to the next succeeding business day.

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
Customer No.: 21186

By: /Ryan J. Connell/
Ryan J. Connell
Reg. No. 74,611

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s):	Neal Solomon	Examiner: Marly Camargo	
Serial No.:	13/691,805	Group Art Unit: 2699	
Filed:	December 2, 2012	Docket No.: 5311.001US3	
Customer No.:	21186	Confirmation No.: 6244	
Title:	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS		

UPDATED PETITION UNDER 37 CFR 1.78(c) AND 1.78(e) TO ACCEPT AN UNINTENTIONALLY DELAYED PRIORITY CLAIM

Director, Office of Petitions
Attention: Charles Steven Brantley
Attorney Advisor
Office of Petitions
P.O. Box 1450
Alexandria, VA 22313-1450

Patentee respectfully requests that the priority claim for the above-identified patent be corrected to clarify that it is a continuation of U.S. Patent Application Ser. No. 12/586,221 filed on September 18, 2009, now issued as U.S. Patent 8,451,339, which is a continuation of U.S. Patent Application Ser. No. 11/825,521 filed on Jul. 11, 2007 now issued as U.S. Patent 7,612,805, which claims the benefit of Provisional Patent Application Ser. No. 60/807,065 filed on July 11, 2006.

Patentee has submitted herewith an Updated Supplemental Application Data Sheet to reflect the correction of the priority claim.

Therefore, Patentee respectfully requests that the priority claim under 35 U.S.C. §120 be corrected for the above-referenced patent to clearly show that it (U.S. Application Serial No. 13/691,805) is a continuation of U.S. Patent Application Ser. No. 12/586,221 filed on September 18, 2009, now issued as U.S. Patent 8,451,339, which is a continuation of U.S. Patent Application Ser. No. 11/825,521 filed on Jul. 11, 2007 now issued as U.S. Patent 7,612,805. Patentee further requests that priority under 35 U.S.C. § 119(e) be corrected to clearly show that the above-referenced patent (U.S. Application Serial No. 13/691,805) further claims the benefit of priority of U.S. Provisional Patent Application Ser. No. 60/807,065 filed on July 11, 2006.

Accordingly, it is respectfully requested that this Petition be granted to accept Patentee's delayed claims of priority. Patentee certifies that the entire delay between the date the claims of priority were first made and the date of correction was unintentional.

The Commissioner is authorized to charge Deposit Account No. 19-0743 in the amount of $1000.00, which is the fee set forth under 37 C.F.R. § 1.17(m). Patentee submits herewith a Certificate of Correction and a Petition to Expedite Consideration Under 37 C.F.R. § 1.182 with authorizations to pay the requisite fees for each, respectively. The Commissioner is further authorized to charge any fees deemed necessary for the consideration and grant of this Petition and its supporting documents to Deposit Account 19-0743.

CONCLUSION

Applicant respectfully submits that the claims are in condition for allowance and notification to that effect is earnestly requested. The Examiner is invited to telephone Applicant's representative at (612) 373-6912 to facilitate prosecution of this application.

If necessary, please charge any additional fees or credit overpayment to Deposit Account 19-0743.

Respectfully submitted,

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. Box 2938
Minneapolis, MN 55402
(612) 373-6912

Date October 17, 2019

By /Ryan J. Connell/
Ryan J. Connell
Reg. No. 74,611

Modified PTO/AIA/14 (12-13)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ **Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)**

Inventor Information:

Inventor:

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix

Residence Information (Select One) ☐ US Residency ☐ Non US Residency ☐ Active US Military Service

City		State/Province		Country of Residence	

Mailing Address of Inventor:

Address 1	
Address 2	

City		State/Province	
Postal Code		Country	

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	
Email Address	

Application Information:

Title of the Invention			
Attorney Docket Number		Small Entity Status Claimed ☐	
Application Type			
Subject Matter			
Suggested Class (if any)		Sub Class (if any)	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)		Suggested Figure for Publication (if any)	

Modified PTO/AIA/14 (12-13)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). **Do not** complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country Publication

Publication Information:

☐ **Request Early Publication (Fee required at time of Request 37 CFR 1.219)**

☐ **Request Not to Publish.** **I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application has not and will not be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.**

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Enter either Customer Number or complete the Representative Name section below. If both sections are completed the Customer Number will be used for the Representative Information during processing.

Please Select One:	☐ Customer	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)
Customer Number			

Modified PTO/AIA/14 (12-13)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78(a)(2) or CFR 1.78(a)(4), and need not otherwise be made part of the specification.

Prior Application Status	Patented		
Application Number	**Continuity Type**	**Prior Application Number**	**Filing or 371(c) Date (YYYY-MM-DD)**
This application	is a continuation of	12/586,221	2009-09-18
Prior Application Status	Patented		
Application Number	**Continuity Type**	**Prior Application Number**	**Filing or 371(c) Date (YYYY-MM-DD)**
~~This application~~ 12/586,221	is a continuation of	11/825,521	2007-07-06
Prior Application Status	Expired		
Application Number	**Continuity Type**	**Prior Application Number**	**Filing or 371(c) Date (YYYY-MM-DD)**
11/825,521	Claims benefit of provisional	60/807,065	2006-07-11

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(d). When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)i the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(h)(1) and (2). Under the POX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Application Number	Country	Parent Filing Date (YYYY-MM-DD)	Access Code (if applicable)

Modified PTO/AIA/14 (12-13)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant must opt-out of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is ONLY reviewed and processed with the INITIAL filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby grants the USPTO authority to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ **A. Applicant DOES NOT authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.**

☐ **B. Applicant DOES NOT authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.**

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Modified PTO/AIA/14 (12-13)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

☐ Assignee	☐ Legal Representative under 35 U.S.C. 117	☐ Joint Inventor
☐ Person to whom the inventor is obligated to assign	☐ Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

☐ Deceased	☐ Legally incapacitated

Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here: ☐

Organization Name:

Prefix	Given Name	Middle Name	Family Name	Suffix

Mailing Address Information:

Address 1			
Address 2			
City		State/Province	
Country		Postal Code	
Phone Number			
Email Address			

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	Given Name	Middle Name	Family Name	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		State/Province	
Country		Postal Code	
Phone Number		Fax Number	
Email Address			

Signature:

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is **a juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Ryan J. Connell/			Date (YYYY-MM-DD)	2019-10-17
First Name	Ryan	Last Name	Connell	Registration Number	74,611

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-14**

Modified PTO/AIA/26 (04-14)
Approved for use through 07/31/2016. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TERMINAL DISCLAIMER TO OBVIATE A DOUBLE PATENTING REJECTION OVER A "PRIOR" PATENT	Docket Number 5311.001US3

In re Application of: Neal Solomon

Application No.: 13/691,805

Filed: December 2, 2012

For: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

The applicant, **Optimum Imaging Technologies LLC**, owner of the entire interest in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of **prior patent** No.(s) **8,451,339** as the term of said **prior patent(s)** is presently shortened by any terminal disclaimer. The applicant hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and the **prior patent(s)** are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the applicant does not disclaim the terminal part of the term of any patent granted on the instant application that would extend to the expiration date of the full statutory term of the **prior patent(s)**, "as the term of said **prior patent(s)** is presently shortened by any terminal disclaimer," in the event that said **prior patent(s)** later:

expires for failure to pay a maintenance fee;
is held unenforceable;
is found invalid by a court of competent jurisdiction;
is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321;
has all claims canceled by a reexamination certificate;
is reissued; or
is in any manner terminated prior to the expiration of its full statutory term as presently shortened by any terminal disclaimer.

Check either box 1 or 2 below, if appropriate.

1. ☐ The undersigned is the applicant. If the applicant is an assignee, the undersigned is authorized to act on behalf of the assignee.

I hereby acknowledge that any willful false statements made are punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

2. ☒ The undersigned is an attorney or agent of record. Reg. No. 39,610

/Timothy E. Bianchi/	November 15, 2019
Timothy E. Bianchi	**Date**
Principal	**612-373-6912**
Title	**Telephone Number**

☒ Terminal disclaimer fee under 37 CFR 1.20(d) included.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s): Neal Solomon
Title: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

Docket No.:	5311.001US3	Serial No.:	13/691,805
Filed:	December 2, 2012	Due Date:	November 15, 2019
Examiner:	Marly Camargo	Group Art Unit:	2699
Customer No.:	21186	Confirmation No.:	6244

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

We are transmitting herewith the following attached items (as indicated with an "X"):

X Amendment and Response under 37 C.F.R. § 1.111 (10 pgs.)
X Petition for Extension of Time (1 pg.)
X Terminal Disclaimer (1 pg.)
X **Authorization to charge Deposit Account 19-0743 in the amount of $500.00 to cover the fee for additional claims.**
X **Authorization to charge Deposit Account 19-0743 in the amount of $700.00 to cover the Extension of Time Fee.**
X **Authorization to charge Deposit Account 19-0743 in the amount of $160.00 to cover the fee for the Terminal Disclaimer**

The fee for additional claims has been calculated as follows:

CLAIMS AS AMENDED						
	Claims Remaining After Amendment		Highest Number Previously Paid For	Present Extra	Rate	Fee
TOTAL CLAIMS	30	-	20	10	x 50.00 =	500.00
INDEPENDENT CLAIMS	3	-	3	0	x 230.00 =	0.00
[] MULTIPLE DEPENDENT CLAIMS PRESENTED						0.00
TOTAL						500.00

If not provided for in a separate paper filed herewith, please consider this a PETITION FOR EXTENSION OF TIME for sufficient number of months to enter these papers and please charge any additional fees or credit overpayment to Deposit Account No. 19-0743. If applicable, any papers or fees supplied herewith are considered to be timely filed pursuant to 37 C.F.R. § 1.7(a), the response period falling on a Federal Holiday, Saturday or Sunday being extended to the next succeeding business day.

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
Customer No.: 21186

By: /Timothy E. Bianchi/
Timothy E. Bianchi
Reg. No. 39,610

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s):	Neal Solomon	Examiner:	MARLY S.B. CAMARGO
Application No.:	13/691,805	Group Art Unit:	2699
Filed:	December 2, 2012	Docket No.:	5311.001US3
Confirmation No.:	6244		
Title:	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS		

AMENDMENT & RESPONSE UNDER 37 C.F.R. § 1.111

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Applicant has received the Non-Final Office Action dated May 15, 2019. Please enter the following.

This response is accompanied by a Petition, as well as the appropriate fee, to obtain a three-month extension of the period for responding to the Office Action, thereby moving the deadline for response from August 15, 2019 to November 15, 2019.

IN THE CLAIMS

Please amend the claims as follows:

1. (Currently Amended) A digital imaging system for correcting optical image aberrations in a digital video, comprising:

a digital video camera ~~mechanism~~ including in-camera software, an optical lens mechanism, at least one digital sensor for capturing the digital video, an integrated circuit including, ~~a~~ digital signal processor~~, system software,~~ configured to access a database management system including a plurality of optical image aberration corrections, and a memory storage sub-system;

wherein the optical lens mechanism is a zoom lens or a fixed focal length lens;

wherein ~~an~~ the integrated circuit uses ~~system~~ the in-camera software to identify at least one optical image aberration and ~~by accessing the database;~~

~~wherein the integrated circuit uses the database to identify at least one algorithm to use~~ to correct the at least one optical ~~and/or digital~~ image aberration in at least one frame of the digital video using at least one of the plurality of optical image aberration corrections in the database;

wherein ~~when~~ the video ~~image file~~ is captured by the at least one digital sensor ~~the digital file~~ and is forwarded to the digital signal processor;

wherein the video image file with the at least one optical ~~or digital~~ image aberration is corrected by applying digital filtration ~~by~~ using ~~at least one algorithm in~~ the digital signal processor; and

wherein the ~~modified~~ corrected ~~digital file~~ video consisting of the digital data optimized from the at least one optical ~~or digital~~ image aberration that are corrected from the original video image is stored in the memory storage sub-system.

2. (Currently Amended) The system of claim 1:

wherein the optical image aberrations include at least one of spherical, comatic, lens distortion, astigmatism, curvature of field, pin cushion, barrel distortion, chromatic aberrations, scattered light, ~~red-eye, dust~~ and/or flare types of optical image aberrations.

3. (Currently Amended) The system of claim 1:

wherein the optical image aberration is vignetting;

wherein the digital signal processor applies neutral density filtration from one third of a stop to three stops in the center of the image and/or wherein the digital signal processor applies an algorithm to lighten the comers of the image or the digital signal processor applies both neutral density filtration in the image center and/or an algorithm to lighten the comers of the image; and

wherein the image exposure is optimized to correct the vignetting.

4. (Currently Amended) The system of claim 1:

wherein the digital signal processor applies at least one fast Fourier transform (FFT) algorithm to correct the at least one optical image aberration.

5. (Currently Amended) The system of claim 1:

wherein each lens type is registered in the camera database;

wherein the multiple optical aberrations of each lens is listed in the database;

wherein the filtration solutions to the lens optical aberrations are listed in the database;

wherein the filtration of each lens optical aberration is applied by the digital signal processor; and

wherein after the digital signal processor applies the filtration to correct the optical image aberrations the corrected digital file is forwarded to storage in memory.

6. (Currently Amended) A digital imaging system for correcting image aberrations comprising:

a digital video camera ~~mechanism,~~ including in-camera software, an optical lens mechanism, at least one digital sensor for capturing digital video, an integrated circuit~~,~~ including a digital signal processor~~, system software,~~ configured to access a database management system including a plurality of optical image aberration corrections, and a memory storage sub-system;

wherein the optical lens mechanism is a zoom lens or a fixed focal length lens;

wherein the video ~~image data file~~ is forwarded ~~from the at least one digital sensor~~ to storage in memory;

wherein at least one optical ~~and/or digital~~ aberration in at least two frames of the digital video ~~image file~~ are identified ~~by comparing image files in the database management system by~~ using the ~~system~~ in-camera software and the integrated circuit;

~~wherein the at least one filtration algorithms required to correct the at least one optical and/or digital aberration of at least two frames of the digital video file are sent from the integrated circuit to the digital signal processor;~~

wherein the at least one optical ~~and/or digital~~ aberration from the optical lens mechanism of at least two frames of the digital video ~~file~~ are corrected by using the digital signal processor to apply at least one digital filtration algorithm; and

wherein the ~~modified~~ corrected digital video file ~~consisting of the digital data optimized from the at least one aberration that are corrected from the original video images~~ is stored in memory.

7. (Currently Amended) The system of claim 6:

wherein the optical image aberrations include spherical, comatic, lens distortion, astigmatism, chromatic aberrations, curvature of field, pin cushion, barrel distortion, scattered light, ~~red-eye, dust~~ and/or flare types of optical aberrations.

8. (Currently Amended) The system of claim 6:

~~wherein the digital aberrations include moire and/or aliasing~~ wherein the digital signal processor applies at least one fast Fourier transform (FFT) algorithm to correct the at least one optical image aberration.

9. (Currently Amended) The system of claim 6:

wherein the digital signal processor applies a fast Fourier transform (FFT) algorithm to correct ~~optical and/or~~ digital aberrations of at least two frames in the digital video ~~file~~.

10. (Currently Amended) The system of claim 6:

wherein the digital signal processor applies color filtration to at least two frames of the digital video image ~~file~~.

11. (Currently Amended) The system of claim 6:

wherein the digital video ~~image file~~ is filtered to correct at least one optical and/or digital aberrations after initial capture and before the digital video ~~image file~~ is initially sent to storage.

12. (Original) The system of claim 6:

wherein the integrated circuit may be a microprocessor, an application specific integrated circuit or a system on a chip.

13. (Currently Amended) The system of claim 6:

wherein the optical image aberration is vignetting;

wherein the digital signal processor applies neutral density filtration from one third of a stop to three stops in the center of the image and/or wherein the digital signal processor applies an algorithm to lighten the comers of the at least two image frames or the digital signal processor applies both neutral density filtration in the image center and/or an algorithm to lighten the comers of the image of at least two image frames; and

wherein the image exposure for at least two frames in the digital video file is optimized to correct the vignetting.

14. (Currently Amended) A digital imaging system for correcting image aberrations comprising:

a digital video camera ~~mechanism,~~ including in-camera software, an optical lens mechanism, at least one digital sensor for capturing digital video, an integrated circuit~~,~~ including a digital signal processor~~, system software,~~ configured to access a database management system including a plurality of optical image aberration corrections, and a memory storage sub-system;

wherein the optical lens mechanism is a zoom lens;

wherein the zoom lens changes focal length positions;

wherein when the digital video ~~image file~~ is ~~captured by the at least one digital sensor the file is~~ forwarded to the digital signal processor and to memory;

wherein the integrated circuit uses system software to access the database to identify at least one optical ~~and/or digital aberrations~~ aberration in at least one frame of the video ~~file~~ at any focal length of a zoom lens configuration;

wherein the integrated circuit accesses the database to obtain at least one filtration correction algorithm to the optical ~~and/or digital aberrations~~ image aberration of at least one frame in the video file and forwards the at least one filtration algorithms to the digital signal processor;

wherein the digital video ~~image file~~ is forwarded to the digital signal processor which applies at least one filtration algorithm to optimize the digital video ~~file~~ and corrects the at least one optical ~~and/or digital aberrations~~ image aberration in at least one video frame for the at least one focal length in the zoom lens configuration; and

wherein the ~~modified~~ corrected digital video ~~image file consisting of the digital data optimized from the at least one optical and/or digital aberrations in at least one frame of the video file of at least one focal length of the zoom lens that are corrected from the original video image~~ is stored in memory.

15. (Currently Amended) The system of claim 14:

wherein the optical aberrations include vignetting, spherical, comatic, lens distortion, chromatic aberrations, curvature of field, pin cushion, barrel distortion, scattered light, ~~red eye, dust~~ and/or flare types of optical aberrations.

16. (Currently Amended) The system of claim 14:

wherein the digital signal processor applies a fast Fourier transform (FFT) algorithm to correct optical and/or digital aberrations in the digital video ~~file~~.

17. (Original) The system of claim 14:

wherein each focal length of a zoom lens in at least one video image frame is analyzed for a different set of optical aberrations.

18. (Currently Amended) The system of claim 14:

wherein the digital signal processor applies color filtration to at least one frame of the digital video image ~~file~~.

[[18.]]19. (Currently Amended) The system of claim 14:

wherein the optical image aberration is vignetting;

wherein the digital signal processor applies neutral density filtration from one third of a stop to three stops in the center of the image and/or wherein the digital signal processor applies an algorithm to lighten the corners of at least one image frame or the digital signal processor applies both neutral density filtration in the image center and/or an algorithm to lighten the comers of the image of at least one image frame; and

wherein the image exposure for at least one frame in the digital video file is optimized to correct the vignetting.

20. (New) The system of claim 1, wherein the system is configured to correct red-eye.

21. (New) The system of claim 1, wherein the system is configured to correct for dust.

22. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for spherical aberrations.

23. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for chromatic aberrations.

25. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for comatic aberrations.

26. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for astigmatism aberrations.

27. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for lens distortion aberrations.

28. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for pin cushion aberrations.

29. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for curvature of field aberrations.

30. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for barrel distortion aberrations.

Electronic Acknowledgement Receipt	
EFS ID:	37771504
Application Number:	13691805
International Application Number:	
Confirmation Number:	6244
Title of Invention:	Digital imaging system for correcting video image aberrations
First Named Inventor/Applicant Name:	Neal Solomon
Customer Number:	21186
Filer:	Timothy E. Bianchi/Amanda Brace
Filer Authorized By:	Timothy E. Bianchi
Attorney Docket Number:	5311.001US3
Receipt Date:	15-NOV-2019
Filing Date:	02-DEC-2012
Time Stamp:	19:22:00
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$1360
RAM confirmation Number	E2019AEJ22357452
Deposit Account	190743
Authorized User	Amanda Brace
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

37 CFR 1.19 (Document supply fees)

37 CFR 1.20 (Post Issuance fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		5311001US3_RespforFiling.pdf	211624 fc4812bb46b59a1d0d8a905c693cc940bdad7380	yes	13

Multipart Description/PDF files in .zip description

Document Description	Start	End
Transmittal Letter	1	1
Extension of Time	2	2
Terminal Disclaimer Filed	3	3
Amendment/Req. Reconsideration-After Non-Final Reject	4	4
Claims	5	11
Applicant Arguments/Remarks Made in an Amendment	12	13

Warnings:

Information:

2	Fee Worksheet (SB06)	fee-info.pdf	34059 a0fe91343db3f07b561ed34630ecd431ec483325	no	2

Warnings:

Information:

Total Files Size (in bytes):	245683

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

REMARKS

This responds to the Non-Final Office Action dated May 15, 2019. As requested all future communications will be directed to Art Unit 2699. This response includes a petition to extend the due date of the response for 3 months and authorization to charge the SLW deposit account 19-0743 for any fees necessary to keep the application pending.

Claims 1-11, 13-16, and 18-19 are presently amended. New claims 20-30 are added. As a result, claims 1-30 are now pending in this application.

New Claims

Claims 20-30 are dependent claims that relate to correction of certain aberrations which are stated in original claim 2 and generally disclosed in the application. Accordingly, Applicant respectfully requests that the Examiner consider and allow the newly added claims.

Interview Summary

The undersigned would like to thank Examiner MARLY S.B. CAMARGO for the courtesy of a telephone interview on August 16, 2019.

Amendments to claim 1 were discussed. Applicant's representative provided a marked up claim 1 as a proposal for amendment to make it more readable. Applicant agreed to file a terminal disclaimer. Applicant's representative also informed the Examiner that a priority claim was being corrected.

Claim Objections

Claim set includes two claims numbered 18. Correction to the claim disclosure was required. The second instance of claim 18 was amended to relabel it as claim 19.

Claim Amendments

The claims were amended for consistency. Claim 1 was further amended to correct antecedent basis and to include a zoom lens option. If there are any questions about the claim amendments the Examiner is invited to contact Applicant's representative at the number below.

Double Patenting Rejection

Claims 1 - 18 were rejected on the ground of nonstatutory obviousness-type double patenting as being unpatentable over claims 1 - 18 of parent Application No. 12/586,221, now US 8,451,339 B2.

Applicant does not admit that the claims are obvious in view of U.S. Patent No. 8,451,339. However, a Terminal Disclaimer and the requisite fees in compliance with 37 C.F.R. § 1.321 is enclosed herewith to obviate these rejections.

CONCLUSION

It is respectfully submitted that the claims are in condition for allowance, and notification to that effect is earnestly requested. The Examiner is invited to telephone the undersigned at 612-373-6912 to facilitate prosecution of this application.

If necessary, please charge any additional fees or deficiencies, or credit any overpayments to Deposit Account No. 19-0743.

Respectfully submitted,

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. Box 2938
Minneapolis, MN 55402-0938
612-373-6912

Date: November 15, 2019

By /Timothy E. Bianchi/

Timothy E. Bianchi
Reg. No. 39,610

Electronic Patent Application Fee Transmittal

Application Number:	13691805
Filing Date:	02-Dec-2012
Title of Invention:	Digital imaging system for correcting video image aberrations
First Named Inventor/Applicant Name:	Neal Solomon
Filer:	Timothy E. Bianchi/Amanda Brace
Attorney Docket Number:	5311.001US3

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
CLAIMS IN EXCESS OF 20	2202	10	50	500
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Extension - 3 months with $0 paid	2253	1	700	700
Miscellaneous:				
STATUTORY OR TERMINAL DISCLAIMER	2814	1	160	160
		Total in USD ($)		**1360**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s):	Neal Solomon	Examiner:	Marly Camargo
Serial No.:	13/691,805	Group Art Unit:	2699
Filed:	December 2, 2012	Docket:	5311.001US3
Customer No.:	21186	Confirmation No.:	6244
Title:	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS		

PETITION FOR A THREE-MONTH EXTENSION OF TIME

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

In accordance with the provision of 37 C.F.R § 1.136(a), it is respectfully requested that a three-month extension of time be granted in which to respond to the Office Action mailed May 15, 2019, said period of response being extended from August 15, 2019 to November 15, 2019.

Please charge Deposit Account No. 19-0743 in the amount of $700.00 to cover the required extension fee. Please charge any additional fees or credit overpayment to deposit Account No. 19-0743.

Respectfully submitted,

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. Box 2938
Minneapolis, MN 55402
(612) 373-6912

Date November 15, 2019

By /Timothy E. Bianchi/
Timothy E. Bianchi
Reg. No. 39,610

Notice of Non-Compliant Amendment (37 CFR 1.121)	Application No. 13/691,805	Applicant(s) Solomon, Neal
	Art Unit OED2	AIA (FITF) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

The amendment document filed on 15 November 2019 is considered non-compliant because it has failed to meet the requirements of 37 CFR 1.121 or 1.4. In order for the amendment document to be compliant, correction of the following item(s) is required.

THE FOLLOWING MARKED (X) ITEM(S) CAUSE THE AMENDMENT DOCUMENT TO BE NON-COMPLIANT:

- ☐ 1. Amendments to the specification:
  - ☐ A. Amended paragraph(s) do not include markings.
  - ☐ B. New paragraph(s) should not be underlined.
  - ☐ C. Other _____ .
- ☐ 2. Abstract:
  - ☐ A.Not presented on a separate sheet. 37 CFR 1.72.
  - ☐ B.Other _____ .
- ☐ 3. Amendments to the drawings:
  - ☐ A. The drawings are not properly identified in the top margin as "Replacement Sheet", "New Sheet", or "Annotated Sheet" as required by 37 CFR 1.121(d).
  - ☐ B. The practice of submitting proposed drawing correction has been eliminated. Replacement drawings showing amended figures, without markings, in compliance with 37 CFR 1.84 are required .
  - ☐ C. Other _____ .
- ☑ 4. Amendments to the claims:
  - ☑ A. A complete listing of all of the claims is not present.
  - ☐ B. The listing of claims does not include the text of all pending claims (including withdrawn claims)
  - ☐ C. Each claim has not been provided with the proper status identifier, and as such, the individual status of each claim cannot be identified. Note: the status of every claim must be indicated after its claim number by using one of the following status identifiers: (Original), (Currently amended), (Canceled), (Previously presented), (New), (Not entered), (Withdrawn) and (Withdrawn-currently amended).
  - ☐ D. The claims of this amendment paper have not been presented in ascending numerical order.
  - ☑ E. Other: Claim 24 is missing .
- ☐ 5. Other (e.g., the amendment is unsigned or not signed in accordance with 37 CFR 1.4): For further explanation of the amendment format required by 37 CFR 1.121, see MPEP § 714.

TIME PERIODS FOR FILING A REPLY TO THIS NOTICE:

1. Applicant is given **no new time period** if the non-compliant amendment is an after-final amendment or an amendment filed after allowance, or a drawing submission (only) If applicant wishes to resubmit the non-compliant after-final amendment with corrections, the **entire corrected amendment** must be resubmitted.

2. Applicant is given **two months** from the mail date of this notice to supply the correction, if the non-compliant amendment is one of the following: a preliminary amendment, a non-final amendment (including a submission for a request for continued examination (RCE) under 37 CFR 1.114), a supplemental amendment filed within a suspension period under 37 CFR 1.103(a) or (c), and an amendment filed in response to a Quayle action. If any of above boxes 1 to 4 are checked, the correction required is only the corrected section of the non-compliant amendment in compliance with 37 CFR 1.121.

Extensions of time are available under 37 CFR 1.136(a) only if the non-compliant amendment is a non-final amendment or an amendment filed in response to a *Quayle* action.

Failure to timely respond to this notice will result in:

Abandonment of the application if the non-compliant amendment is a non-final amendment or an amendment filed in response to a *Quayle* action; or

Non-entry of the amendment if the non-compliant amendment is a preliminary amendment or supplemental amendment.

Legal Instruments Examiner (LIE), if applicable /JULIET MCMILLAN/ Telephone No: (571)272-1598

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 13/691,805	Filing Date 12/02/2012	☐ To be Mailed

ENTITY: ☐ LARGE ☑ SMALL ☐ MICRO

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A		N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A		N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*		x $31 =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*		x $125 =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).				
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))					
* If the difference in column 1 is less than zero, enter "0" in column 2.				TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT	11/15/2019	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 29	Minus	** 30	= 0		x $50 =	0
	Independent (37 CFR 1.16(h))	* 3	Minus	*** 3	= 0		x $230 =	0
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	0

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=		x $0 =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=		x $0 =	
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.	SLIE
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".	/JULIET MCMILLAN/
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".	
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.	

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/SB/06 (09-11)
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ENTITY: ☐ LARGE ☑ SMALL ☐ MICRO

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FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A		N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A		N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*		x $31 =	
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☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))					
* If the difference in column 1 is less than zero, enter "0" in column 2.				TOTAL	

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		(Column 1)		(Column 2)	(Column 3)			
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	Total (37 CFR 1.16(i))	* 29	Minus	** 20	= 9		x $50 =	450
	Independent (37 CFR 1.16(h))	* 3	Minus	*** 3	= 0		x $230 =	0
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	450

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=		x $0 =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=		x $0 =	
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.	SLIE
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".	/SHANDA E ROSS/
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".	
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.	

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REMARKS

This responds to the Non-Final Office Action dated May 15, 2019. As requested all future communications will be directed to Art Unit 2699. This response includes a petition to extend the due date of the response for 3 months and authorization to charge the SLW deposit account 19-0743 for any fees necessary to keep the application pending.

Claims 1-11, 13-16, and 18-19 are presently amended. New claims 20-30 are added. As a result, claims 1-30 are now pending in this application.

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The undersigned would like to thank Examiner MARLY S.B. CAMARGO for the courtesy of a telephone interview on August 16, 2019.

Amendments to claim 1 were discussed. Applicant's representative provided a marked up claim 1 as a proposal for amendment to make it more readable. Applicant agreed to file a terminal disclaimer. Applicant's representative also informed the Examiner that a priority claim was being corrected.

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Double Patenting Rejection

Claims 1 - 18 were rejected on the ground of nonstatutory obviousness-type double patenting as being unpatentable over claims 1 - 18 of parent Application No. 12/586,221, now US 8,451,339 B2.

Applicant does not admit that the claims are obvious in view of U.S. Patent No. 8,451,339. However, a Terminal Disclaimer and the requisite fees in compliance with 37 C.F.R. § 1.321 is enclosed herewith to obviate these rejections.

CONCLUSION

It is respectfully submitted that the claims are in condition for allowance, and notification to that effect is earnestly requested. The Examiner is invited to telephone the undersigned at 612-373-6912 to facilitate prosecution of this application.

If necessary, please charge any additional fees or deficiencies, or credit any overpayments to Deposit Account No. 19-0743.

Respectfully submitted,

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. Box 2938
Minneapolis, MN 55402-0938
612-373-6912

Date: November 15, 2019

By /Timothy E. Bianchi/

Timothy E. Bianchi
Reg. No. 39,610

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s): Neal Solomon

Title: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

Docket No.:	5311.001US3	Serial No.:	13/691,805
Filed:	December 2, 2012	Due Date:	
Examiner:	Marly Camargo	Group Art Unit:	2699
Customer No.:	21186	Confirmation No.:	6244

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

We are transmitting herewith the attached:

X Communication Re: Late Submission of Declaration (1 pg.).
X Signed Declaration (1 pg.).

It is believed that no additional fee is required. However, if necessary, please charge any additional required fees or credit overpayment to Deposit Account No. 19-0743.

Schwegman Lundberg & Woessner, P.A.
Customer No: 21186
TEB:CMG:cb

By: /Timothy E. Bianchi/
Timothy E. Bianchi
Reg. No. 39,610

CERTIFICATE UNDER 37 CFR 1.8: The undersigned hereby certifies that this correspondence is being transmitted using the USPTO's electronic filing system EFS-Web, and is addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on this 22nd day of November, 2019.

Cheryl Breyfogle
Name

/Cheryl Breyfogle/
Signature

Electronic Acknowledgement Receipt

EFS ID:	37839065
Application Number:	13691805
International Application Number:	
Confirmation Number:	6244
Title of Invention:	Digital imaging system for correcting video image aberrations
First Named Inventor/Applicant Name:	Neal Solomon
Customer Number:	21186
Filer:	David L. Buck/Cheryl Breyfogle
Filer Authorized By:	David L. Buck
Attorney Docket Number:	5311.001US3
Receipt Date:	22-NOV-2019
Filing Date:	02-DEC-2012
Time Stamp:	17:58:57
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		5311001US3DEC.pdf	295167 6b2dd6fd840bfee02db4216a4656cb601bb13a88	yes	3

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Oath or Declaration filed	3	3
	Miscellaneous Incoming Letter	2	2
	Transmittal Letter	1	1
Warnings:			
Information:			
	Total Files Size (in bytes):	295167	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

S/N 13/691,805 **PATENT**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s):	Neal Solomon	Examiner: Marly Camargo	
Serial No.:	13/691,805	Group Art Unit: 2699	
Filed:	December 2, 2012	Docket: 5311.001US3	
Customer No.: 21186		Confirmation No.: 6244	
Title:	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS		

COMMUNICATION RE: LATE SUBMISSION OF DECLARATION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

In compliance with 37 CFR 1.63, we submit the Signed Declaration. Corresponding fees with regard to the late submission were paid with the filing of the Petition for Revival of an Application on February 11, 2019, therefore applicants believe no additional fees are due at this time.

Applicants assume the application is now in proper order and in condition for allowance. Please direct any inquiries to the undersigned at (612) 373-6912. If necessary, please charge any additional fees or credit overpayment to Deposit Account 19-0743.

Respectfully submitted,

Schwegman Lundberg & Woessner, P.A.
P.O. Box 2938
Minneapolis, MN 55402
(612) 373-6912

Date November 22, 2019 By /Timothy E. Bianchi/
Timothy E. Bianchi
Reg. No. 39,610

TEB:CMG:cb

Amended PTO/AIA/01 (06-12)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number 13/691,805, filed on December 2, 2012 .

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Neal Solomon Date (Optional) : _____

Signature: /Neal Solomon/

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

5311.001US3

REMARKS

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The claims were amended for consistency. Claim 1 was further amended to correct antecedent basis and to include a zoom lens option. If there are any questions about the claim amendments the Examiner is invited to contact Applicant's representative at the number below.

Double Patenting Rejection

Claims 1 - 18 were rejected on the ground of nonstatutory obviousness-type double patenting as being unpatentable over claims 1 - 18 of parent Application No. 12/586,221, now US 8,451,339 B2.

Applicant does not admit that the claims are obvious in view of U.S. Patent No. 8,451,339. However, a Terminal Disclaimer and the requisite fees in compliance with 37 C.F.R. § 1.321 is enclosed herewith to obviate these rejections.

CONCLUSION

It is respectfully submitted that the claims are in condition for allowance, and notification to that effect is earnestly requested. The Examiner is invited to telephone the undersigned at 612-373-6912 to facilitate prosecution of this application.

If necessary, please charge any additional fees or deficiencies, or credit any overpayments to Deposit Account No. 19-0743.

Respectfully submitted,

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. Box 2938
Minneapolis, MN 55402-0938
612-373-6912

Date: January 15, 2020

By /Timothy E. Bianchi/

Timothy E. Bianchi
Reg. No. 39,610

PTO/AIA/26 (04-14)
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TERMINAL DISCLAIMER TO OBVIATE A DOUBLE PATENTING REJECTION OVER A "PRIOR" PATENT	Docket Number (Optional) 5311.001US3

In re Application of: Neal Solomon

Application No.: 13/691,805

Filed: December 2, 2012

For: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

The applicant, **Neal Solomon**, owner of **100** percent interest in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of **prior patent** No. **8,451,339** as the term of said **prior patent** is presently shortened by any terminal disclaimer. The applicant hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and the **prior patent** are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the applicant does not disclaim the terminal part of the term of any patent granted on the instant application that would extend to the expiration date of the full statutory term of the **prior patent**, "as the term of said **prior patent** is presently shortened by any terminal disclaimer," in the event that said **prior patent** later:

expires for failure to pay a maintenance fee;
is held unenforceable;
is found invalid by a court of competent jurisdiction;
is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321;
has all claims canceled by a reexamination certificate;
is reissued; or
is in any manner terminated prior to the expiration of its full statutory term as presently shortened by any terminal disclaimer.

Check either box 1 or 2 below, if appropriate.

1. ☐ The undersigned is the applicant. If the applicant is an assignee, the undersigned is authorized to act on behalf of the assignee.

I hereby acknowledge that any willful false statements made are punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

2. ☒ The undersigned is an attorney or agent of record. Reg. No. 39,610

/Timothy E. Bianchi/	January 15, 2020
Signature	Date
Timothy E. Bianchi	
Typed or printed name	
Principal	(612) 373-6912
Title	Telephone Number

☒ Terminal disclaimer fee under 37 CFR 1.20(d) included.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

This collection of information is required by 37 CFR 1.321. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) and application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner of Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

IN THE CLAIMS

Please amend the claims as follows:

1. (Currently Amended) A digital imaging system for correcting optical image aberrations in a digital video, comprising:

a digital video camera ~~mechanism~~ including in-camera software, an optical lens mechanism, at least one digital sensor for capturing the digital video, an integrated circuit including~~,~~ a digital signal processor~~, system software,~~ configured to access a database management system including a plurality of optical image aberration corrections, and a memory storage sub-system;

wherein the optical lens mechanism is a zoom lens or a fixed focal length lens;

wherein ~~an~~ the integrated circuit uses ~~system~~ the in-camera software to identify at least one optical image aberration and ~~by accessing the database;~~

~~wherein the integrated circuit uses the database to identify at least one algorithm to use~~ to correct the at least one optical ~~and/or digital~~ image aberration in at least one frame of the digital video using at least one of the plurality of optical image aberration corrections in the database;

wherein ~~when~~ the video ~~image file~~ is captured by the at least one digital sensor ~~the digital file~~ and is forwarded to the digital signal processor;

wherein the video image file with the at least one optical ~~or digital~~ image aberration is corrected by applying digital filtration ~~by~~ using ~~at least one algorithm in~~ the digital signal processor; and

wherein the ~~modified~~ corrected ~~digital file~~ video consisting of the digital data optimized from the at least one optical ~~or digital~~ image aberration that are corrected from the original video image is stored in the memory storage sub-system.

2. (Currently Amended) The system of claim 1:

wherein the optical image aberrations include at least one of spherical, comatic, lens distortion, astigmatism, curvature of field, pin cushion, barrel distortion, chromatic aberrations, scattered light, ~~red eye, dust~~ and/or flare types of optical image aberrations.

3. (Currently Amended) The system of claim 1:

wherein the optical image aberration is vignetting;

wherein the digital signal processor applies neutral density filtration from one third of a stop to three stops in the center of the image and/or wherein the digital signal processor applies an algorithm to lighten the comers of the image or the digital signal processor applies both neutral density filtration in the image center and/or an algorithm to lighten the comers of the image; and

wherein the image exposure is optimized to correct the vignetting.

4. (Currently Amended) The system of claim 1:

wherein the digital signal processor applies at least one fast Fourier transform (FFT) algorithm to correct the at least one optical image aberration.

5. (Currently Amended) The system of claim 1:

wherein each lens type is registered in the camera database;

wherein the multiple optical aberrations of each lens is listed in the database;

wherein the filtration solutions to the lens optical aberrations are listed in the database;

wherein the filtration of each lens optical aberration is applied by the digital signal processor; and

wherein after the digital signal processor applies the filtration to correct the optical image aberrations the corrected digital file is forwarded to storage in memory.

6. (Currently Amended) A digital imaging system for correcting image aberrations comprising:

a digital video camera ~~mechanism,~~ including in-camera software, an optical lens mechanism, at least one digital sensor for capturing digital video, an integrated circuit~~,~~ including a digital signal processor~~, system software,~~ configured to access a database management system including a plurality of optical image aberration corrections, and a memory storage sub-system;

wherein the optical lens mechanism is a zoom lens or a fixed focal length lens;

wherein the video ~~image data file~~ is forwarded ~~from the at least one digital sensor~~ to storage in memory;

wherein at least one optical ~~and/or digital~~ aberration in at least two frames of the digital

video ~~image file~~ are identified ~~by comparing image files in the database management system by~~ using the ~~system~~ in-camera software and the integrated circuit;

~~wherein the at least one filtration algorithms required to correct the at least one optical and/or digital aberration of at least two frames of the digital video file are sent from the integrated circuit to the digital signal processor;~~

wherein the at least one optical ~~and/or digital~~ aberration from the optical lens mechanism of at least two frames of the digital video ~~file~~ are corrected by using the digital signal processor to apply at least one digital filtration algorithm; and

wherein the ~~modified~~ corrected digital video file ~~consisting of the digital data optimized from the at least one aberration that are corrected from the original video images~~ is stored in memory.

7. (Currently Amended) The system of claim 6:

wherein the optical image aberrations include spherical, comatic, lens distortion, astigmatism, chromatic aberrations, curvature of field, pin cushion, barrel distortion, scattered light, ~~red eye, dust~~ and/or flare types of optical aberrations.

8. (Currently Amended) The system of claim 6:

~~wherein the digital aberrations include moire and/or aliasing~~ wherein the digital signal processor applies at least one fast Fourier transform (FFT) algorithm to correct the at least one optical image aberration.

9. (Currently Amended) The system of claim 6:

wherein the digital signal processor applies a fast Fourier transform (FFT) algorithm to correct ~~optical and/or~~ digital aberrations of at least two frames in the digital video ~~file~~.

10. (Currently Amended) The system of claim 6:

wherein the digital signal processor applies color filtration to at least two frames of the digital video image ~~file~~.

11. (Currently Amended) The system of claim 6:

wherein the digital video ~~image file~~ is filtered to correct at least one optical and/or digital aberrations after initial capture and before the digital video ~~image file~~ is initially sent to storage.

12. (Original) The system of claim 6:

wherein the integrated circuit may be a microprocessor, an application specific integrated circuit or a system on a chip.

13. (Currently Amended) The system of claim 6:

wherein the optical image aberration is vignetting;

wherein the digital signal processor applies neutral density filtration from one third of a stop to three stops in the center of the image and/or wherein the digital signal processor applies an algorithm to lighten the comers of the at least two image frames or the digital signal processor applies both neutral density filtration in the image center and/or an algorithm to lighten the comers of the image of at least two image frames; and

wherein the image exposure for at least two frames in the digital video file is optimized to correct the vignetting.

14. (Currently Amended) A digital imaging system for correcting image aberrations comprising:

a digital video camera ~~mechanism,~~ including in-camera software, an optical lens mechanism, at least one digital sensor for capturing digital video, an integrated circuit~~,~~ including a digital signal processor~~, system software,~~ configured to access a database management system including a plurality of optical image aberration corrections, and a memory storage sub-system;

wherein the optical lens mechanism is a zoom lens;

wherein the zoom lens changes focal length positions;

wherein when the digital video ~~image file~~ is ~~captured by the at least one digital sensor the file is~~ forwarded to the digital signal processor and to memory;

wherein the integrated circuit uses system software to access the database to identify at least one optical ~~and/or digital aberrations~~ aberration in at least one frame of the video ~~file~~ at any focal length of a zoom lens configuration;

wherein the integrated circuit accesses the database to obtain at least one filtration correction algorithm to the optical ~~and/or digital aberrations~~ image aberration of at least one frame in the video file and forwards the at least one filtration algorithms to the digital signal processor;

wherein the digital video ~~image file~~ is forwarded to the digital signal processor which applies at least one filtration algorithm to optimize the digital video ~~file~~ and corrects the at least one optical ~~and/or digital aberrations~~ image aberration in at least one video frame for the at least one focal length in the zoom lens configuration; and

wherein the ~~modified~~ corrected digital video ~~image file consisting of the digital data optimized from the at least one optical and/or digital aberrations in at least one frame of the video file of at least one focal length of the zoom lens that are corrected from the original video image~~ is stored in memory.

15. (Currently Amended) The system of claim 14:

wherein the optical aberrations include vignetting, spherical, comatic, lens distortion, chromatic aberrations, curvature of field, pin cushion, barrel distortion, scattered light, ~~red eye, dust~~ and/or flare types of optical aberrations.

16. (Currently Amended) The system of claim 14:

wherein the digital signal processor applies a fast Fourier transform (FFT) algorithm to correct optical and/or digital aberrations in the digital video ~~file~~.

17. (Original) The system of claim 14:

wherein each focal length of a zoom lens in at least one video image frame is analyzed for a different set of optical aberrations.

18. (Currently Amended) The system of claim 14:

wherein the digital signal processor applies color filtration to at least one frame of the digital video image ~~file~~.

[[18.]]19. (Currently Amended) The system of claim 14:

wherein the optical image aberration is vignetting;

wherein the digital signal processor applies neutral density filtration from one third of a stop to three stops in the center of the image and/or wherein the digital signal processor applies an algorithm to lighten the corners of at least one image frame or the digital signal processor applies both neutral density filtration in the image center and/or an algorithm to lighten the comers of the image of at least one image frame; and

wherein the image exposure for at least one frame in the digital video file is optimized to correct the vignetting.

20. (New) The system of claim 1, wherein the system is configured to correct red-eye.

21. (New) The system of claim 1, wherein the system is configured to correct for dust.

22. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for spherical aberrations.

23. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for chromatic aberrations.

24. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for scattered light aberrations.

25. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for comatic aberrations.

26. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for astigmatism aberrations.

27. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for lens distortion aberrations.

28. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for pin cushion aberrations.

29. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for curvature of field aberrations.

30. (New) The system of claim 1, wherein the system includes machine readable instructions for the system to correct for barrel distortion aberrations.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s): Neal Solomon
Application No.: 13/691,805
Filed: December 2, 2012
Confirmation No.: 6244
Title: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

Examiner: MARLY S.B. CAMARGO
Group Art Unit: 2699
Docket No.: 5311.001US3

AMENDMENT & RESPONSE UNDER 37 C.F.R. § 1.111 (CORRECTED)

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Applicant received a Non-Final Office Action dated May 15, 2019. An Amendment and Response was timely filed with a Petition, as well as the appropriate fee, to obtain a three-month extension of the period for responding to the Office Action, thereby moving the deadline for response from August 15, 2019 to November 15, 2019.

The Office sent a Notice of Non-Compliant Amendment (37 C.F.R. 1.121) in response to the Amendment and Response of November 15, 2019, noting that claim 24 was missing.

Additionally, a Terminal Disclaimer was rejected because the Office asserts that the undersigned representative does not have Power of Attorney. The Terminal Disclaimer is corrected to list Applicant Neal Solomon (who is the sole owner and Chief Managing Member of Optical Imaging Technologies LLC) as providing the Terminal Disclaimer. The requisite terminal disclaimer fee was submitted with the last submission of the Terminal Disclaimer.

Please enter the following:

Electronic Acknowledgement Receipt

EFS ID:	38309332
Application Number:	13691805
International Application Number:	
Confirmation Number:	6244
Title of Invention:	Digital imaging system for correcting video image aberrations
First Named Inventor/Applicant Name:	Neal Solomon
Customer Number:	21186
Filer:	Timothy E. Bianchi/Jamie Agnes
Filer Authorized By:	Timothy E. Bianchi
Attorney Docket Number:	5311.001US3
Receipt Date:	15-JAN-2020
Filing Date:	02-DEC-2012
Time Stamp:	23:15:34
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		SIGNED_5311_001US3_RespTD.pdf	222878 01a93caeaaf159ee3634822aa7286feadcc23e11	yes	12

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Terminal Disclaimer Filed	12	12
	Applicant Arguments/Remarks Made in an Amendment	10	11
	Claims	3	9
	Amendment/Req. Reconsideration-After Non-Final Reject	2	2
	Transmittal Letter	1	1
Warnings:			
Information:			
	Total Files Size (in bytes):	222878	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s): Neal Solomon
Title: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

Docket No.:	5311.001US3	Serial No.:	13/691,805
Filed:	December 2, 2012	Due Date:	January 15, 2020
Examiner:	Marly Camargo	Group Art Unit:	2699
Customer No.:	21186	Confirmation No.:	6244

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

We are transmitting herewith the following attached items (as indicated with an "X"):

X Response to Notice of Non-Compliance (10 pgs.)
X Terminal Disclaimer (1 pg.)

If not provided for in a separate paper filed herewith, please consider this a PETITION FOR EXTENSION OF TIME for sufficient number of months to enter these papers and please charge any additional fees or credit overpayment to Deposit Account No. 19-0743. If applicable, any papers or fees supplied herewith are considered to be timely filed pursuant to 37 C.F.R. § 1.7(a), the response period falling on a Federal Holiday, Saturday or Sunday being extended to the next succeeding business day.

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
Customer No.: 21186

By: /Timothy E. Bianchi/
Timothy E. Bianchi
Reg. No. 39,610

US 20030095197A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2003/0095197 A1

Wheeler et al. (43) Pub. Date: May 22, 2003

(54) SYSTEM AND METHOD FOR DECIDING WHEN TO CORRECT IMAGE-SPECIFIC DEFECTS BASED ON CAMERA, SCENE, DISPLAY AND DEMOGRAPHIC DATA

(75) Inventors: **Richard B. Wheeler**, Webster, NY (US); **Brian W. Keelan**, Rochester, NY (US)

Correspondence Address:
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Patent Legal Staff
Eastman Kodak Company
343 State Street
Rochester, NY 14650-2201 (US)

(73) Assignee: **Eastman Kodak Company**

(21) Appl. No.: **09/957,013**

(22) Filed: **Sep. 20, 2001**

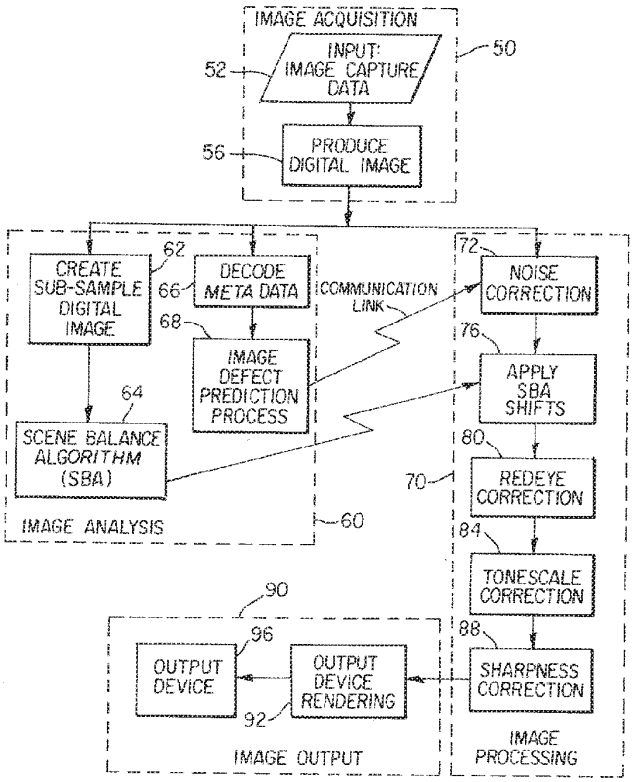
Publication Classification

(51) **Int. Cl.**[7] **H04N 5/217**; G06K 9/40; G03B 15/03

(52) **U.S. Cl.** **348/241**; 382/275; 348/211.5; 348/231.6; 396/158; 348/222.1

(57) **ABSTRACT**

A captured image is processed with one or more correction processes selected from a plurality of such processes, each associated with correction of a specific type of image defect, in order to improve the appearance of a viewed image generated from the captured image. Preliminary to the image processing, meta data related to image capture is obtained that is unique to each captured image, where the meta data is capable of indicating whether the specific types of image defects are likely to be present in the viewed image generated from the captured image. The processing then involves predicting the presence of the image defects based at least in part on the meta data, thereby generating process application criteria which indicate a level of image defect that if left untreated would reduce the perceived quality of the viewed image; selecting one or more correction processes to employ on the captured image based on the process application criteria; and applying the one or more selected correction processes to the captured image to generate the viewed image.



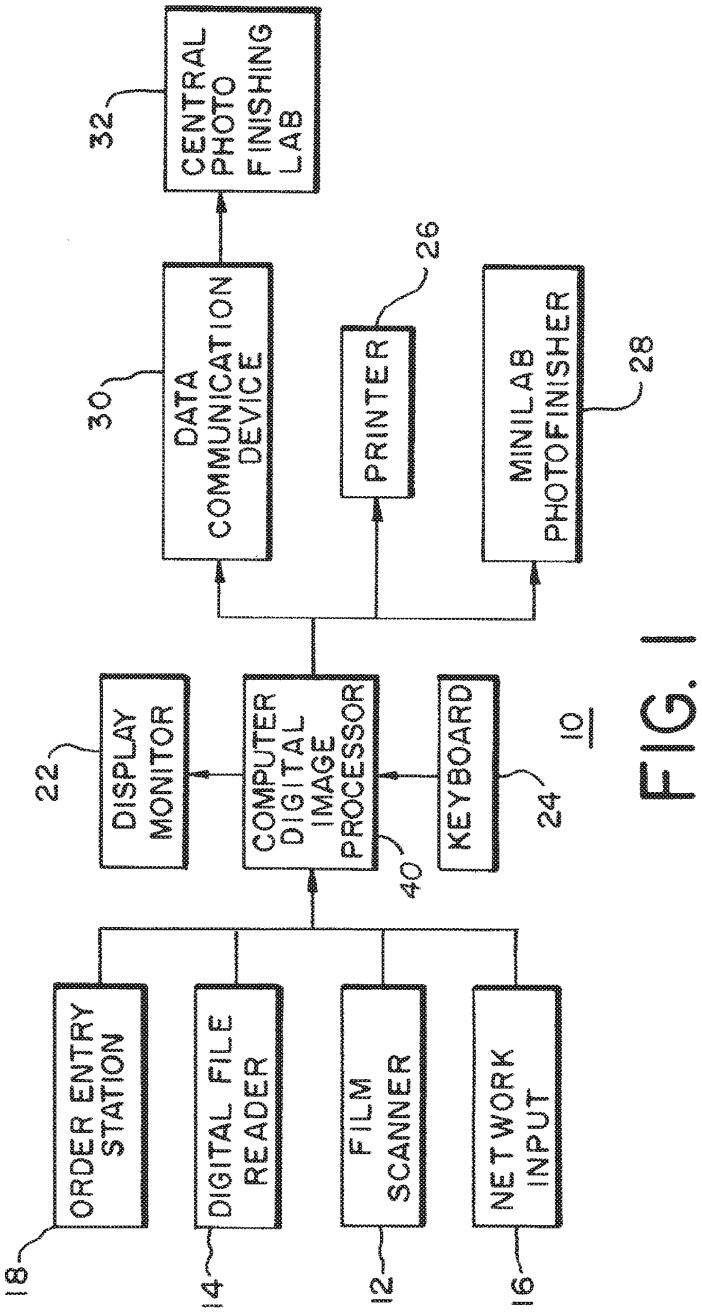


FIG. 1

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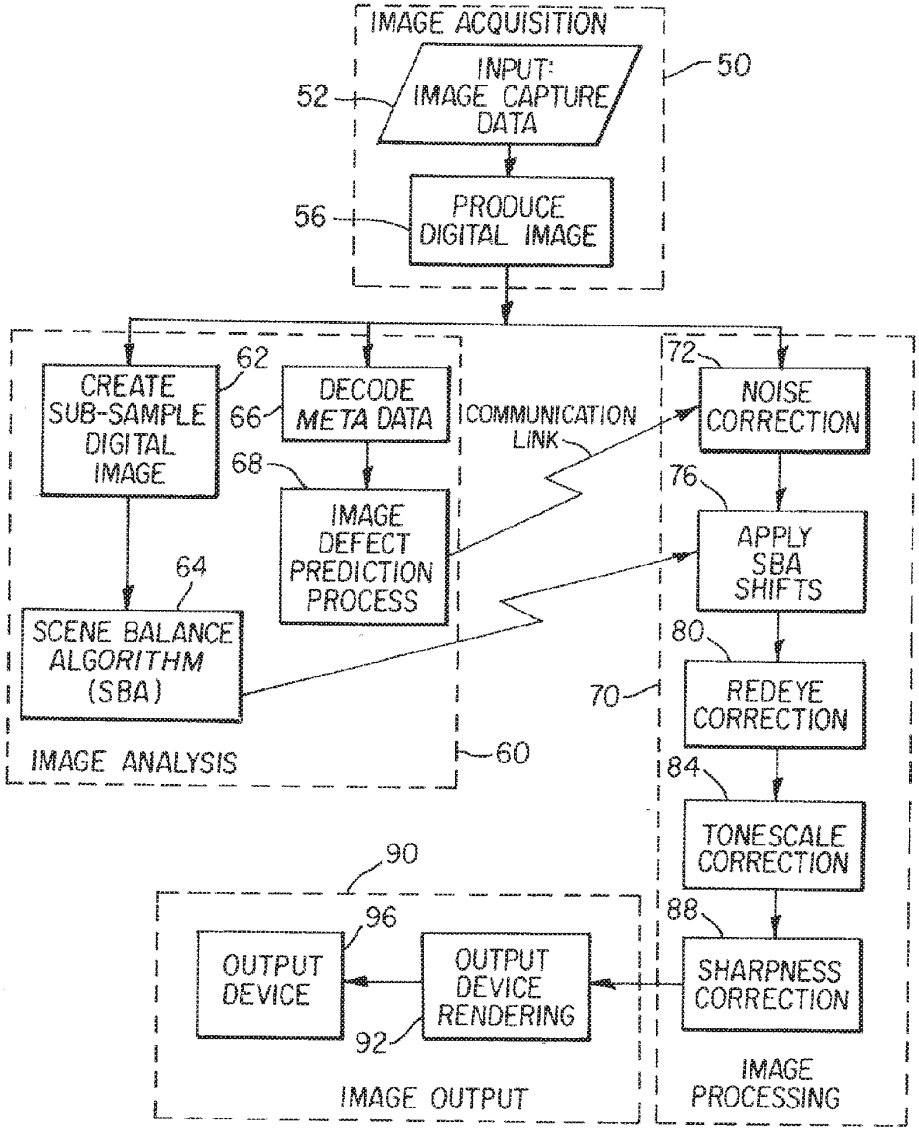

IMAGE ACQUISITION
INPUT: IMAGE CAPTURE DATA
50
52
PRODUCE DIGITAL IMAGE
56
CREATE SUB-SAMPLE DIGITAL IMAGE
62
DECODE META DATA
66
68
IMAGE DEFECT PREDICTION PROCESS
64
SCENE BALANCE ALGORITHM (SBA)
IMAGE ANALYSIS
60
COMMUNICATION LINK
72
NOISE CORRECTION
76
APPLY SBA SHIFTS
80
70
REDEYE CORRECTION
84
TONESCALE CORRECTION
88
SHARPNESS CORRECTION
IMAGE PROCESSING
90
96
OUTPUT DEVICE
OUTPUT DEVICE RENDERING
92
IMAGE OUTPUT

FIG. 2

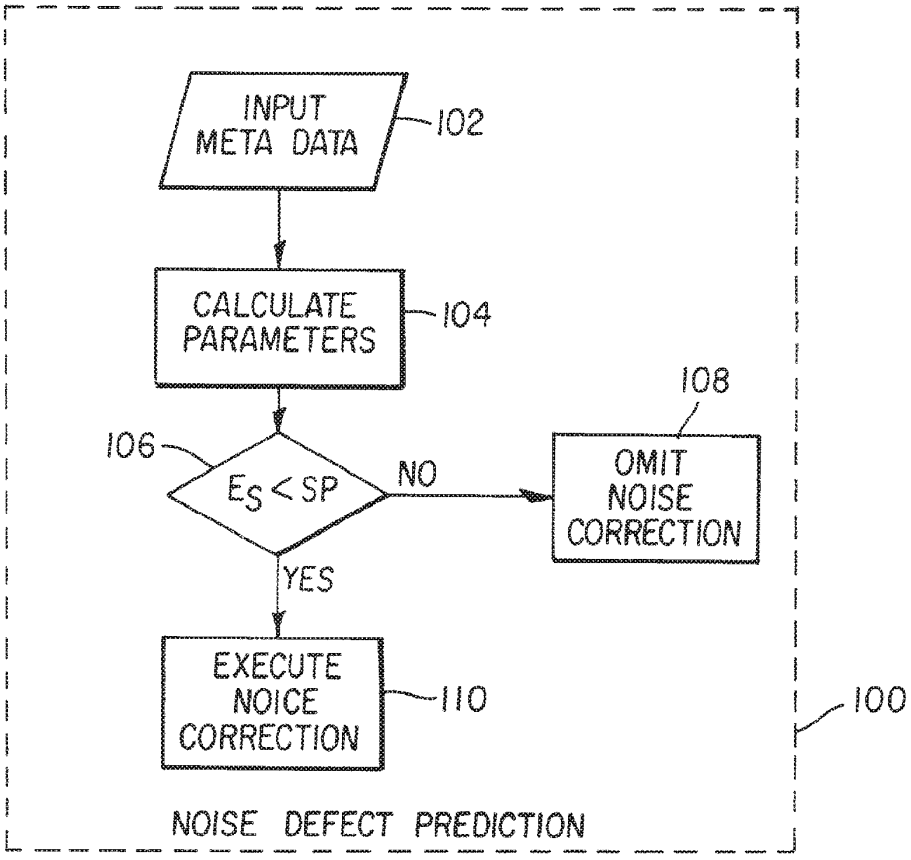

INPUT META DATA
102
CALCULATE PARAMETERS
104
108
106
$E_S < SP$
NO
OMIT NOISE CORRECTION
YES
EXECUTE NOICE CORRECTION
110
100
NOISE DEFECT PREDICTION

FIG. 3

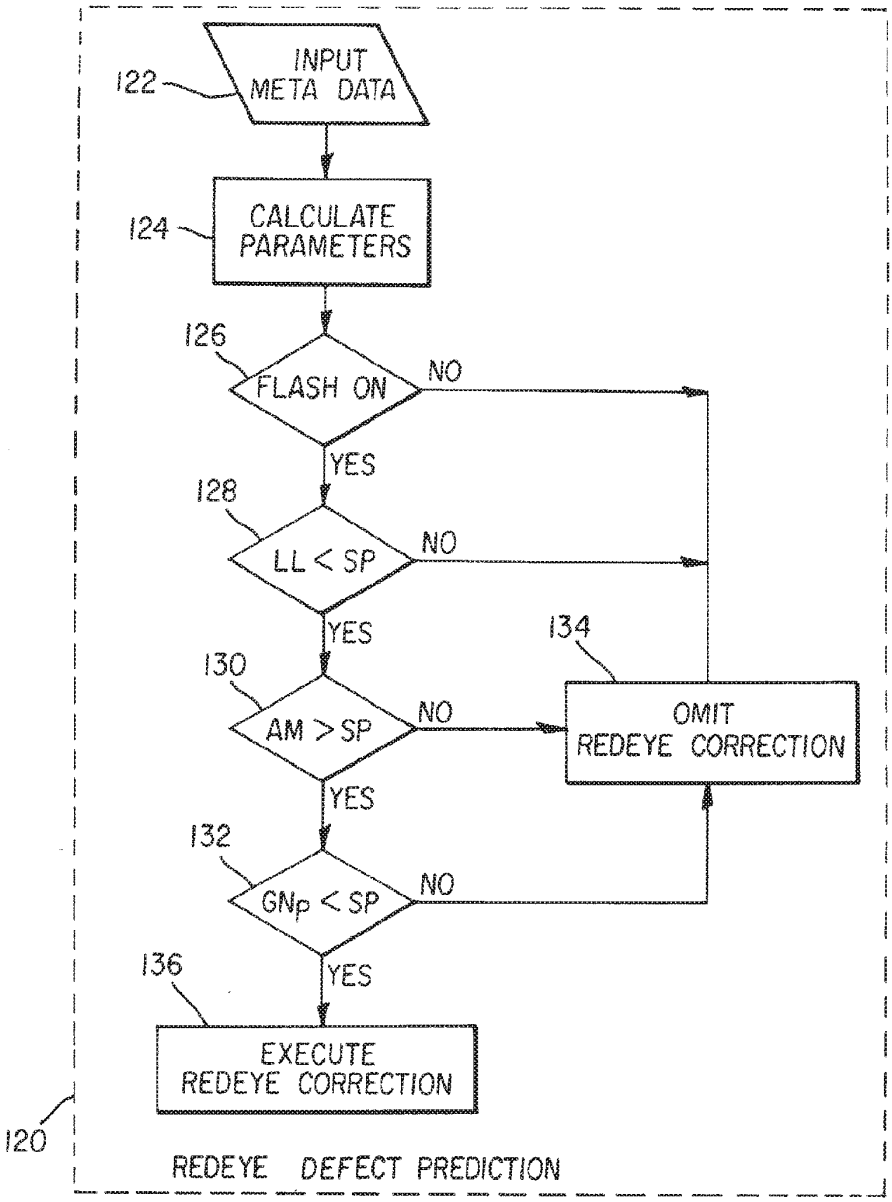

INPUT META DATA
122
CALCULATE PARAMETERS
124
126
FLASH ON
NO
YES
128
LL < SP
NO
YES
134
130
AM > SP
NO
OMIT REDEYE CORRECTION
YES
132
GNp < SP
NO
136
YES
EXECUTE REDEYE CORRECTION
120
REDEYE DEFECT PREDICTION

FIG. 4

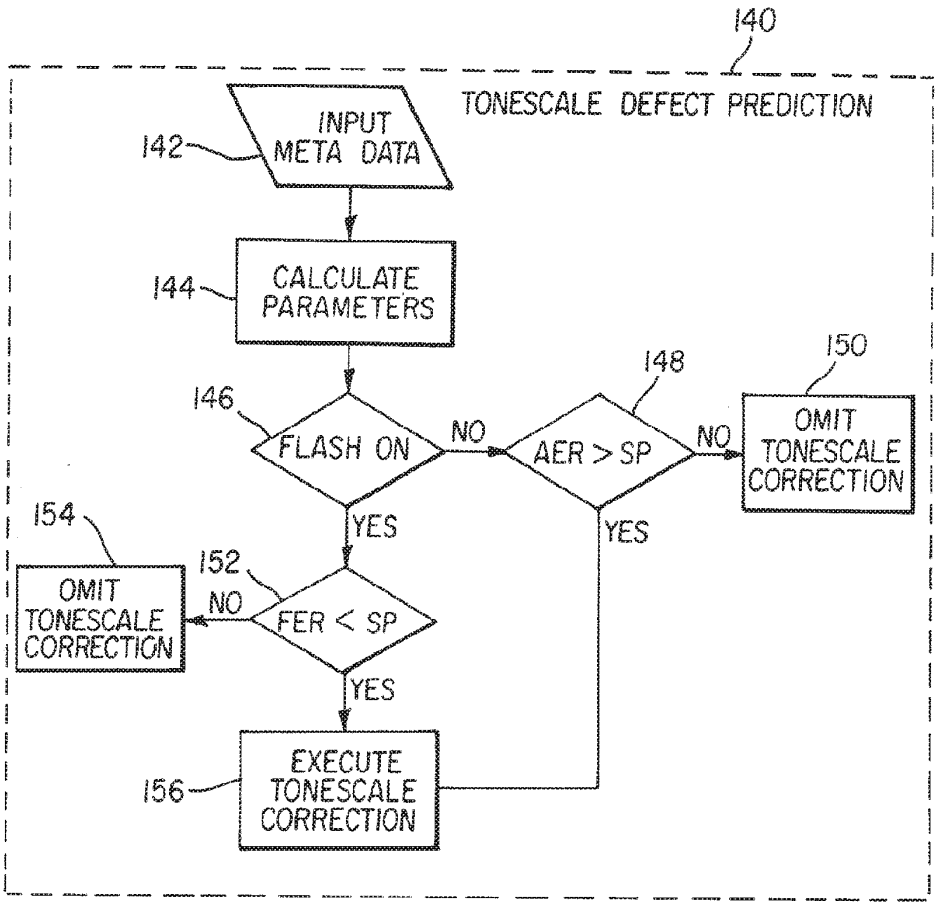

140
TONESCALE DEFECT PREDICTION
INPUT META DATA
142
CALCULATE PARAMETERS
144
146
FLASH ON
NO
148
AER > SP
NO
150
OMIT TONESCALE CORRECTION
YES
YES
154
OMIT TONESCALE CORRECTION
152
NO
FER < SP
YES
156
EXECUTE TONESCALE CORRECTION

FIG. 5

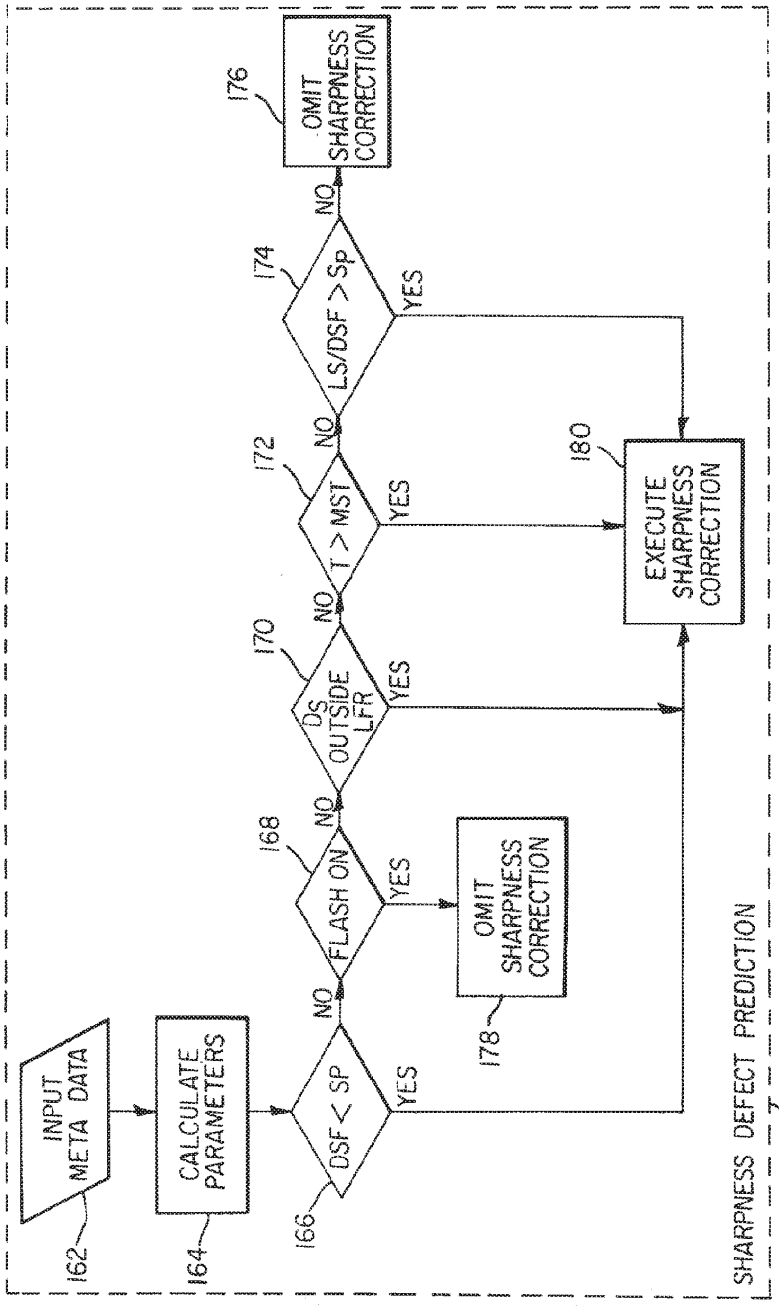


FIG 6

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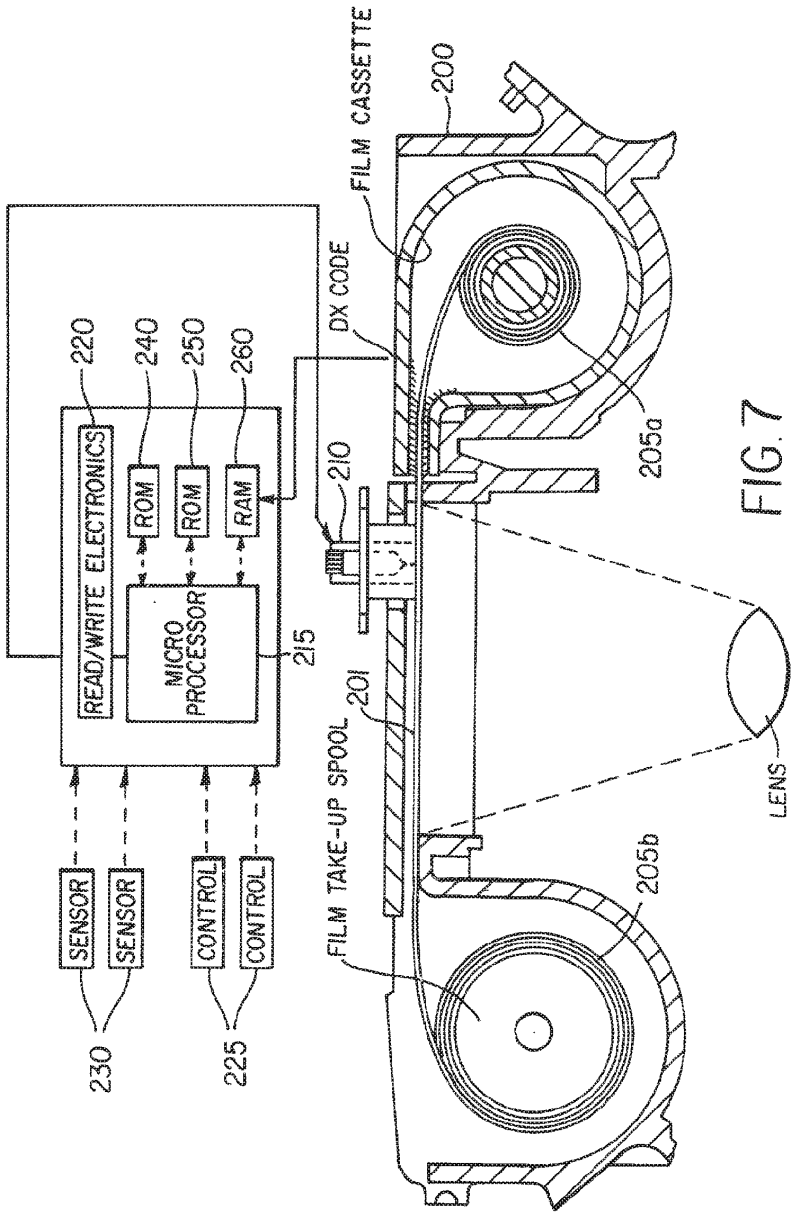


FIG. 7

EX1002 - Page 244

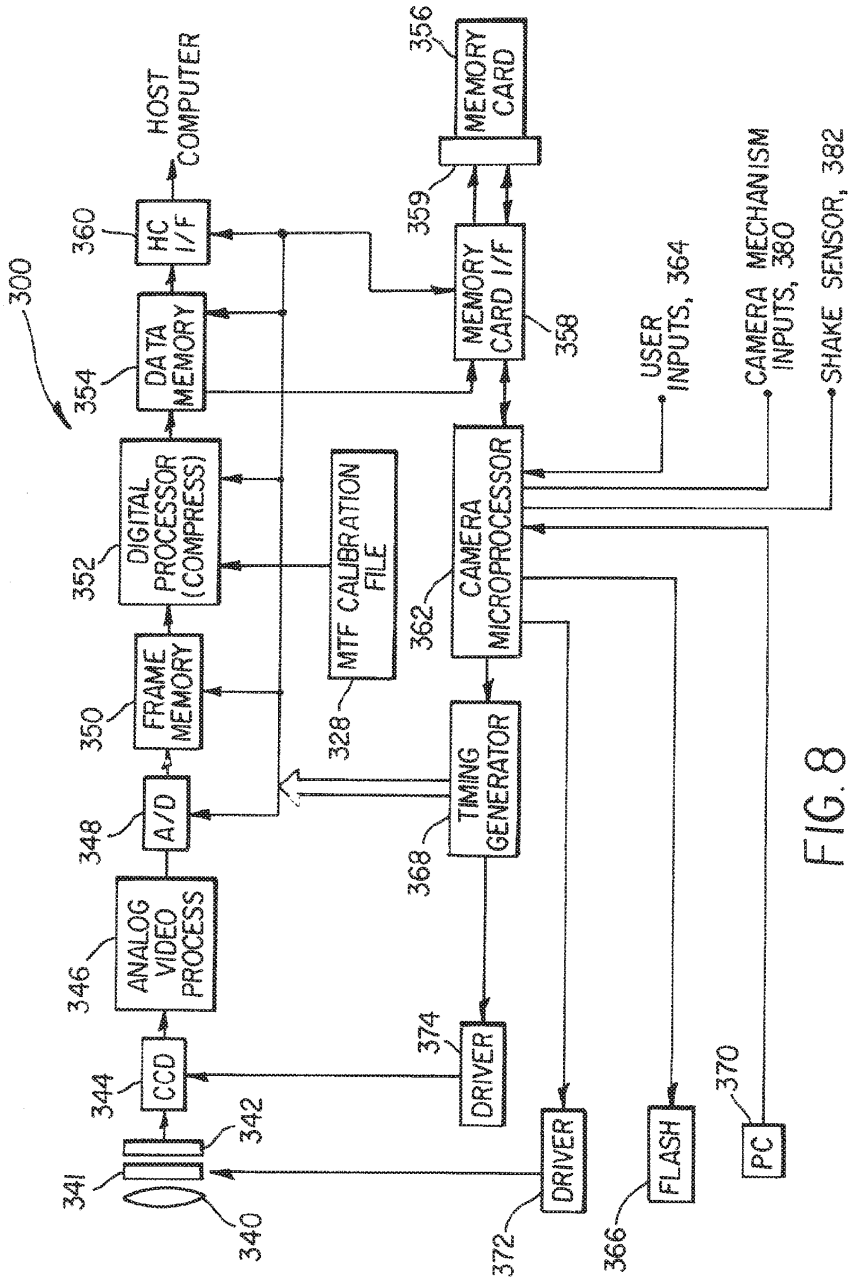


FIG. 8

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SYSTEM AND METHOD FOR DECIDING WHEN TO CORRECT IMAGE-SPECIFIC DEFECTS BASED ON CAMERA, SCENE, DISPLAY AND DEMOGRAPHIC DATA

FIELD OF THE INVENTION

[0001] This invention relates generally to the field of digital image processing, and, in particular, to the prediction and correction of image defects in a photograph.

BACKGROUND OF THE INVENTION

[0002] Photographic systems produce a wide range of image quality when operated by amateur, often referred to as "point-and-shoot", photographers. If the photographic environment for a given scene is well suited to the image capture system (e.g. subjects are stationary and within the focus range, ambient light level is uniform and of sufficient intensity, and lens magnification is appropriate for the subject matter), good results are typically obtained. However, when these conditions are not present, image defects may be introduced due to failures in the capture or reproduction system, thereby reducing the quality of the final viewed image. To minimize the effects of suboptimal image capture conditions, camera designers have attempted to compensate by adding features intended to expand the range of light levels and distances where images can be captured. Unfortunately, these features often solve the primary problem, but add a secondary, sometimes severe, image defect.

[0003] For example, if the intensity of the ambient light is insufficient to provide adequate exposure, and the primary subject is located less than 20 feet from the camera, most built-in electronic flash units are able to provide auxiliary illumination sufficient to at least partially expose the primary subject. However, even if the primary subject now receives adequate illumination, the flash may introduce image defects.

[0004] As is well known in the art, the image defect known as redeye may occur when the angle between a narrow light source, the photographic subject, and the camera lens is less than approximately three degrees. This criterion is frequently met in flash exposures from compact cameras. The light from the flash enters the pupil nearly on-axis and propagates to the fundus of the eye, where it is reflected back out of the eye, having been colored red by the blood vessels in the fundus. The light exits the eye in a narrow cone, and if the camera lens falls within that cone, the red reflection will be recorded, and may appear in the final image as a red glow in the pupils, which is very undesirable in terms of image quality.

[0005] Redeye is more objectionable when the size of the pupil in the viewed image is larger and when the red saturation of the pupil is greater. The former may occur when the pupil is dilated, as occurs at low ambient light levels, or when the subject is rendered at a larger size in the image, for example due to shorter camera to subject distance, longer camera lens focal length, higher printing magnification (including zoom and crop), and/or shorter viewing distance. The primary techniques used in the camera to reduce or eliminate redeye are: increasing flash to lens separation; firing a preflash to transiently stop down the pupil in response to the bright light; and decreasing lens focal length and/or electronic zoom.

[0006] While all these methods are efficacious, all have associated disadvantages. Increased flash-lens separation may lead to more expensive and bulkier cameras and produces more noticeable shadows due to the farther off-axis lighting. After a preflash is fired, the eye requires half a second or more to respond fully, and during this delay between the preflash fire and the image capture, facial expressions of the subject often change in an undesirable fashion due to the annoyance and surprise of the preflash. The preflash also increases camera cost, reduces the power available during the main flash pulse, and increases battery consumption. Finally, restriction of optical or electronic zoom factors interferes with the photographer's ability to obtain the desired composition, with the subjects appearing large enough in the image to provide a pleasing rendition.

[0007] Given the disadvantages of the in-camera redeye reduction techniques summarized above, and the increased availability of digital printing devices capable of making corrections to selected portions of individual images, considerable effort has been directed towards the development of techniques for locating and correcting the redeye defect during the photofinishing (digital printing) process.

[0008] U.S. Pat. No. 5,748,764 issued May 5, 1998 teaches a method of locating and correcting the redeye image defect in an image. U.S. Pat. No. 5,892,837 issued Apr. 6, 1999, and related commonly assigned US. Pat. No. 6,292,574 issued Sep. 18, 2001 and U.S. Pat. No. 6,151,403 issued Nov. 21, 2000 generally describe additional methods suitable for locating human eyes in an image, and specifically describe locating and correcting the appearance of human eyes with the redeye image defect. These digital redeye removal techniques, while effective, are computationally intensive, and therefore increase the time required to optimally render and reproduce copies of captured images. The time required to perform these operations may in some cases be the rate limiting step in automated high speed printing operations. If the redeye defect location and correction processes are applied to every image in a customer order, even though only a portion of those images actually contain the defect, productivity and profit may be reduced. In addition, if computational time is spent searching for redeye defects in every image, other beneficial image processing operations such as tone scale mapping, digital noise reduction and sharpening may not be possible in the time interval allocated for each image. It is therefore desirable to be able to predict when redeye will occur, and to invoke the redeye location and correction processes only when needed.

[0009] From an extensive study to determine whether it is possible to predict from data collected at the time the original scene is photographed, the probability and severity of the redeye defect that will be present in the final image, it was discovered that the extent of the redeye defect depends primarily on the following factors: subject race, subject age, preflash illumination level, flash-to-lens separation, camera to subject distance, ambient light level, camera lens focal length, reproduction magnification, and final image viewing distance. In the present invention these factors are used to predict, on an image by image basis, the severity of the redeye defect, and that information is transferred from the camera to the photofinishing system where it commands the automatic printer control system, or in the case of human assisted printers, alerts the operator, to apply

redeye defect location and correction techniques only when warranted, thereby improving picture quality and enhancing photofinishing productivity.

[0010] In addition to the redeye image defect, it is well-known that the physics of light intensity loss as a function of distance from a narrow source, such as an electronic flash tube, often leads to a defect in lighting contrast and consequently distorted tone reproduction in the final viewed image. Specifically, with every doubling of camera-to-subject distance, the light intensity per unit area on the subject drops by a factor of four. For example, if the primary subject is located 6 feet from the camera and the background is located 12 feet from the camera, the captured image of the background has an exposure level only one quarter that of the image of the primary subject. This causes the background to appear much darker than the primary subject does in the final viewed image. Because light falls off according to this squared function with respect to distance, the exposure difference between the primary subject and the background are often larger than illustrated above, particularly when images are captured outdoors at night or in large rooms. When presented with an image having a large exposure range (high contrast scene) with no knowledge of which portion of the scene is the primary subject, the exposure control system in the printer often calculates an average or area-weighted exposure that may excessively lighten the primary subject. This defect is particularly detrimental in pictures of people, whose faces are washed out and lack proper flesh reproduction.

[0011] If images of high contrast scenes universally contained overexposed primary subjects and underexposed backgrounds, as illustrated above, it would be practical to introduce a darken bias when printing all high contrast scenes. Unfortunately, there is a class of scenes known as backlight that are high in contrast, but have a subject-to-background exposure ratio that is opposite that of flash scenes. In the case of backlight scenes the illumination source is often behind the primary subject, or the primary subject is shaded by another object, such as a tree or a building, and therefore receives only a fraction of the ambient illumination. Consequently, the primary subject is underexposed relative to the background. In this case if the darkening bias needed to correct harsh flash scenes was applied, the already dark primary subject would be rendered even darker, having the effect of further reducing the image quality.

[0012] The information exchange (IX) feature of the Advanced Photo System offered by Eastman Kodak Company may make use of information collected at the time of image capture and passed to the printer to indicate whether, for the current image, the electronic flash was employed. (The Advanced Photo System specifications documents can be found at http://www.kodak.com/global/en/consumer/APS/redBook/specsIndex.shtml.) If the flash was fired, and a high contrast scene is inferred from the scanned image densities, a darkening bias can be applied to the image during printing. This information helps discriminate between backlight and harsh flash shots, and increases the probability that the primary subject will be printed to the proper lightness. However, because in both backlight and harsh flash scenes the dynamic range of the scene may exceed the tonal range of the print material, the primary subject and background can not be simultaneously rendered properly by invoking a full-image-field darken (in the case of harsh flash) or lighten (in the case of backlight) printing correction. This means that optical (analog) printing systems, which are only capable of producing full-field exposure corrections, can not produce optimal renditions of high contrast scenes.

[0013] Recent advances in digital image processing make practical methods for digitally segmenting the image field, analyzing the dynamic range, and adjusting tone reproduction (lightening or darkening) on an image area specific basis. By remapping the tone reproduction in this fashion, both the overexposed and underexposed portions of high contrast scenes can be rendered within the tonal range of the print material, thereby making the information in both regions visible in the final image. These digital area-specific tone scale remapping techniques, while effective, are computationally intensive, and therefore increase the time required to optimally render and reproduce copies of captured images. The time required to perform these operations may in some cases be the rate limiting step in automated high speed printing operations. If the tone scale remapping techniques are applied to every image in a customer order, even though only a portion of those images actually contain the defect, productivity and profit may be reduced. In addition, if computational time is spent searching for tone scale defects in every image, other beneficial image processing operations such as redeye location and correction, digital noise reduction and sharpening may not be possible in the time interval allocated for processing each image. It is therefore desirable to be able to predict when tone scale defects will be present, and to invoke tone scale remapping processes only when needed.

[0014] From a study to determine whether it is possible to predict from data collected at the time the original scene is photographed, the probability and severity of the tone scale defect that will be present in the final image, it was discovered that the extent of the tone scale defect depends primarily on the following factors: flash state (full,fill,off), primary subject light level, background light level, primary subject distance, background distance, and if available, state of the manual or automatic camera backlight exposure compensation control. In the present invention, these factors are used to predict, on an image by image basis, the severity of the tone scale defect, and that information is transferred from the camera to the photofinishing system where it commands the automatic printer control system, or in the case of human assisted printers, alerts the operator, to apply tone scale defect location and correction techniques only when warranted, thereby improving picture quality and enhancing photofinishing productivity.

[0015] If the ambient light level is not sufficient to provide adequate exposure, and the flash is deactivated or the primary subject is located beyond the maximum flash range, the image capture system will produce an underexposed image. In the case of film-based camera systems underexposure leads to latent image formation in primarily the most sensitive (fastest) layer, comprised of the largest silver halide grains. When processed and printed, images comprised of these fast, large grains permit a reproduction of the scene to be created, but the final viewed image typically contains noticeable grain structure, which masks fine detail and lowers the perceived image quality. The appearance of the grain, referred to more generally as image noise,

becomes more objectionable when the reproduction magnification is increased, for example, in enlargements, pseudo-panoramic or pseudo-telephoto print formats.

[0016] In the case of digital still cameras (DSCs) with, for example, CCD or CMOS image sensors, the photographic sensitivity (exposure index) of the sensor may be adjusted automatically or manually, by the photographer, in response to the scene light level, to attempt to maintain adequate tone reproduction. The photographic sensitivity is adjusted by changing the gain of the sensor signal amplifier, taking into account the color temperature (white balance) of the ambient illuminant. When the ambient light level is high (bright scene), the amplifier gain is low, thereby producing a high (favorable) signal-to-noise ratio (SNR). When the ambient light level is low (dim scene), the amplifier gain is increased, which produces a low (unfavorable) SNR. When the gain is increased in this fashion, the tone reproduction of the image is improved relative to the standard amplifier gain; however, due to the low SNR, the final viewed image will typically contain noticeable noise, analogous to the grain in under-exposed film images, which masks fine detail and lowers the perceived image quality. The appearance of noise defects becomes more objectionable when the reproduction magnification is increased, for example, in enlargements, pseudo-panoramic or pseudo-telephoto (electronic zoom) print formats.

[0017] Techniques such as those exemplified in The Sigma filter, described by Jong-Sen Lee in the journal article *Digital Image Smoothing and the Sigma Filter,* Computer Vision, Graphics, and Image Processing Vol 24, p. 255-269, 1983, are useful as noise reduction algorithms to enhance the visual appearance of the processed digital image. These digital area-specific noise reduction techniques, while effective, are computationally intensive, and therefore increase the time required to optimally render and reproduce copies of captured images. The time required to perform these operations may in some cases be the rate limiting step in automated high speed printing operations. If the digital noise reduction techniques are applied to every image in a customer order, even though only a portion of those images actually contain the defect, productivity and profit may be reduced. In addition, if computational time is spent searching for and correcting noise defects in every image, other beneficial image processing operations such as redeye location and correction, tone scale remapping and sharpening may not be possible in the time interval allocated for processing each image. It is therefore desirable to be able to predict when noise defects will be present, and to invoke digital noise reduction processes only when needed.

[0018] From an extensive study to determine whether it is possible to predict from data collected at the time the original scene is photographed, the probability and severity of the noise defect that will be present in the final image, it was discovered that the extent of the noise defect depends primarily on the following factors: Reproduction magnification; final image viewing distance; baseline exposure index film noise, or, in the case of DSCs, baseline exposure index sensor noise and the state of the manual or automatic DSC (R,G,B) exposure index control, which determines the sensor amplifier gain level; and the film or the sensor exposure level. In the present invention these factors are used to predict, on an image by image basis, the severity of the noise defect, and that information is transferred from the camera to the photofinishing system where it commands the automatic printer control system, or in the case of human assisted printers, alerts the operator, to apply noise defect location and correction techniques only when warranted, thereby improving picture quality and enhancing photofinishing productivity.

[0019] Even if the photographic environment provides ambient light that is uniform and of sufficient intensity to provide an exposure level that obviates the need for electronic flash or high-noise ambient captures, and the primary subject is within the focus range of the camera, the camera lens magnification provided by the normal lens (often defined as the diagonal dimension of the image capture frame) may be insufficient to capture an image of the primary subject that is the preferred size in the final viewed image. The size of the primary subject in the final viewed image is proportional to a quantity known as the angular magnification (AM) of the system, which can be characterized by the following equation:

$$AM=[(Fl)(Mr)]/Vd$$

[0020] Where:

[0021] Fl=camera lens focal length (specified in inches)

[0022] Mr=reproduction magnification (ratio of image to display size)

[0023] Vd=final image viewing distance (specified in inches)

[0024] The eye-to-display separation (viewing distance) has been found to vary with respect to final display size according to the following formula disclosed by the present inventors, in columns 43-44 of commonly-assigned U.S. Pat. No. 5,323,204:

$$Vd=3.64+11.34[\log_{10}(D)]$$

[0025] Where:

[0026] D=the diagonal dimension of the final display (specified in inches)

[0027] The most common method for increasing the AM involves the inclusion of telephoto or variable (zoom) focal length image capture optics on the camera. This approach produces larger subjects in the final viewed image by increasing the image capture magnification and maintaining a standard (full frame) printing magnification. Other methods involving pseudo-telephoto optical printing or electronic zoom digital printing are well known in the art. These techniques produce larger subjects in the final viewed image by increasing the printing magnification and cropping out a portion of the image frame, while retaining the standard print size (e.g. 4×6 inch) and the standard image capture lens focal length. Finally, by simply producing a larger (e.g. 8×10 inch) final image size, the reproduction magnification is increased, and therefore the AM and perceived subject size, even after including the longer final viewing distance, are also larger. The increase in AM provided by the aforementioned techniques may lead to a more pleasing composition, however, it also magnifies image blur resulting from inadequate lens depth-of-field, subject motion, and photographer hand tremor. The magnified image blur causes sharpness defects to be visible in the final viewed image.

[0028] Recent advances in digital image sharpness enhancement, as exemplified in U.S. Pat. No. 5,398,077,

teach methods for digitally segmenting the image field, analyzing the content to separate signal and noise components, and boosting the sharpness on an image area specific basis. These digital area-specific sharpening techniques, while effective, are computationally intensive, and therefore increase the time required to optimally render and reproduce copies of captured images. The time required to perform these operations may in some cases be the rate limiting step in automated high speed printing operations. If the digital sharpening techniques are applied to every image in a customer order, even though only a portion of those images actually contain the defect, productivity and profit may be reduced. In addition, if computational time is spent searching for and correcting sharpness defects in every image, other beneficial image processing operations such as redeye location and correction, tone scale remapping and noise reduction may not be possible in the time interval allocated for processing each image. It is therefore desirable to be able to predict when sharpness defects will be present, and to invoke digital sharpening processes only when needed.

[0029] From an extensive study to determine whether it is possible to predict from data collected at the time the original scene is photographed, the probability and severity of the sharpness defect that will be present in the final image, it was discovered that the extent of the sharpness defect depends primarily on the following factors: reproduction magnification, final image viewing distance, camera lens focal length, DSC resolution or camera film speed, shutter time, subject motion, photographer hand tremor, and subject distance if outside of focus range. In the present invention, these factors are used to predict, on an image by image basis, the severity of the sharpness defect, and that information is transferred from the camera to the photofinishing system where it commands the automatic printer control system, or in the case of human assisted printers, alerts the operator, to apply sharpness defect location and correction techniques only when warranted, thereby improving picture quality and enhancing photofinishing productivity.

[0030] One proposal for optimizing multiple image processing operations is described in U.S. Pat. No. 5,694,484, issued Dec. 2, 1997, to Cottrell et al. Cottrell et al. disclose an image processing system that proposes to optimize the perceptual quality of images undergoing a series of image-processing operations selected by an operator. The system consists of a set of selected image-processing operations, an architecture, and a control system. These elements take into consideration profiles of source characteristics from which the images are generated, profiles of output device characteristics, and the impact that image processing operations (individually or in concert) will have on perceived image quality. Control parameters for the individual image processing operations are modified by optimizing an image quality metric (a single numerical quality) based on mathematical formulas relating objective metrics (such as sharpness, grain, tone, and color) with perceived image quality. In the method described by Cottrell et al., the values for the individual control parameters are varied over useful ranges until the image quality metric achieves an optimal value. Besides involving significant computation resources to evaluate the multitude of parameter permutations, this method requires operator intervention to select the set of image processing operations that will be applied in each case.

[0031] In U.S. Pat. No. 5,835,627, issued Nov. 10, 1998 to Higgins, Hultgren and Cottrell, the process described above in the '484 patent is refined with the addition of an algorithm selector that tries each possible sequence of image processing operations and a customer satisfaction index (CSI), which proposes to balance the perceived image quality and the image processing time, as exhibited by the different image processing sequences. As was the case in U.S. Pat. No. 5,694,484, the image quality estimate is based on device profiles that are constant value inputs for each image source and downstream device, and that are typically generated during calibration of the individual devices in a factory or laboratory setting (see U.S. Pat. No. 5,835,627, col. 3, line 60-5). Besides involving significant computation resources to evaluate the multitude of parameter permutations as in the '484 patent, this refinement increases the amount of computation by causing the process to iterate through each new sequence until an optimal CSI is obtained.

[0032] Despite the elaborate methodology disclosed in U.S. Pat. Nos. 5,694,484 and 5,835,627, such systems fail to recognize the importance and use of capture-specific data, that is, variable data collected at the time of image capture, to predict on an image by image basis the best selection of image defect correction algorithms to apply. In particular, it would be desirable to make advantageous use of scene- and exposure-specific data to predict the best selection of image defect correction algorithms to apply.

SUMMARY OF THE INVENTION

[0033] It is an object of the present invention to improve the quality and efficiency of digital printing by applying image defect location and correction processes only when the current image is predicted to have a level of image defect that if left untreated would reduce the perceived quality of the final viewed image.

[0034] It is a further object to make use of camera, scene, and demographic data collected at the time of image capture to predict on an image by image basis the best selection of image defect correction algorithms to apply.

[0035] The present invention is directed to overcoming one or more of the problems set forth above. Briefly summarized, according to one aspect of the present invention, the invention resides in a system and method for processing a captured image with one or more correction processes selected from a plurality of such processes, each associated with correction of a specific type of image defect, in order to improve the appearance of a viewed image generated from the captured image. The inventive method includes the steps of (a) collecting meta data related to image capture that is unique to each image that is captured, wherein the meta data is capable of indicating whether the specific types of image defects are likely to be present in the viewed image generated from the captured image; (b) predicting the presence of the image defects based at least in part on the meta data, thereby generating process application criteria which indicate a level of image defect that if left untreated would reduce the perceived quality of the viewed image; (c) selecting one or more correction processes to employ on the image based on the process application criteria; and (d) applying the one or more selected correction processes to the image to generate the viewed image.

[0036] The meta data, which may be collected at the time of image capture or at some other time to the extent possible,

such as at a photofinishing kiosk, includes scene, camera or demographic data specifically related on an image-by-image basis to the image capture. Moreover, the step of predicting the presence of the image defects may also predict the severity of the defects and the strength of the corresponding correction process can be altered in response to the degree of severity. In addition, the collection of meta data may further include the collection of display parameters of the viewed image generated from each image that is captured, wherein such display parameter meta data is also capable of indicating whether the different types of image defects are likely to be present in the viewed image.

[0037] Advantageous Effect of the Invention

[0038] The present invention is advantageous in that it improves the quality and efficiency of digital photofinishing processes, whether fully automated or operator assisted. Specifically, the advantage is realized by applying image defect location and correction processes only when needed for the current scene, thereby eliminating time consuming operations that would fail to substantially improve the quality of the current image.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] **FIG. 1** is a block diagram of a digital image reproduction system according to the invention;

[0040] **FIG. 2** is a functional block diagram of an image processing system illustrating the image analysis, image defect prediction, image processing (defect correction), and image output steps of the present invention;

[0041] **FIG. 3** is a logic diagram illustrating one technique of using data captured at the time of image capture to decide when to apply noise defect location and correction processes in digital image reproduction apparatus;

[0042] **FIG. 4** is a logic diagram illustrating one technique of using data captured at the time of image capture to decide when to apply redeye defect location and correction processes in digital image reproduction apparatus;

[0043] **FIG. 5** is a logic diagram illustrating one technique of using data captured at the time of image capture to decide when to apply tonescale defect location and correction processes in digital image reproduction apparatus;

[0044] **FIG. 6** is a logic diagram illustrating one technique of using data captured at the time of image capture to decide when to apply sharpness defect location and correction processes in digital image reproduction apparatus.

[0045] **FIG. 7** is a diagram illustrating a film camera adapted to write meta data on a photographic film.

[0046] **FIG. 8** is a diagram illustrating a digital camera adapted to write meta data on a digital record.

DETAILED DESCRIPTION OF THE INVENTION

[0047] Because image processing systems employing defect recognition and correction are well known, the present description will be directed in particular to attributes forming part of, or cooperating more directly with, system and method in accordance with the present invention. System and method attributes not specifically shown or described herein may be selected from those known in the art. In the following description, a preferred embodiment of the present invention would ordinarily be implemented as a software program, although those skilled in the art will readily recognize that the equivalent of such software may also be constructed in hardware. Given the system as described according to the invention in the following materials, software not specifically shown, suggested or described herein that is useful for implementation of the invention is conventional and within the ordinary skill in such arts. If the invention is implemented as a computer program, the program may be stored in conventional computer readable storage medium, which may comprise, for example; magnetic storage media such as a magnetic disk (such as a floppy disk or a hard drive) or magnetic tape; optical storage media such as an optical disc, optical tape, or machine readable bar code; solid state electronic storage devices such as random access memory (RAM), or read only memory (ROM); or any other physical device or medium employed to store a computer program.

[0048] Prior to providing a detailed description of each embodiment of the present invention, the methods used to set the image quality switch-points for activating the image defect location and correction processes will be discussed. Because it is the purpose of this invention to predict from data collected at the time of image capture the presence and severity of image defects, to determine which correction processes to employ, each of the defects must be assessed with respect to the same image quality standard. To accomplish this goal, perceptually relevant image quality assessment and modeling techniques disclosed by the present inventors in the proceedings of The Society for Imaging Science and Technology (IS&T), Image Processing Image Quality Image Capture Systems (PICS 2000) Conference, ISBN: 0-89298-227-5, are employed. Specifically, the papers entitled "*Characterization and Prediction of Image Quality*" by B. W. Keelan, and "*Use of System Image Quality Models to Improve Product Design*" by R. B. Wheeler, which are incorporated herein by reference, should be consulted for additional background information. The image quality scale is based on just-noticeable-difference (JND) units of quality. In experiments, a JND is defined as the smallest image quality difference that can be detected by 50% of observers in forced-choice (no ties allowed) paired image comparisons. Stated another way, when two images are separated by exactly one JND, 50% of human observers will perceive the quality advantage of the better image and rate it best. The other 50% of the human observers will not perceive the difference, but will guess correctly half the time. Consequently, in a forced-choice comparison between two images that differ by exactly one JND, the higher quality image will be rated better 75% of the time. As the quality difference between image pairs becomes larger there will be nearly universal agreement as to which one is better; as a result, a scale covering a wide range of quality is composed of many JNDs. For example, when cast in subjective quality terms such as excellent, very good, good, fair, poor, etc., we have found that a difference of about 6 JNDs constitutes a full quality category.

[0049] While it is possible to set image quality switch-points for activating image defect location and correction processes at different absolute quality levels without departing from the spirit of the invention, the preferred embodiment employs a three JND (one-half quality category) criteria. This provides a reasonable balance between image

quality enhancement and photofinishing throughput (images processed per unit of time). If the image quality switch-point is set at a lower JND value (e.g. one JND of degradation), the image defect location and correction processes will be invoked more frequently, which may lead to higher average image quality, but lower throughput due to extended image processing time. If the quality switch-point is set at a higher JND value (e.g. 6 JNDs of degradation), the image defect location and correction processes will be invoked less frequently, which may lead to lower average image quality, but higher throughput due to shortened image processing time.

[0050] In the detailed description of our preferred embodiments, image defect correction switch-points are defined that either activate or deactivate the image defect location and correction processes. It is to be understood that while this description pertains to correction processes that are applied in the same manner every time the quality loss due to an image defect is equal to or greater than the switch-point (e.g. 3 JNDs), the strength of the image defect correction processes can be altered in response to the degree of image quality loss predicted for the current scene.

[0051] For example, in the case of sharpness correction, as the predicted level of the image defect becomes worse the gain of the spatial filter applied in the sharpening operation can be increased. Similarly, in the case of noise defect correction, customized noise correction tables can be applied in response to the predicted magnitude of the image defect. In addition, the preferred embodiment of the present invention can be used to determine which image defect correction processes should be activated, and the strength of the corrections employed in those activated processes can be determined by analyzing the image pixel data using a series of pixel data predictors that correlate with the degree of the degradation caused by the defect. For example, the gradient of edges can be used to estimate the strength of the spatial filtering needed to correct sharpness defects.

[0052] As noted previously, the inventive process uses information collected at the time of image capture, which is referred to as meta data, to predict the presence of image defects in a photograph, and to subsequently decide when to apply image defect correction processes in digital photofinishing. A variety of meta data describing the scene and camera conditions used to capture the current image, can be recorded by the camera and transferred to photofinishing equipment, as is described in commonly assigned U.S. Pat. No. 5,229,810, which is incorporated herein by reference. In the case of cameras employing silver halide based films containing an integral magnetic layer, commonly referred to as Advanced Photo System (APS) films, the information recording device preferably comprises a magnetic recording head for magnetically encoding data on the surface of the film. Alternatively, in the case of film cameras without magnetic writing capability, latent image bar code data may be exposed outside the area of the primary image frame, and later decoded in the photofinishing equipment. In the case of DSCs, other known data recording techniques may also be utilized such as optical or magnetic recording on separable media such as disks or integrated circuit cards. In the detailed description of the embodiments that follows, it is understood that the method by which information is exchanged between the image capture device and the photofinishing equipment, while not specifically identified in each case, can be accomplished with any of the aforementioned well-known methods.

[0053] In **FIG. 1**, a general digital image processing system **10** useful in the practice of the invention is shown in which input pictorial image data and related image classification parameters are provided by means of one of a variety of indicated devices. The illustrated input devices include a photographic film scanner **12** which optically scans the image frames on a film strip and converts the scanned signals into digital image data. If the scanner is capable of reading APS film, then the scanner will typically read from the magnetic layer or optical bar code on the film, information encoded in the APS meta data information exchange (IX) and manufacturer data areas. Such meta data may include film type, camera settings, scene conditions, intended print format, and other data fields. Other possible image input devices include a digital file reader **14** which may contain data from a variety of sources, including digital cameras or a picture disk reader, a network input (e.g. modem) **16** which receives digital file data from a remote, central source, as in the case of Kodak Picture Network, or an order entry station input device **18** located at a retail store which scans a customers film, reads digital disks, and accepts order instructions, including print aspect ratio, size, zoom, crop and magnification instructions. This data is then input to an image processing computer **40** which may also include a display monitor **22** and a user data input device such as a keyboard **24**. In the case of a home-based personal computer, for example, the key board may be used to input some of the scene, camera, and output size related data mentioned above. Included in the image processing functions of the computer **40**, in accordance with the present invention is a process that makes use of camera, scene, and demographic factors to predict the presence of image defects in a photograph and subsequently to applies image defect correction means only when needed.

[0054] The output of the image processing computer **40** is applied to an appropriate output path for generation of hardcopy images. Representative output paths are illustrated and include a printer **26**, such as a thermal dye printer or inkjet printer which are exemplary of printers useful for home computer use. Alternatively, the output path may comprise retail photofinisher equipment **28**, such as a Noritsu 2711 Series Printer. Yet another exemplary output path comprises data communications device **30** which communicates with, for example, a remote commercial photofinishing laboratory **32** using a CRT or other photographic printer. Alternatively, the essential functions of image processing system **10**, such as film scanning and conversion of scan data to digital image files, reading of digital camera image files, reading of information pertaining to camera, scene, and output parameters, and making use of camera, scene, and demographic data to predict the presence of image defects in a photograph, and subsequently applying image defect correction means only when needed, can be incorporated in an integrated apparatus such as a retail photofinisher unit.

[0055] An important feature of the system shown in **FIG. 1** is the collection of meta data at the time of image capture indicating, or capable of indicating, whether a defect is likely to be present in the final viewed image. In the preferred embodiments, this is accomplished with data col-

lected by either a film camera or a digital camera, although some of the meta data (e.g., demographic data and display parameters) could be collected at the order entry station **18** or some other location subsequent (or prior) to the time of capture. In a typical film camera embodiment, as shown in **FIG. 7**, a film camera **200** transports a film strip **201** between the reels **205***a,b* of a film cartridge and a take-up sprocket respectively. The camera **200** includes a magnetic read/write head **210** facing a magnetic layer on the unsensitized side of the film strip **201**. A microprocessor **215** controls magnetic data recording or playback by the head **210** through head electronics **220**.

[0056] The microprocessor **215** may accept meta data to be magnetically recorded on the film strip **100** from the camera user or the camera mechanisms themselves through camera controls **225**, such information pertaining, for example, to the desired display parameters, lens parameters (e.g., focal length, F-number, camera lens focus range), shutter speed, autofocus distance measurements of subject and background, backlight and flash fire state indicators, and the like, for ultimate use by the photofinisher. If a suitable input device is provided, for example a keypad, demographic data could be generated at this time. The microprocessor **215** may also accept scene related information from scene sensors **230** to be magnetically recorded on the film strip **100** for ultimate use by the photofinisher. Such information may include the ambient light level of the primary subject and background, and the like.

[0057] The advantage of the longitudinal dedicated track format is that magnetic recording of data on the film strip **201** may be performed by the camera using a relatively stationary head (i.e. the head **210**) by buffering all of the data to be recorded in a particular frame in a particular camera track and then transmitting the data to the head just as the film is being wound to the next frame.

[0058] The microprocessor **215** includes a read only memory **240** containing instructions sufficient to ensure that each type of information received is recorded in the correct one of the dedicated camera tracks in accordance with a universal pre-arrangement common to both the camera and the photofinisher. (The aforementioned APS information exchange (IX) specifications illustrate dedicated camera tracks for meta data storage and information exchange. Section 10, "Writing and Reading Magnetic Information", and more specifically Section 10.4 "Data Dictionary", contain the relevant information.) For this purpose, the microprocessor sorts and buffers each piece of information in compliance with the instructions stored in the read only memory **240**. The microprocessor also includes a ROM **250** with other camera-specific data, such as main flash and preflash guide number and camera to flash separation (if the flash is integral with the camera), lens-specific data (e.g., focal length and focus range, if the lens is integral with the camera), and the like, as well as a RAM **260** for storing film-specific information read from the film cassette, such as film ISO speed read from the DX coding on the film cassette. The meta data in the ROM **250** and the RAM **260** is then magnetically recorded on the film strip **100** for ultimate use by the photofinisher.

[0059] In a typical digital camera embodiment, such as shown in **FIG. 8**, a digital camera **300** includes a lens **340** that directs image light from a subject (not shown) through an aperture/shutter controller **341** and an anti-aliasing filter **342** upon an image sensor, which is typically a CCD or CMOS sensor **344**. The sensor **344** generates an image signal that is processed by an analog video processor **346** before being converted into a digital image signal by an analog to digital (A/D) converter **348**. The digitized image signal is temporarily stored in a frame memory **350**, and then compressed by a digital signal processor **352**. The compressed image signal is then stored in a data memory **354** or, if a memory card **356** is present in a memory card slot of the camera, transferred through a memory card interface **358** to the memory card **356**. In this embodiment, the memory card is adapted to some appropriate interface standard, such as the PCMCIA card interface standard as described in the *PC Card Standard, Release* 2.0, published by the Personal Computer Memory Card International Association, Sunnyvale, Calif., September, 1991.

[0060] Electrical connection between the memory card **356** and the camera **300** is maintained through a card connector **359** positioned in the memory card slot. The card interface **358** and the card connector **359** provide, e.g., an interface according to the aforementioned PCMCIA card interface standard. The compressed image signal may also be sent to a host computer, which is connected to the camera **300** through a host computer interface **360**. A camera micro-processor **362** receives user inputs **364**, such as from a shutter release, and initiates a capture sequence by triggering a flash unit **366** (if needed) and signaling a timing generator **368**. The timing generator **368** is connected generally to the elements of the camera **300**, as shown in **FIG. 8**, for controlling the digital conversion, compression, and storage of the image signal. The microprocessor **362** also processes a signal from a scene sensor (photodiode) **370** for determining a proper exposure, and accordingly signals an exposure driver **372** for setting the aperture and shutter speed via the aperture/shutter controller **341**. The CCD sensor **344** is then driven from the timing generator **368** via a sensor driver **374** to produce the image signal.

[0061] The microprocessor **362** may accept meta data to be recorded on the digital record from the camera user inputs **364** or from camera mechanism inputs **380**, such information pertaining, for example, to the desired display parameters, lens parameters (e.g., focal length, F-number, camera lens focus range), shutter speed, autofocus distance measurements of subject and background, backlight and flash fire state indicators, and the like, for ultimate use by the photofinisher. The user inputs **364** can also include the resolution setting and gain factor of the camera (number of pixels in the captured image and the sensor-based ISO speed, if such is settable). If a suitable input device is provided, for example a keypad or a voice-actuated input, demographic data could be generated at this time by operator input of the information, although other techniques may be employed without limitation. The microprocessor **362** may also accept scene related information from the scene sensors **370** to be recorded on the digital record for ultimate use by the photofinisher. Such information may include the ambient light level of the primary subject and background, and the like. The microprocessor **362** may also accept camera shake data (measure of handheld stability of the camera) from a shake sensor **382**.

[0062] Certain camera meta data may be contained in the camera PROM **328**, which is connected to the digital signal

processor **352**. The camera PROM **328** includes camera-specific data, such as main flash and preflash guide number, camera to flash separation, sensor ISO speed, resolution setting, camera shake factor, and the like. Such camera-specific data may be variable (for example, if the flash unit is separable, movable, or otherwise adjustable) or invariant (for example, if the flash is non-movable and integral with the camera). Likewise, the sensor ISO speed may be the base ISO speed and the resolution setting may be the native setting, if this data is invariant. Different data structures may be used to transfer the meta data and the image data from the camera. For example, the digital signal processor **352** may write the meta data into a camera header, followed by individual image trailer records. In another data structure, the meta data is written into individual camera headers together with individual image trailer records. Alternatively, certain of the meta data, such as the camera-specific data stored in the PROM **328** may be contained in a computer file **330** (instead of, or in addition to being, in the PROM **328**), which is provided as a floppy disk or the like in combination with the camera **300**. This meta data is then accessed by the host computer through a conventional disk drive interface (not shown) when the user loads the disk into the interface. The meta data may also be embedded with the image data in a form of digital watermarking, e.g., as taught in U.S. Pat. No. 6,044,156, entitled "Method for Generating an Improved Carrier for Use in an Image Data Embedding Application", which is incorporated herein by reference.

[**0063**] It should be understood from the foregoing description of meta data creation in connection with film and digital cameras that other forms of meta data pertaining to camera, scene, demographic and display factors would be known to those of skill in this art, and are intended to be within the ambit of this invention. Likewise, other structures and mechanisms for the transfer of such meta data to subsequent utilization devices, such as digital photofinishers, would be clear to the skilled person and are intended to be within the scope of this invention. In addition, while the capture devices are described as film and digital cameras, it is possible that other capture devices such as a linear or area scanner could benefit from the invention, and to that extent are also included within the inventive concept.

[**0064**] In the case of the film or digital camera, the camera, scene or demographic factors can be directly recorded on the output medium, or the microprocessor **215** (film) or **362** (digital) may be employed to perform image processing upon the factors, for instance to determine if the current image will have a level of defect that if left untreated would reduce the perceived quality of the final viewed image. Consequently, in the latter case, the microprocessors **215** and **362** may perform some, or all, of the image processing performed by the digital image processor **40** shown in **FIG. 1**, that is, to predict the presence of image defects in a photograph and subsequently to enable image defect correction means only when needed.

[**0065**] The present invention can be implemented in computer hardware. For example, **FIG. 2** represents a functional block diagram of a digital photofinishing system where the image acquisition block **50** includes image data and meta (e.g. APS IX) data from a capture device **52** such as the conventional photographic film camera **200** shown in **FIG. 7** for recording a scene on color negative or reversal film, and a film scanner device for scanning the developed image on the film and producing a source digital image **56** and extracting the image meta data. Another example of an image capture device **52** is the digital camera **300** shown in **FIG. 8** that has the ability to produce a source digital image **56** directly. The formed digital image file and associated meta data is transferred to the image analysis block **60**, where the meta data decoder **66** extracts the information to be used in the image defect prediction process block **68**. The primary purpose of the image defection correction process block **68** is to analyze available meta data pertaining to camera, scene, demographic, and image display factors, predict the presence of image defects in the final image display, and subsequently to activate only those correction processes in image processing block **70** that will improve the quality of the current image.

[**0066**] Prior to providing a detailed description of image defect prediction process block **68**, the other functions of the image analysis **60**, image processing **70**, and image output **90** blocks will be described.

[**0067**] In the image analysis block, the full resolution digital image containing the red, green, and blue pixel data is subsampled in block **62** to create a smaller, for example 24×36 pixel, image that is analyzed by the scene balance algorithm **64**. Scene balance algorithms use analog or digital processing to obtain the correct color balance and overall lightness for each image. The algorithms are commonly known as "white-balance,""color-constancy" or "scene-balance" algorithms. These algorithms can work on a single image, several images, or an entire set of images. An example of a suitable scene balance algorithms is described by E. Goll et al., "*Modern Exposure Determination for Customizing Photofinishing Printer Response*", Journal of Applied Photographic Engineering, 2, 93 (1979), which is incorporated herein by reference. Further improvements in scene-balance algorithms include setting a degree of illuminant chromatic correction using inferential illuminant detection, as disclosed in U.S. Pat. No. 6,133,983, which is incorporated herein by reference. Additional information on the film can help to characterize the variability of the chemical process that was used to develop the film. For example, as taught in U.S. Pat. No. 5,649,260, which is incorporated herein by reference, at least one or more gray reference patches with known exposure could have been exposed on the film during manufacturing, and then used to provide full-order film color balance calibration information to the scene balance algorithm.

[**0068**] The present invention may be practiced with any scene balance module such as the one described by Cok et al. in U.S. Pat. No. 4,945,406, which is incorporated herein by reference. The scene balance module calculates the pixel values of a theoretical 20% gray card corresponding to the exposure of the scene digital image. A look-up-table is calculated and applied to the scene state digital image, which results in a balanced digital image. Although no scene balance module performs perfectly at the task of compensating the digital image for variations in exposure and illumination color effects, the scene balance module does improve the accuracy of the color representation of the digital image. Because the scene balance algorithm is needed for nearly all images, due to imperfections in image capture exposure and/or illuminant color balance, and the scene balance algorithm is computationally efficient, due to

the use of a smaller subsampled image, it is applied to every image in the preferred embodiment of the present invention.

[0069] However, in accordance with the invention, and as noted earlier, the remaining image processing steps, which are located in the image processing block **70**, are selectively applied based on the output of the image defect prediction process **68**. For this purpose, the digital image produced in block **56** is provided in separate chrominance and luminance channels, as needed, for the subsequent image processing steps.

[0070] If activated by the image defect prediction process **68**, the noise correction process **72** is applied prior to the scene balance shift **76** to make use of the unbalanced color channel specific exposure information of the capture. The Sigma filter, described by Jong-Sen Lee in the aforementioned journal article *Digital Image Smoothing and the Sigma Filter*, which is incorporated herein by reference, is a noise reduction algorithm to enhance the visual appearance of the processed digital image. The values of the pixels contained in a sampled local region, n by n pixels where n denotes the length of pixels in either the row or column direction, are compared with the value of the center pixel, or pixel of interest. Each pixel in the sampled local region is given a weighting factor of one or zero based on the absolute difference between the value of the pixel of interest and the local region pixel value. If the absolute value of the pixel value difference is less or equal to a threshold, the weighting factor is set to one. Otherwise, the weighting factor is set to zero. The numerical constant ϵ is set to two times the expected noise standard deviation. Mathematically the expression for the calculation of the noise reduced pixel value is given as:

$$q_{mn}=\Sigma_{ij}a_{ij}p_{ij}/\Sigma_{ij}a_{ij} \quad \text{EQ. 1}$$

[0071] and

[0072] $a_{ij}=1$ if $|p_{ij}-p_{mn}|<=\epsilon$

[0073] $a_{ij}=0$ if $|p_{ij}-p_{mn}|>\epsilon$

[0074] where p_{ij} represents the ij^{th} pixel contained in the sampled local region, p_{mn} represents the value of the pixel of interest located at row m and column n, a_{ij} represents a weighting factor, and q_{mn} represents the noise reduced pixel value. Typically, a rectangular sampling region centered about the center pixel is used with the indices i and j varied to sample the local pixel values.

[0075] The signal dependent noise feature is incorporated into the expression for ϵ given by:

$$\epsilon=Sfac\ \sigma_n(p_{mn}) \quad \text{EQ. 2}$$

[0076] where σ_n represents the noise standard deviation of the source image evaluated at the center pixel value p_{mn}. The parameter Sfac is termed a scale factor can be used to vary the degree of noise reduction. The calculation of the noise reduced pixel value q_{mn} as the division of the two sums is then calculated. The process is completed for some or all of the pixels contained in the digital image channel and for some or all the digital image channels contained in the digital image. The noise reduced pixel values constitute the noise reduced digital image.

[0077] A median filter may also be used as a noise reduction algorithm to reduce the noise present in a digital image. The noise reduced pixel value produced with a median filter is typically derived by calculating the statistical mean of values taken from a sampling region centered about the pixel of interest. Typically an n by n square window size is chosen where n denotes the length of pixels in either the row or column direction. The degree of noise reduction is controlled by the size of the window. Larger window sizes result in more noise removed from the digital image.

[0078] If activated by the image defect prediction process **68**, the redeye correction process **80** locates and removes eye color defects. The present invention may be practiced with a variety of methods which locate and correct redeye defects. One suitable method is disclosed by Benati et al. in U.S. Pat. No. 5,748,764, which issued May 5, 1998 and which is incorporated herein by reference. This method locates redeye defects in an image and provides separate corrections for body, border, and glint pixels in the pupil of the affected eye. The redeye defect detection process involves defining a spatial region within the digital image in which one or more eye color defects may exist, which includes at least a portion of the subject's head; sampling the color content of the pixels within the spatial region and comparing the sampled pixels with threshold values indicative of redeye defect pixels; segmenting the potentially defective pixels into contiguous groups; calculating a first score for each pixel of each group based on a plurality of features including group size, group shape, coloration, and brightness to identify redeye defect candidates; selecting a seed pixel based on its score from each identified eye color defect group candidate and determining all of the neighboring pixels which are within a predetermined score range of their neighboring pixels and those pixels which represent a significant pixel score transition indicative of the outer boundary of the redeye defect. Each of the three redeye defect pixel types (body, border, glint) is rendered differently to remove the defect and create a natural appearing correction.

[0079] An alternative embodiment of the present invention employs a method of applying a redeye defect location and correction process disclosed by Schildkraut et al. in commonly-assigned U.S. Pat. No. 6,292,574 issued Sep. **18, 2001**, entitled *A Computer Program Product for Redeye Detection*. This process is advantageously used in conjunction with the method disclosed in commonly-assigned U.S. Pat. No. 6,151,403 issued Nov. 21, 2000 entitled *Method for Automatic Detection of Human Eyes in Digital Images* by Jiebo Luo. Both patents are incorporated herein by reference.

[0080] Many natural scenes photographed under ambient lighting conditions result in photographic images which have a luminance dynamic range that far exceeds the dynamic range of conventional display systems. For example, photographic images taken in sunny outdoor conditions can have 10 or more photographic stops of recorded information while photographic paper can reproduce approximately seven photographic stops of information. In addition, as noted above, electronic flash illumination, by virtue of the distance-induced exposure difference between the main subject and background, can also produce dynamic range that exceeds the capacity of the chosen display. In digital imaging systems scene dependent tone scale function algorithms may be employed to reduce the dynamic range of

the source digital image thus providing a better match of the processed digital image to the dynamic range capabilities of the output medium.

[0081] If a high dynamic range scene is anticipated by the image defect prediction process **68**, the scene dependent tonescale correction process **84** is employed. The tone scale correction process **84** uses the pixels in the balanced digital image to calculate a tone scale function, i.e., a single valued mathematical equation or transformation that has a single output value corresponding to each input value. The present invention implements the tone scale function as a look-up-table for computation efficiency. The result of the application of the tone scale processing produces a tone scale adjusted digital image such that the tone scale, or brightness and contrast, of the digital image is enhanced without modification of the color content.

[0082] The present invention may be practiced with a variety of methods that generate tone scale functions. The preferred embodiment of the present invention uses the methods disclosed in U.S. Pat. Nos. 4,731,671 and 5,822,453, which are both incorporated herein by reference. These methods are employed by the present invention to produce two individual tone scale functions. These two tone scale functions are then cascaded into single tone scale function which is used to adjust the brightness and contrast of the balanced digital image.

[0083] In U.S. Pat. No. 5,822,453, Lee and Kwon disclose a method of calculating a tone scale function using the pixel values of a digital image, and involving the estimation of the scene contrast from the digital image. The method taught by Lee and Kwon involves calculating a Laplacian filtered version of the digital image, forming a histogram of the Laplacian signal; determining from the Laplacian histogram two threshold values which when applied to the Laplacian signal substantially eliminate uniform areas; sampling pixels from the digital image which are based on the thresholds; forming a histogram from the sampled pixels; computing a standard deviation of the sampled histogram; and estimating contrast of the digital image by comparing the computed standard deviation with a predetermined contrast for determining contrast of the input image in relationship with the predetermined contrast. The method described by Lee and Kwon is used to calculate a first tone scale function.

[0084] In U.S. Pat. No. 4,731,671, Alkofer discloses a method of calculating a tone scale function using the pixel values of a digital image based on normalizing the histogram of a digital image. This method involves determining the contrast of the digital image by calculating the standard deviation of a sample of pixel values. The second tone scale function is calculated by normalizing a histogram of the sample of pixel values. The sample of pixel values is selected from one of a plurality of samples of pixel values corresponding to a plurality of contrast intervals based upon the shape of the histogram of the selected sample of pixel values. To facilitate the adjustment of contrast, the tone scale function is constructed to produce values in units of a standard normal variate Z. These Z values are then multiplied by a constant, which is a function of the standard deviation of the sample of pixel values to determine the contrast of the processed digital image.

[0085] The first and second tone scale functions are combined into a final tone scale function using the mathematical formula:

$$LUT_F = LUT_1[LUT_2[j]] \quad \text{EQ.3}$$

[0086] where LUT_2 represents the second tone scale function, LUT_1 represents the first tone scale function, and LUT_F represents the final tone scale function. The j variable represent the index of pixel values of the digital image to be processed. The final tone scale function LUT_F is calculated by evaluating the expression of equation 3 for the range of possible pixel values.

[0087] The final tone scale function LUT_F and the balanced digital image is received by the tone scale correction block **84**. The present invention applies the final tone scale function to the luminance digital image channel of the balanced digital image to adjust the brightness and contrast attributes of the digital image. The preferred embodiment of the present invention applies the final tone scale function, in the form of a look-up-table, directly to the pixels of the luminance digital image channel of the balanced digital image. This method is preferred primarily for its computational efficiency properties.

[0088] An alternative embodiment of the present invention employs a method of applying a tone scale function disclosed by Lee et al. in U.S. Pat. No. 5,012,333, which is incorporated herein by reference, for improved image quality results. Although Lee et al. describe a method for interactively modifying image attributes, the present invention employs the method of applying tone scale functions to digital images based on spatial filtering techniques. This method involves spatially filtering the luminance digital image channel resulting in two spatial frequency components (high and low frequency components), applying the tone scale function to the low spatial frequency component, and combining the tone scale modified low spatial frequency component with the high spatial frequency component. This approach, employing frequency separable tone scale manipulation and sharpening, is superior to methods such as those disclosed in U.S. Pat. No. 5,739,924, which involve emphasizing the outline and the contrast of the subject based on subject brightness, and subject distance.

[0089] In the preferred embodiment of the present invention, if a scene with sharpness problems is anticipated by the image defect prediction process **68**, the sharpness correction process **88** is employed. The sharpness correction block **88** receives the tone scale adjusted digital image from the tone scale module **84** and applies a spatial filter to the tone scale adjusted digital image to adjust spatial modulation content. The present invention may be practiced with a variety of different spatial filters; however, a key aspect of the present invention relies on the combination of the method of manipulation of the color, tone and spatial detail attributes of a digital image. An example of a spatial filter that may be used is described by Kwon et al. in U.S. Pat. No. 5,398,077, which is incorporated herein by reference. Kwon et al teach a method of spatially processing a digital image involving transforming a red-green-blue image into a luminance chrominance domain and applying an adaptive filter to the luminance channel. The adaptive filter employs a method of calculating a statistical measure of local spatial activity and varying the sharpness of the image detail structure based on the statistical measure. The result of the application of the

spatial filter produces a tone scale adjusted digital image with modified values such that the spatial detail of the digital image is enhanced without modification of the color content.

[0090] The image output block **90** receives the modified digital image from the sharpness correction block **88**. The digital image processing steps conducted within the output device rendering block **92** involve transforming the pixel values of the modified digital image into a corresponding set of device code values to account for the color manipulation characteristics of the output device and media. The transformation between device code values and the colorimetry of the colors reproduced by a particular device/media combination can be obtained by a device characterization. An example of a device characterization is a procedure that involves generating and printing or displaying a suitable array of device code values in the form of color patches of a size large enough for subsequent measurement. These patches can be measured using a calorimeter, a spectrophotometer or a telespectroradiometer, depending on the nature of the display. If spectra are measured, CIE XYZ values and other related quantities such as CIELAB or CIELUV values can be calculated for the display illuminant using standard calorimetric procedures. This data set can be used to construct the appropriate sequence of one-dimensional look-up tables, multidimensional look-up tables, matrices, polynomials and scalars that accomplishes that transformation of the digital representation of the scene resulting from the combined processing operations performed in the output device rendering block **92** into a set of device code values that produces this desired visual representation of the scene. Another example of the implementation of this transformation is an ICC profile that maps the specifications of the desired visual reproduction, encoded in profile connection space (PCS), to device code values.

[0091] This operation may also include gamut mapping. The color gamut characteristics of the modified digital image are determined by the set of primaries that was used for encoding the data. Examples include the primaries corresponding to the color-matching functions of the CIE 1931 Standard Colorimetric Observer or any linear combinations thereof. Gamut mapping is performed between the gamut defined by this encoding and the gamut of the output device/media combination. The preferred gamut mapping algorithms used in combination with this invention are those that maintain hue.

[0092] From an imaging processing point of view, the data transformation performed by the output device rendering block **92**, whether dedicated to neutral balance or color gamut functions can be combined to form a single set of one-dimensional look-up tables, multidimensional look-up tables, matrices, polynomials and scalars in any sequence. Reproductions according to the specifications of this invention can be produced by a variety of technologies. Reproductions can be obtained on silver halide or other light-sensitive materials.

[0093] The light-sensitive material, as used by an image output device **96**, may be transparent film, reflective paper, or semi-transparent film. These materials are exposed by visible or infrared light derived from many different sources. The materials may be designed for typical photofinishing applications or they may be specially designed for digital printing applications. The photo-sensitive materials respond primarily to three different spectral regions of incident light. Typically, these are red (600-720 nm), green (500-600 nm), and blue (400-500 nm) light. However, any combination of three different spectral sensitivities can be used. These could include green, red, and infrared light or red, infrared 1, and infrared 2 light, or 3 infrared lights of different wavelengths. Or a material sensitive to the three primary wavelengths of visible light may be false sensitized so that the color of the exposing light does not produce image dye of the complementary hue, such as red, green, and blue sensitivity producing magenta, yellow, and cyan dye, respectively. Printing can be effected by exposing all pixels sequentially, by exposing a small array of pixels at the same time, or by exposing all the pixels in the image at the same time.

[0094] Devices which can be used to print on light-sensitive materials include CRT, LED (Light Emitting Diode), LVT (Light Valve Technology), LCD, Laser, as well as any other controlled optical light generating device. All these devices have the ability to expose 3 or more light-sensitive layers in a light-sensitive material to produce a colored image. They differ mainly in the technology on which the devices are based. A suitable embodiment of a CRT printer is the Kodak Digital Science LF CRT Color Printer which can be used in combination with Kodak Professional Digital III Color Paper.

[0095] Non-light-sensitive imaging materials are conveniently used by electronic printing processes to produce high-quality reproductions. The printing process can be based on many technologies. The method of image formation can be half-tone, continuous tone, or complete material transfer. The imaging material can be transparent film, reflective paper, or semi-transparent film. The materials can be written on to produce pictorial images by thermal dye transfer, ink jet, wax, electrophotographic, or other pixel-wise writing techniques. These processes use three or more colorants to create colored pictorial representations of pictorial scenes. The colorants may be dyes, toner, inks, or any other permanent or semi-permanent colored material. A suitable embodiment of a thermal printer is the Kodak XLS 8650 thermal dye transfer printer.

[0096] In addition to hardcopy viewed images, it is also possible with the current invention to efficiently create projected images. Many technologies are appropriate for this kind of image generation. All these techniques rely on producing color images with two or more colored lights. These are typically red, green, and blue in nature although they can be any set of primaries. Devices which can be used to create the preferred viewed reproduction include CRT, LCD, EL (Electro-Luminescence), LED, OLED (organic LEDs), light bulbs, lasers, plasma display panels, or any other three or more colored lighting apparatus capable of pixelwise illumination. The images can be created by display within the device, projection, or backlighting. Many devices create an image on a screen or display area which is physically a part of the mechanical unit. However, images can also be created by optically projecting the image in the form of light rays from behind or in front of the viewer toward a screen which is in front of a viewer or by projecting a reversed image toward the viewer onto a screen between the viewer and the projecting device. A suitable embodiment of a CRT display is a Sony Trinitron CRT.

[0097] This concludes the detailed description of the functions of the image analysis **60**, image processing **70**, and

image output **90** blocks. A detailed description of the image defect prediction process block **68**, that controls the state (active or inactive) of each of the previously detailed image defect correction processes in the image processing block **70**, will now be provided.

[**0098**] After the meta data associated with the current image is decoded in block **66**, a number of intermediate parameters are calculated in the image defect prediction block **68** from the decoded data and subsequently used in the Noise Defect Prediction Block **100** shown in **FIG. 3**, the Redeye Defect Prediction Block **120** shown in **FIG. 4**, the Tonescale Defect Prediction Block **140** shown in **FIG. 5**, and the Sharpness Defect Prediction Block **160** shown in **FIG. 6**. Other parameters such as Flash Fire State (on/off) can be used directly, and still other parameters may require units conversion; for example, ambient light level, which is converted from camera BV (brightness value) to luminance units in foot lamberts. The intermediate parameter values, calculated from decoded meta data, and used in multiple defect prediction blocks, are calculated once and shared among the defect prediction blocks **100**,**120**,**140**,**160**. However, for purposes of illustrating the functionality of each of the defect prediction blocks, the processing steps (**104**,**124**, **144**,**164**) that follow the meta data input block show the creation of each of the intermediate parameters.

[**0099**] This section defines the meta data items and shows the manner in which the intermediate parameters are calculated from the meta data items in the preferred embodiment. Those skilled in the art will understand that the units of distance, exposure, flash output, system magnification, and image defect level can be recast without departing from the intent of the teachings of the present invention. In the preferred embodiment the following meta data items, or a subset thereof, collected by camera sensors and/or manual photographer input are employed in the image defect prediction blocks (**100**,**120**,**140**,**160**):

[**0100**] General Parameters:

[**0101**] Subject Demographic Data includes: subject race and age

[**0102**] User-Specified or Camera-Measured Parameters:

[**0103**] BL: Camera Backlight Indicator State (on/off; on=high contrast scene)

[**0104**] CSF: Camera Shake Factor (measure of hand-held stability of camera)

[**0105**] D: Diagonal Dimension of the Final Display (inches)

[**0106**] DG: DSC Gain Factor (multiple of sensor base ISO speed)

[**0107**] DR: DSC Resolution Setting (number of pixels in captured image)

[**0108**] Ds: Camera-to-Subject Distance (feet)

[**0109**] Db: Camera-to-Background Distance (feet)

[**0110**] f: Camera Lens F-number

[**0111**] FL: Camera Lens Focal Length (inches)

[**0112**] FF: Flash Fire State (on/off)

[**0113**] FLS: Flash-to-Camera Lens Separation (center-to-center, inches)

[**0114**] GNm: Main Flash Output (Guide Number, Current ISO, feet)

[**0115**] GNp: Preflash Output (Guide Number, Current ISO, feet)

[**0116**] K: ANSI Lens Exposure Constant (default=3.91)

[**0117**] LFR: Camera Lens Focus Range (inside or outside of range)

[**0118**] LS: Linear Smear (in mm at capture plane during exposure)

[**0119**] LLs: Ambient Light Level of Primary Subject (camera light meter reading in foot lamberts)

[**0120**] LLb: Ambient Light Level of Background (camera light meter reading in foot lamberts)

[**0121**] Mc: Current Reproduction (e.g. printing) Magnification

[**0122**] Ms: Standard Reproduction (e.g. printing) Magnification

[**0123**] Mn: Non-Standard (e.g. enlargement) Magnification

[**0124**] S: Film or DSC Sensor ISO Speed

[**0125**] T: Camera Shutter Speed (seconds)

[**0126**] Intermediate Parameters:

[**0127**] In the preferred embodiment, a number of intermediate parameters are calculated from the meta data listed above and employed in the image defect prediction blocks (**100**,**120**,**140**,**160**).

[**0128**] The intermediate parameters quantifying the degree of exposure of the main subject and the background, which have been found to be useful in the noise defect prediction **100** and tonescale defect prediction **140** blocks, are calculated as follows:

[**0129**] Es: Exposure on Subject ($\log_{10}$E Units)

$$Esf \text{ for flash illumination} = \log_{10}[(GNm/Ds)/f]^2 \quad \text{EQ. 4}$$

$$Esa \text{ for ambient illumination} = \log_{10}[LLs/LLn] \quad \text{EQ. 5}$$

[**0130**] Where LLn (EQ. 6) is defined as the light level (foot lamberts) where an ISO normal exposure occurs with the current camera settings, and is found with the following equation, set forth in the ISO/ANSI standard for general-purpose photographic exposure meters ANSI 3.49-1987.

$$LLn = (K)(f^2)/(S)(T) \quad \text{EQ. 6}$$

FLASH ILLUMINATION EXAMPLE

[**0131**] Let camera main flash GN=48 for ISO 200 film

[**0132**] Ds (subject distance)=6 feet

[**0133**] f (lens f-number)=5.6

[**0134**] Esf=$\log_{10}[(48/6)/5.6]^2$=0.30 log E (one-stop over exposed)

AMBIENT (NATURAL) ILLUMINATION EXAMPLE

[0135] Let LLs (light level of subject)=4 foot lamberts

[0136] K=3.91

[0137] f (lens f-number)=4

[0138] S (ISO film speed)=400

[0139] T (shutter time, seconds)=0.01

[0140] LLn=[(3.91)(4²)]/[(400)(0.01)]=16 foot lamberts

[0141] Esa=log10(4/16)=−0.6 log E (two-stops under exposed)

[0142] The flash and ambient exposures for the background are calculated in the same fashion, but in this case the measured camera-to-background distance data and background illuminance levels are used in the equations.

[0143] Eb: Exposure on Background ($\log_{10}$E Units)

$$Ebf \text{ for flash illumination} = \log_{10}[(GNm/Db)/f] \quad \text{EQ. 7}$$

$$Eba \text{ for ambient illumination} = \log_{10}[LLb/LLn] \quad \text{EQ. 8}$$

[0144] Where LLn (EQ. 6) is defined as the light level (foot lamberts), in this case for the background portion of the scene, where an ISO normal exposure occurs with the current camera settings.

[0145] The intermediate parameters, hereafter identified as FER (Flash Exposure Ratio) and AER (Ambient Exposure Ratio), which quantify the ratio between the exposure on the main subject and the background, and have been found to be useful in the Tonescale Defect Prediction Block **140**, are calculated as follows:

FER: Flash Exposure Ratio

$$FER = 10^{[Esa - Ebf]} \quad \text{EQ. 9}$$

AER: Ambient Exposure Ratio

$$AER = 10^{[Esa - Eba]} \quad \text{EQ. 10}$$

[0146] The absolute value signs are needed in the exponent term of EQ. 9 and EQ. 10 to reflect the fact that the magnitude of the exposure ratio, whether the subject or background is receiving the dominant exposure, is the key parameter.

[0147] The intermediate parameters quantifying the format and subject reproduction magnifications as perceived in the final display, which have been found to be useful in the Noise Defect Prediction Block **100**, the Redeye Defect Prediction Block **120**, and the Sharpness Defect Prediction Block **160**, are calculated as follows:

[0148] AM: Angular Magnification of Subject

[0149] In the Sharpness Defect Prediction Block **160**, at decision point **172**, the AM parameter has been found to be a useful predictor for determining the maximum handheld shutter time required to minimize hand-tremor-induced blur for the average photographer. And in the Redeye Defect Prediction Block **120**, at decision point **130**, the AM is a useful predictor in that it correlates with the size of the subject's eyes, and therefore contributes to the perceived severity of the redeye image defect.

$$AM = [(FL)(Mc)]/Vd \quad \text{EQ. 11}$$

[0150] Where:

[0151] Vd: Final Image Viewing Distance (Specified in Inches)

[0152] As disclosed in columns 43-44 of U.S. Pat. No. 5,323,204, which issued Jun. 21, 1994 to the present assignee and which is incorporated herein by reference, and contrary to conventional wisdom, human observers do not view photographs at distances that are linearly related to the display size. In this regard, empirical-based perceptual measurements of eye-to-display separation suggest that the average viewing distance (Vd) for handheld prints of varying sizes can be characterized as follows:

$$Vd = 3.64 + 11.34[\log_{10}(D)] \quad \text{EQ. 12}$$

[0153] Where:

[0154] D=the diagonal dimension of the final display (specified in inches)

[0155] Viewing Distance Examples

[0156] Vd for 4 by 6 inch print=3.64+11.34 [$\log_{10}$(7.2)]=13.4 inches

[0157] Vd for 8 by 12 inch print=3.64+11.34 [$\log_{10}$(14.4)]=16.8 inches

[0158] MST: Maximum Handheld Shutter Time (Seconds)

[0159] The maximum handheld shutter time is an intermediate parameter that specifies for the current camera lens focal length, reproduction magnification, and final image viewing distance, the longest handheld shutter time that can be employed by a person with average hand tremor with out causing noticeable blur to be perceived in the final image. The MST is affected by the camera shake factor (CSF), which specifies the stability of the camera. The CSF is one of the items that may be included in the general camera meta data. If the CSF is not available, the default value of unity, appropriate for typical 35 mm point-and-shoot cameras is used. We have found that interchangeable lens (SLR) cameras are more stable and typically have CSF values of about 1.4.

$$MST = [(0.169)(Vd)(CSF)]/[(FL)(25.4)(Mc)] \quad \text{EQ. 13}$$

[0160] Where: the constant 0.169 is needed to fit the experimental data such that the result of the MST equation is the longest exposure time that will not produce significant image blur. The value of this constant was derived by rating the quality of images shot by a representative population of photographers, where the exposure times were systematically varied. The constant 25.4 converts the camera lens focal length from inches to mm.

[0161] Maximum Handheld Shutter Time Examples

[0162] 35-mm format SLR camera, 35 mm lens, 4×6 inch print:

[0163] FL=1.38 inch

[0164] Mc=4.44

[0165] Vd=13.36 inch

[0166] CSF=1.4

[0167] MST=[(0.169)(13.36)(1.4)]/[(1.38)(25.4)(4.44)]=0.02 second

[0168] APS point-and-shoot camera, 25 mm lens, 4×10 inch panoramic print:

[0169] FL=0.98 inch

[0170] Mc=10.6

[0171] Vd=15.35 inch

[0172] CSF=1.0

[0173] MST=[(0.169)(15.35)(1.0)]/[(0.98)(25.4)(10.6)]=0.01 second

[0174] These examples show that a shorter exposure time is needed to maintain an acceptable level of hand-tremor-induced blur with higher reproduction magnification and less stable (lower CSF) cameras.

[0175] DSF: Display Size Factor

[0176] The present authors disclose the Display Size Factor (DSF) in columns 44-45 of the aforementioned U.S. Pat. No. 5,323,204, which quantitatively accommodates the independent selection of display size and reproduction magnification. The DSF was conceived in order to account for the differences between full-frame reproductions and cropped image reproductions where the final display size is not the product of the capture media format size and the reproduction magnification. This occurs when pseudo-panoramic or pseudo-telephoto (electronic zoom) features, which are popular on APS and DSC cameras, are selected by the photographer and/or when a device such as a Kodak Picture Maker is used to selectively zoom and crop a portion of a full-frame image to create a new composition. DSF has been found to be advantageous when predicting the severity of defects that vary in response to the reproduction and viewing magnifications, rather than the subject reproduction magnification, as was the case with the AM parameter. For example, the DSF parameter is used in the Noise Defect Prediction Block **100** to create lookup tables for decision point **106**, and in the Sharpness Defect Prediction Block **160** at decision point **166**.

[0177] These are cases where the perceived quality loss due to the image defect is correlated with the degree to which the structure of the image is magnified.

$$DSF=(Ms/Mn)(Vdn/Vds) \quad \text{EQ. 14}$$

[0178] Where:

[0179] Vds is the viewing distance for the standard display size

[0180] Vdn is the viewing distance for the non-standard display size

[0181] Display Size Factor Examples

[0182] 35-mm format camera, 4×6 inch full-frame print:

[0183] Ms=4.44

[0184] Mn=4.44

[0185] Vds=13.4 inches

[0186] Vdn=13.4 inches

[0187] DSF=(4.44)/(4.44)(13.4/13.4)=1.0

[0188] 35-mm format camera, 8×12 inch full-frame print:

[0189] Ms=4.44

[0190] Mn=8.88

[0191] Vds=13.4 inches

[0192] Vdn=16.8 inches

[0193] DSF=(4.44/8.88)(16.8/13.4)=0.63

[0194] 35-mm format camera, 2× electronic zoom (EZ) 4×6 inch print:

[0195] Ms=4.44

[0196] Mn=8.88

[0197] Vds=13.4 inches

[0198] Vdn =13.4 inches

[0199] DSF=(4.44/8.88)(13.4/13.4)=0.5

[0200] These examples show that the DSF decreases when the reproduction magnification increases and the viewing distance decreases. For example, the full-frame 8×12 inch case and the 2× EZ 4×6 inch print case have the same reproduction magnification (Mn), but the 2× EZ case produces a smaller print and therefore a closer viewing distance that leads to a smaller DSF, which correlates with lower perceived image quality.

[0201] As outlined in the Background section, each of the image defects included in the inventive process was studied to determine the relationship between the amount of defect present and the perceived image quality loss. The image quality loss data was correlated with scene, camera, demographic, and display parameters to develop the predictors employed in Image Defect Prediction Blocks **100**,**120**,**140** and **160**, which were found to be useful in determining when to activate the digital image defect correction processes contained in Blocks **72**,**80**,**84** and **88**. The empirical studies leading to the development of the predictors involved the generation of images of a variety of scene types containing camera, illumination, display, and subject characteristics spanning the range encountered in consumer photography. By varying the imaging system and scene characteristics in this fashion, a population of images containing a wide range of image defects was produced. These images were visually rated for quality using the perceptually uniform JND scale previously described, and their associated capture and display characteristics were analyzed to develop the final parameters suitable for predicting the probability and severity of image defects.

[0202] SP: Switch Point (on/off) Values for Decision Points

[0203] From this perceptually-derived image quality data, the predictor values, hereafter denoted as switch-point (SP) values, are selected for each decision point parameter **106**, **128**,**130**,**132**,**148**,**152**,**166**,**170**,**172**,**174** that correspond with 3 JNDs of image quality loss. As discussed at the beginning of this section, the 3 JND value, which corresponds with about one-half of a subjective image quality category, was selected for the preferred embodiment because it provides a good balance between image processing efficiency (number of images processed per unit time) and image quality improvement. The SP values in the table should cover the range of conditions encountered in consumer photography. If a general or intermediate parameter falling outside of the

current SP values in the decision tables is encountered, the table value closest to the current parameter is applied in the decision process. If a general or intermediate parameter falling between the current SP values in the decision tables is encountered, intermediate values may be obtained by well-known interpolation techniques.

[0204] A detailed description of the processes contained in Image Defect Prediction Blocks **100**,**120**,**140** and **160** will now be provided. To illustrate the functionality of the Image Defect Prediction Blocks in the preferred embodiments of the present invention, SP parameter values for traditional film (e.g. AgX-based media) will be shown. However, it should be appreciated that the inventive image defect prediction processes are equally applicable to other capture media, whether based on chemical or electronic capture technologies. In the description that follows, the points in the process where specific parameter values vary depending on the image capture modality will be highlighted.

[0205] **FIG. 3**: Noise Defect Prediction Block **100**

[0206] Block **102**: Meta Data Input List

[0207] Camera Model Data

[0208] K,Ms,Mn,D,LLs,f,T,GNm

[0209] Block **104**: Processes

[0210] Calculate Vd EQ. 12

[0211] Calculate DSF EQ. 14

[0212] Calculate Esf EQ. 4

[0213] Calculate Esa EQ. 5

[0214] Select a switch point from the SP Table appropriate for current display size factor (DSF) and Film Speed (S).

[0215] Block **106**: Decision Point

[0216] Compare the calculated Es and SP Values:

[0217] If calculated Es>=SP, omit noise correction process **108**;

[0218] If calculated Es<SP, execute noise correction process **110**;

[0219] In cases where the noise level of the current capture media and DSF combination does not require noise correction at any exposure (Es) level, an SP value substantially below any obtainable by the system (e.g. −100) is entered in the table. In cases where the noise level of the current capture media and DSF combination requires noise correction at every exposure (Es) level, an SP value substantially above any obtainable by the system is entered in the table.

TABLE 1

SP (Es) Values for Block 106 (3 JND Level)

Speed S –>	ISO 100	ISO 200	ISO 400
Es @ DSF = 1.00	−100	−0.52	−0.30
Es @ DSF = 0.85	−0.48	−0.13	0
Es @ DSF = 0.63	+0.25	+1.08	+100

[0220] Table 1 shows the Es ($\log_{10}$ Exposure units) SP values for three display sizes and three film speeds. In this example, the DSF values are appropriate for a full-frame 35-mm format consumer grade color negative film frame enlarged to make a 4×6 inch print (DSF 1.0), a full-frame 35-mm format consumer grade color negative film frame enlarged to make a 5×7 inch print (DSF=0.85), and a full-frame 35-mm format consumer grade color negative film frame enlarged to make a 8×12 inch print (DSF=0.63). Since the noise versus exposure relationship may vary depending on the film technologies selected by the manufacturer, it may be necessary to employ different SP values for other film types. This is easily verified by shooting an exposure series on the new film and assessing the noise level in the final images. In the preferred embodiment, the SP Table includes all of the DSF possibilities for the particular image processing apparatus. For example, some digital printers may only produce prints with fixed magnifications, as shown in the current example, while others may offer a wide range of print sizes and intermediate zoom ratios. In these more versatile printers, the Noise SP Table preferably contains DSF entries corresponding to each print size and zoom magnification. Alternatively, intermediate SP values can be obtained by interpolating between values in the table.

[0221] The Noise SP Table for digital still cameras (DSCs) also varies with respect to DSF; however, rather than loading in films with different sensitivities, as shown above, the photographer or camera exposure control selects a Digital Gain Factor (DG) appropriate for the current scene. Therefore, the DSC Noise SP Table lists DSF versus DG. The 3 JND quality loss values populating the DSC Noise SP Table can be derived with the empirical photographic testing and perceptual evaluations referenced above, alternatively, the values can be generated using the methods referenced by the present inventors in the aforementioned articles entitled "*Characterization and Prediction of Image Quality*"by B. W. Keelan, and "*Use of System Image Quality Models to Improve Product Design*"by R. B. Wheeler.

[0222] **FIG. 4**: Redeye Defect Prediction Block **120**

[0223] Block **122**: Meta Data Input List

[0224] Demographic Data (user-specified or region-specific)

[0225] Camera Model Data

[0226] FF,FI,S,LLs,FL,Mc,D,GNp,Ds

[0227] The severity of redeye is a strong function of demographic classification of the subject photographed, due to two effects. First, more highly pigmented races tend to have more melanin in their pupils, which attenuates the light propagating through the pupil via absorption, and reduces the amount of red light exiting the eye. Second, as people age, the maximum diameter to which their pupil will dilate at low light levels decreases. Consequently, young people exhibit larger pupil sizes than older people under the conditions in which flash photographs are typically taken. The dramatic nature of the dependence of redeye severity on demographics is demonstrated in Table 2, which shows the frequency of occurrence of noticeable redeye in over one hundred subjects belonging to different demographic groups and photographed under rigidly controlled conditions (0.016 foot-candles ambient light; 2.6 inch flash-to-lens separation; subject distance 6 feet; no preflash; focal length 80 mm; normally viewed 4×6 inch print from 35-mm format film).

TABLE 2

Effect of Demographics on Frequency of Redeye

Demographic Group	Caucasian Youth	Caucasian Adult	Hispanic	Asian	African-American
Frequency of Occurrence	82%	70%	41%	15%	9%

[0228] Both the pigmentation and age affects are evident in this data, although the age effect is more obvious at larger flash-to-lens separation (e.g. at 3.8 inches, with other parameters the same), where Caucasian adults exhibit redeye only 20% of the time, but Caucasian youth show redeye in 67% of photographs.

[0229] The SP Tables employed in Redeye Defect Prediction Block **120** at points **128**, **130** and **132** may contain different values depending on the demographic characteristics supplied. If no demographic data is available, the SP Tables for Caucasian Adult, which are shown hereafter in the preferred embodiment, are used as the default.

[0230] The flash-to-lens separation (FLS) has a significant impact on the level of redeye defect. However, FLS is a fixed value in most cameras (flash is stationary); therefore, the SP Tables employed in Redeye Defect Prediction Block **120** at points **128**, **130** and **132** would typically contain SP values derived from the quality evaluation of images produced with the FLS of the current camera. To accommodate cameras capable of changing the FLS in response to the photographer's lens focal length (FL) selection, for example, as disclosed in U.S. Pat. No. 5,331,362, which issued Jul. 19, 1994 and is incorporated herein by reference, the current invention employs a separate SP Table for each FL (zoom setting) selected by the photographer.

[0231] Table 3 shows the affect of FLS on image quality (JNDs) for the following system: Caucasian adult population; 0.5 foot lamberts ambient light; subject distance 10 feet; no preflash; unit angular magnification; normally viewed 4×6 inch print from 35-mm format film.

TABLE 3

Effect of FLS on Redeye Defect Level

FLS (inches)	1.0	1.5	2.5	3.5
Quality Loss (JND Units)	−4.9	−3.25	−1.4	−0.4

[0232] The SP Tables employed in Redeye Defect Prediction Block **120** at points **128**, **130** and **132** are loaded with values that correspond to the specific FLS value supplied in the meta data.

[0233] Empirical studies show that the quality loss due to the redeye image defect is greatest at an intermediate camera-to-subject distance (Ds), which falls within the range commonly occurring in consumer photography. This is due to the competition of two opposing effects: (1) At longer camera-to-subject distance, the angular separation of the flash and lens is reduced, leading to greater red saturation of the pupil, and, (2) At longer distances, the pupil size in the final image is diminished, reducing redeye severity. To a crude approximation, as distance increases, the redeye becomes more intensely red but the pupil size in the image decreases. The former effect dominates at short distances and the latter at longer distances, leading to an extremum in the relationship at intermediate distances. As a result of this finding, the SP Tables employed in Redeye Defect Prediction Block **120** at points **128**, **130** and **132** in the preferred embodiment are populated with values corresponding to the critical camera-to-subject distance, which is defined as the distance producing the most severe defect level. This approach ensures that Redeye Correction Process **80** is applied when the probability of redeye is high but Ds meta data is not available. If Ds meta data is available, and added predictive accuracy is desired, SP Tables for each distance can be advantageously applied.

[0234] Block **124**: Processes

[0235] Calculate Vd EQ. 12

[0236] Calculate AM EQ. 11

[0237] Select switch points from SP Tables appropriate for current demographic group and flash-to-lens separation (FLS).

[0238] Block **126**: Decision Point

[0239] Determine the flash fire state (FF):

[0240] If FF is no (off), omit redeye correction process **134**;

[0241] If FF is yes (on); proceed to Block **128**;

[0242] Block **128**: Decision Point

[0243] Compare the actual LL and SP Values:

[0244] If actual LL>=SP, omit redeye correction process **134**;

[0245] If actual LL<SP, proceed to Block **130**;

TABLE 4

SP (LL) Values for Block 128 (3 JND Level)

FLS (inches)	1.0	1.5	2.5	3.5
LL (foot lamberts)	2.50	1.04	0.48	0.19

[0246] Table 4 shows SP value (LL in foot Lamberts) for the critical distance for each FLS with AM at 1.5, which is a demanding case of the sort found on typical 3× zoom cameras. If FLS is not supplied in meta data, a value of one inch (smallest separation found on consumer cameras) is assumed.

[0247] Block **130**: Decision Point

[0248] Compare the calculated AM and SP Values:

[0249] If calculated AM=<SP, omit redeye correction process **134**;

[0250] If calculated AM>SP, proceed to Block **132**;

TABLE 5

SP (AM) Values for Block 130 (3 JND Level)

LL (foot lamberts)	2.5	1.0	0.5	0.2
AM	1.5	0.82	0.62	0.43

[0251] Table 5 shows SP value for FLS of 1.0 inches and the critical distance for each AM. If LL is not supplied in meta data, a value of 0.2 foot lamberts is assumed.

[0252] Block 132: Decision Point

[0253] Compare the actual GNp and SP Values:

[0254] If actual GNp>=SP, omit redeye correction process 134;

[0255] If actual GNp<SP, execute noise correction process 136->80;

TABLE 6

SP (GNp) Values for Block 132 (3 JND Level)

AM	1.5	1.2	0.9	0.43
GNp	160	70	15	0

[0256] Table 6 shows SP value for FLS of 1.0 inches, at the minimum light level for typical flash pictures (0.2 foot lamberts), and the critical distance for each AM. When the AM is above 1.2, the preflash guide number (GNp) values needed to produce less than 3 JNDs of quality loss indicate higher output than is typically found on consumer cameras; whereas, when the AM is below 0.43, the quality loss due to the redeye defect will be less than 3 JNDs with no preflash applied.

[0257] **FIG. 5**: Tonescale Defect Prediction Block **140**

[0258] Block 142: Meta Data Input List

[0259] Camera Model Data

[0260] FF,GNm,S,f,T,K,LI.s,LI.b,Ds,Db

[0261] Block 144: Processes

[0262] Calculate Esa EQ. 5

[0263] Calculate Eba EQ. 8

[0264] Calculate Esf EQ. 4

[0265] Calculate Ebf EQ. 7

[0266] Calculate AER EQ. 10

[0267] Calculate FER EQ. 9

[0268] Block 146: Decision Point

[0269] Determine the flash fire state (FF):

[0270] If FF is no (off), proceed to Block 148;

[0271] If FF is yes (on); proceed to Block 152;

[0272] Block 148: Decision Point

[0273] Compare the calculated AER and SP Values:

[0274] If actual AER=<SP, omit tonescale correction process 150;

[0275] If actual AER>SP, execute tonescale correction process 156;

[0276] Alternatively, if the AER parameter is not available, but the backlight indicator (BL) is on, execute tonescale correction process 156.

[0277] Block 152: Decision Point

[0278] Compare the calculated FER and SP Values:

[0279] If actual FER=<SP, omit tonescale correction process 154;

[0280] If actual FER>SP, execute tonescale correction process 156;

[0281] Where SP=2.8, which corresponds to a 1.5 stop exposure ratio.

[0282] The preferred value for AER and FER was derived from a review of numerous images with a wide range subject and background exposure ratios, together with learning from the optimization of fill-flash algorithms, as disclosed by the present inventors in columns 50-58 of the aforementioned U.S. Pat. No. 5,323,204. The SP value of 2.8 was selected because we found that it provides a reasonable balance between image quality enhancement and photofinishing throughput (images processed per unit of time). If the values for AER and FER are set to a lower JND value, the tonescale image defect location and correction processes will be invoked more frequently, which may lead to higher average image quality, but lower throughput due to extended image processing time. If the values for AER and FER are set to a higher JND value, the image defect location and correction processes will be invoked less frequently, which may lead to lower average image quality, but higher throughput due to shortened image processing time.

[0283] **FIG. 6**: Sharpness Defect Prediction Block **160**

[0284] Block 162: Meta Data Input List

[0285] Camera Model Data

[0286] Ms,Mn,Mc,LFR,FL,T,CSF,LS

[0287] Block 164: Processes

[0288] Calculate DSF EQ. 14

[0289] Calculate Vds EQ. 12

[0290] Calculate Vdn EQ. 12

[0291] Calculate AM EQ. 11

[0292] Calculate MST EQ. 13

[0293] Block 166: Decision Point

[0294] Compare the display size factor (DSF) and SP:

[0295] If actual DSF>=SP, proceed to Block 168;

[0296] If actual DSF<SP, execute sharpness 180;

[0297] Where SP=0.65, which produces about 3 JNDs of quality loss for typical consumer imaging systems.

[0298] Block 168: Decision Point

[0299] Determine the flash fire state (FF):

[0300] If FF is no (oft); proceed to Block 170;

[0301] If FF is yes (on); omit sharpness correction process 178;

[0302] Block 170: Decision Point

[0303] Determine the lens focus range state (LFR):

[0304] If Ds is not outside LFR; proceed to Block 172;

[0305] If Ds is outside LFR; execute sharpness correction process 180;

[0306] Block 172: Decision Point

[0307] Compare the actual exposure time T and MST:

[0308] If T is =<MST, proceed to Block 174;

[0309] If T is >MST, execute sharpness correction process 180;

[0310] Block 174: Decision Point

[0311] Measure the linear smear at image capture plane (LS):

[0312] If LS/DSF is =<SP, omit sharpness correction process 176;

[0313] If LS/DSF is >SP, execute sharpness correction process 180;

[0314] Where LS=0.04 mm at image capture plane, which produces about 3 JNDs of quality loss with unit DSF.

[0315] Linear smear may be determined in a variety of ways, including the following. The aforementioned U.S. Pat. No. 5,323,204 described in element 225 of FIG. 2, and the hardware description beginning in column 26, line 38, an accelerometer-based camera shake detector capable of measuring linear smear. Alternatively, linear smear at the image plane can be acquired by taking temporally separated autofocusing system readings and comparing the linear translation of the signal patterns (e.g. quantifying the displacement of matching signal profiles as a function of acquisition time).

[0316] The image defect prediction processes 100,120, 140,160, as described above, have shown the preferred embodiments, but it is to be understood that they may be advantageously applied, even if all of the data is not available. For example, the hierarchy is purposefully set so the most readily available data is required earliest in each process, and if data is missing, the decision of the last block containing data has priority. For example, if after the first decision point, the data suggests that there is a probability of an image defect, but no additional data is available, the defect correction process will be executed. This is acceptable, because a "mistake" based on omission of data, simply means that a defect correction may be occasionally applied when not needed. This will not reduce the image quality, but merely lead to a slight reduction in the throughput advantage produced by the preferred embodiment.

[0317] The invention has been described with reference to a preferred embodiment. However, it will be appreciated that variations and modifications can be effected by a person of ordinary skill in the art without departing from the scope of the invention. For instance, while the foregoing description discloses an image processing system incorporating a plurality of image defect location and correction processes that are each associated with correction of a different type of image defect, the invention is intended to encompass an image processing system incorporating a plurality of image defect location and correction processes that are each associated with a specific type of image defect, where the specific type may be a different type or the same defect. The latter situation may apply when two or more processes are applied in series to the same defect depending on severity levels, or different processes may be applied individually for different severity levels of the same type of defect or depending upon the source of the defect.

Parts List

[0318] 10 image processing system

[0319] 12 film scanner

[0320] 14 digital file reader

[0321] 16 network input

[0322] 18 order entry station

[0323] 22 display monitor

[0324] 24 keyboard

[0325] 26 printer

[0326] 28 photofinishing equipment

[0327] 30 data communication device

[0328] 32 photofinishing lab

[0329] 40 computer

[0330] 50 image acquisition block

[0331] 52 capture device/film scanner

[0332] 56 source digital image

[0333] 60 image analysis block

[0334] 62 sub-sampling block

[0335] 64 scene balance algorithm

[0336] 66 meta data decoder

[0337] 68 image defect prediction process

[0338] 70 image processing block

[0339] 72 noise correction process

[0340] 76 scene balance shift

[0341] 80 redeye correction process

[0342] 84 scene dependent tonescale correction

[0343] 88 sharpness correction process

[0344] 90 image output block

[0345] 92 output device rendering

[0346] 96 image output device

[0347] 100 noise defect prediction block

[0348] 102 meta data input list

[0349] 104 parameter calculation

[0350] 106 subject exposure switch point

[0351] **108** omit noise correction
[0352] **110** execute noise correction
[0353] **120** redeye defect prediction block
[0354] **122** meta data input list
[0355] **124** parameter calculation
[0356] **126** flash determination
[0357] **128** light level switch point
[0358] **130** angular magnification switch point
[0359] **132** flash output switch point
[0360] **134** omit redeye correction
[0361] **136** execute redeye correction
[0362] **140** tonescale defect prediction block
[0363] **142** meta data input list
[0364] **144** parameter calculation
[0365] **146** flash determination
[0366] **148** ambient exposure ratio switch point
[0367] **150** omit tonescale correction
[0368] **152** flash exposure ratio switch point
[0369] **154** omit tonescale correction
[0370] **156** execute tonescale correction
[0371] **160** sharpness defect prediction block
[0372] **162** meta data input list
[0373] **164** parameter calculation
[0374] **166** display size factor switch point
[0375] **168** flash determination
[0376] **170** lens focus range switch point
[0377] **172** actual exposure time switch point
[0378] **174** linear smear switch point
[0379] **176** omit sharpness correction
[0380] **178** omit sharpness correction
[0381] **180** execute sharpness correction
[0382] **200** film camera
[0383] **201** film strip
[0384] **205***a* film reel
[0385] **205***b* film reel
[0386] **210** read/write head
[0387] **215** microprocessor
[0388] **220** head electronics
[0389] **225** camera controls
[0390] **230** scene sensors
[0391] **240** ROM
[0392] **250** ROM
[0393] **260** RAM
[0394] **300** digital camera
[0395] **340** lens
[0396] **341** aperture/shutter controller
[0397] **342** blur filter
[0398] **344** CCD sensor
[0399] **346** analog video processor
[0400] **348** A/D converter
[0401] **350** frame memory
[0402] **352** digital signal processor
[0403] **354** data memory
[0404] **356** memory card
[0405] **358** memory card interface
[0406] **359** card connector
[0407] **360** host computer interface
[0408] **362** camera microprocessor
[0409] **364** user inputs
[0410] **366** flash unit
[0411] **368** timing generator
[0412] **370** scene sensor
[0413] **372** exposure driver
[0414] **374** sensor driver
[0415] **380** camera mechanism inputs
[0416] **382** shake sensor input

What is claimed is:

1. A method for processing a captured image with one or more correction processes selected from a plurality of such processes, each associated with correction of a specific type of image defect, in order to improve the appearance of a viewed image generated from the captured image, said method comprising the steps of:

collecting meta data related to image capture that is unique to each image that is captured, wherein the meta data is capable of indicating whether the specific types of image defects are likely to be present in the viewed image generated from the captured image;

predicting the presence of the image defects based at least in part on the meta data, thereby generating process application criteria which indicate a level of image defect that if left untreated would reduce the perceived quality of the viewed image;

selecting one or more correction processes to employ on the captured image based on the process application criteria; and

applying the one or more selected correction processes to the captured image to generate the viewed image.

2. The method as claimed in claim 1 wherein the meta data includes scene, camera or demographic data related to the image capture.

3. The method as claimed in claim 1 wherein the step of predicting the presence of the image defects also predicts the

severity of the defects and the strength of the corresponding correction process can be altered in response to the degree of severity.

4. The method as claimed as in claim 1 wherein the meta data related to image capture is collected at the time of image capture.

5. The method as claimed as in claim 1 wherein the meta data related to image capture is collected at a time other than the time of image capture.

6. The method as claimed in claim 1 wherein the image defect is a noise defect and the meta data is selected from the group consisting of a lens exposure constant, standard (printing) reproduction magnification, non-standard (enlargement) magnification, diagonal dimension of a final display, ambient light level of the primary subject, exposure time, camera lens f-number, and main flash guide number.

7. The method as claimed in claim 1 wherein the image defect is a red-eye defect due to flash illumination of a subject and the meta data is selected from the group consisting of a use (on-off) of the flash illumination, illumination level of the primary subject, subject distance, flash-to-camera lens separation, focal length of camera lens, current reproduction (printing) magnification, diagonal dimension of final display, and preflash guide number.

8. The method as claimed in claim 1 wherein the image defect is a tone scale defect and the meta data is selected from the group consisting of respective illumination levels of the subject and background, subject distance, background distance, exposure time, camera lens f-number, use (on/off) of flash illumination, guide number of a main flash, lens exposure constant and ISO speed of a capture device.

9. The method as claimed in claim 1 wherein the image defect is a sharpness defect and the meta data is selected from the group consisting an exposure time, standard reproduction (printing) magnification, non-standard (enlargement) magnification, current reproduction (printing) magnification, camera lens focus range, camera lens focal length, camera shake factor and linear smear.

10. The method as claimed in claim 1 further comprising the step of collecting meta data related to display parameters of the viewed image generated from each image that is captured, wherein said meta data is capable of indicating whether the specific types of image defects are likely to be present in the viewed image.

11. A computer storage medium having instructions stored therein for causing a computer to perform the method of claim 1.

12. An image processing method incorporating a plurality of image defect location and correction processes, each associated with correction of a specific type of image defect, that are selectively and automatically applied to an image only when the image is predicted from specific capture variables associated with image capture to have a level of image defect, treatable by one or more of the processes, that if left untreated would reduce the perceived quality of the final viewed image.

13. The method as claimed in claim 12 wherein the image capture is a film capture on a film capture device and the capture variables includes at least one variable selected from the group consisting of an ISO rating of the film used, exposure time of an optical system used in the capture device, a f-number of the optical system, a distance of a subject from the capture device, a distance of a background from the capture device, an illumination level on the subject, an illumination level on the background, a distance between a flash illuminator and the optical system, an indication of whether the flash illuminator was used, a guide number for the flash illuminator, an indication of camera shake and an indication that a backlight indicator was turned on.

14. The method as claimed in claim 12 wherein the image capture is an electronic capture on a digital capture device and the capture variables includes at least one variable selected from the group consisting of an ISO equivalent rating of an image sensor used by the capture device, exposure time of an optical system used in the capture device, a f-number of the optical system, a distance of a subject from the capture device, a distance of a background from the capture device, an illumination level on the subject, an illumination level on the background, a distance between a flash illuminator and the optical system, an indication of whether the flash illuminator was used, a guide number for the flash illuminator, an indication of camera shake, an indication that a backlight indicator was turned on, a gain factor for the image sensor and a resolution setting of the capture device.

15. The method as claimed in claim 14 wherein the electronic capture is obtained with a digital camera.

16. The method as claimed in claim 14 wherein the electronic capture is obtained with a digital scanner.

17. The image processing method of claim 12 further comprising the steps of:

a) recording at the time each image is captured, at least one image capture parameter known to indicate whether a image defect is likely to be present in the final viewed image;

b) storing and later transferring to a photofinishing control system at least one of said parameters;

c) employing in the photofinishing control system a means for predicting from at least one of said image capture parameters and current printing parameters, whether the image will have a level of image defect that if left untreated would reduce the perceived quality of the final viewed image; and

d) applying to the image via automated or operator-assisted techniques, image defect location and correction means, when said prediction means indicates a level of image defect that if left untreated would reduce the perceived quality of the final viewed image.

18. The image processing method of claim 12 further comprising the steps of:

a) recording at the time each image is captured, at least one image capture parameter known to indicate whether a image defect is likely to be present in the final viewed image;

b) employing in a camera control system a means for predicting from at least one of said image capture parameters, and from predefined or photographer-selected printing parameters, whether the current image will have a level of image defect that if left untreated would reduce the perceived quality of the final viewed image;

c) storing and later transferring to the photofinishing control system a value indicating whether or not image defect location and correction means should be applied in photofinishing; and

d) applying to the image via automated or operator-assisted techniques, image defect location and correction means, when said image defect prediction value indicates a level of image defect that if left untreated would reduce the perceived quality of the final viewed image.

19. The image processing method of claim 12 further comprising the steps of:

a) recording at the time each image is captured, at least one image capture parameter known to indicate whether a noise defect is likely to be present in the final viewed image;

b) storing and later transferring to a photofinishing control system at least one of said parameters;

c) employing in the photofinishing control system a means for predicting from at least one of said image capture parameters and current printing parameters, whether the image will have a level of noise defect that if left untreated would reduce the perceived quality of the final viewed image; and

d) applying to the image via automated or operator-assisted techniques, noise defect location and correction means, when said noise defect prediction means indicates a level of noise defect that if left untreated would reduce the perceived quality of the final viewed image.

20. The image processing method of claim 12 further comprising the steps of:

a) recording at the time each image is captured, at least one image capture parameter known to indicate whether a noise defect is likely to be present in the final viewed image;

b) employing in a camera control system a means for predicting from at least one of said image capture parameters, and predefined or photographer-selected printing parameters, whether the image will have a level of noise defect that if left untreated would reduce the perceived quality of the final viewed image;

c) storing and later transferring to a photofinishing control system a value indicating whether or not noise defect location and correction means should be applied in photofinishing; and

d) applying to the image via automated or operator-assisted techniques, noise defect location and correction means, when said noise defect prediction value indicates a level of noise defect that if left untreated would reduce the perceived quality of the final viewed image.

21. The image processing method of claim 12 further comprising the steps of:

a) recording at the time each image is captured, at least one image capture parameter known to indicate whether a redeye defect is likely to be present in the final viewed image;

b) storing and later transferring to a photofinishing control system at least one of said parameters;

c) employing in the photofinishing control system a means for predicting from at least one of said image capture parameters and current printing parameters, whether the image will have a level of redeye defect that if left untreated would reduce the perceived quality of the final viewed image; and

d) applying to the image via automated or operator-assisted techniques, redeye defect location and correction means, when said redeye defect prediction means indicates a level of redeye defect that if left untreated would reduce the perceived quality of the final viewed image.

22. The image processing method of claim 12 further comprising the steps of:

a) recording at the time each image is captured, at least one image capture parameter known to indicate whether a redeye defect is likely to be present in the final viewed image;

b) employing in a camera control system a means for predicting from at least one of said image capture parameters, and predefined or photographer-selected printing parameters, whether the image will have a level of redeye defect that if left untreated would reduce the perceived quality of the final viewed image;

c) storing and later transferring to a photofinishing control system a value indicating whether or not redeye defect location and correction means should be applied in photofinishing; and

d) applying to the image via automated or operator-assisted techniques, redeye defect location and correction means, when said redeye defect prediction value indicates a level of redeye defect that if left untreated would reduce the perceived quality of the final viewed image.

23. The image processing method of claim 12 further comprising the steps of:

a) recording at the time each image is captured, at least one image capture parameter known to indicate whether a tone scale defect is likely to be present in the final viewed image;

b) storing and later transferring to a photofinishing control system at least one of said parameters;

c) employing in the photofinishing control system a means for predicting from at least one of said image capture parameters and current printing parameters, whether the image will have a level of tone scale defect that if left untreated would reduce the perceived quality of the final viewed image; and

d) applying to the image via automated or operator-assisted techniques, tone scale defect location and correction means, when said tone scale defect prediction means indicates a level of tone scale defect that if left untreated would reduce the perceived quality of the final viewed image.

24. The image processing method of claim 12 further comprising the steps of:

a) recording at the time each image is captured, at least one image capture parameter known to indicate whether a tone scale defect is likely to be present in the final viewed image;

b) employing in a camera control system a means for predicting from at least one of said image capture

parameters, and predefined or photographer-selected printing parameters, whether the image will have a level of tone scale defect that if left untreated would reduce the perceived quality of the final viewed image;

c) storing and later transferring to a photofinishing control system a value indicating whether or not tone scale defect location and correction means should be applied in photofinishing; and

d) applying to the image via automated or operator-assisted techniques, tone scale defect location and correction means, when said tone scale defect prediction value indicates a level of tone scale defect that if left untreated would reduce the perceived quality of the final viewed image.

25. The image processing method of claim 12 further comprising the steps of:

a) recording at the time each image is captured, at least one parameter known to indicate whether a sharpness defect is likely to be present in the final viewed image;

b) storing and later transferring to a photofinishing control system at least one of said parameters;

c) employing in the photofinishing control system a means for predicting from at least one of said image capture parameters and current printing parameters, whether the current image will have a level of sharpness defect that if left untreated would reduce the perceived quality of the final viewed image; and

d) applying to the image via automated or operator-assisted techniques, sharpness defect location and correction means, when said sharpness defect prediction means indicates a level of sharpness defect that if left untreated would reduce the perceived quality of the final viewed image.

26. The image processing method of claim 12 further comprising the steps of:

a) recording at the time each image is captured, at least one image capture parameter known to indicate whether a sharpness defect is likely to be present in the final viewed image;

b) employing in a camera control system a means for predicting from at least one of said image capture parameters, and predefined or photographer-selected printing parameters, whether the image will have a level of sharpness defect that if left untreated would reduce the perceived quality of the final viewed image;

c) storing and later transferring to a photofinishing control system a value indicating whether or not sharpness defect location and correction means should be applied in photofinishing; and

d) applying to the image via automated or operator-assisted techniques, sharpness defect location and correction means, when said sharpness defect prediction value indicates a level of sharpness defect that if left untreated would reduce the perceived quality of the final viewed image.

27. An image processing method incorporating an image defect location and correction process that is applied to an image only when a demographic characteristic of the image is predicted to cause a level of image defect that if left untreated would reduce the perceived quality of the final viewed image.

28. The method as claimed in claim 27 wherein the image defect is a red-eye defect due to flash illumination of a human subject and the image defect location and correction process is a red-eye correction process.

29. The method as claimed in claim 28 wherein the demographic characteristic of the image includes the age or race of the human subject.

30. A system for processing a captured image with one or more correction processes selected from a plurality of such processes, each associated with correction of a specific type of image defect, in order to improve the appearance of a viewed image generated from the captured image, said system comprising:

a data recording stage for collecting and recording meta data related to image capture that is unique to each image that is captured, wherein the meta data is capable of indicating whether the specific types of image defects are likely to be present in the viewed image generated from the captured image;

a digital image processor for (a) predicting the presence of the image defects based at least in part on the meta data, thereby generating process application criteria which indicate a level of image defect that if left untreated would reduce the perceived quality of the viewed image and (b) selecting one or more correction processes to employ on the captured image based on the process application criteria; and

means for applying the one or more selected correction processes to the captured image to generate the viewed image.

31. The system as claimed in claim 30 wherein the meta data includes scene, camera or demographic data related to the image capture.

32. The system as claimed in claim 30 wherein the digital signal processor also predicts the severity of the defects based at least in part on the meta data and said means for applying the selected correction process alters the strength of the corresponding correction process in response to the degree of severity.

33. The system as claimed as in claim 30 wherein the data recording stage is part of an image capture device and the meta data related to image capture is collected at the time of image capture.

34. The system as claimed as in claim 30 wherein the data recording stage is separated from image capture and the meta data related to image capture is collected at a time other than the time of image capture.

35. The system as claimed in claim 30 further comprising means for collecting meta data related to display parameters of the viewed image, wherein said meta data related to display parameters is capable of indicating whether the specific types of image defects are likely to be present in the viewed image.

36. A system for processing a captured image with one or more correction processes selected from a plurality of such processes, each associated with correction of a specific type of image defect, in order to improve the appearance of a final viewed image generated from the captured image, said system comprising:

a) an image capture device utilizing a camera control system to capture the image;

b) a photofinishing system utilizing a photofinishing control system to produce the final viewed image;

c) means for recording at the time each image is captured, at least one image capture parameter known to indicate whether an image defect is likely to be present in the final viewed image;

d) means for storing and later transferring to the photofinishing control system at least one of said parameters;

e) means for employing in the photofinishing control system a means for predicting from at least one of said image capture parameters and current printing parameters, whether the captured image will have a level of image defect that if left untreated would reduce the perceived quality of the final viewed image; and

f) means for applying to the captured image via automated or operator-assisted techniques, image defect location and correction means, when said prediction means indicates a level of image defect that if left untreated would reduce the perceived quality of the final viewed image.

37. A system for processing a captured image with one or more correction processes selected from a plurality of such processes, each associated with correction of a specific type of image defect, in order to improve the appearance of a final viewed image generated from the captured image, said system comprising:

a) an image capture device utilizing a camera control system to capture the image;

b) a photofinishing system utilizing a photofinishing control system to produce the final viewed image;

c) means for recording at the time each image is captured, at least one image capture parameter known to indicate whether a image defect is likely to be present in the final viewed image;

d) means for employing in the camera control system a means for predicting from at least one of said image capture parameters, and from predefined or photographer-selected printing parameters, whether the captured image will have a level of image defect that if left untreated would reduce the perceived quality of the final viewed image;

e) means for storing and later transferring to the photofinishing control system a value indicating whether or not image defect location and correction means should be applied in photofinishing, and

f) means for applying to the captured image via automated or operator-assisted techniques, image defect location and correction means, when said image defect prediction value indicates a level of image defect that if left untreated would reduce the perceived quality of the final viewed image.

38. An image processing system incorporating a plurality of image defect location and correction processes, each associated with correction of a specific type of image defect, that are selectively and automatically applied to an image only when the image is predicted from specific capture variables associated with image capture to have a level of image defect, treatable by one or more of the processes, that if left untreated would reduce the perceived quality of the final viewed image.

* * * * *

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(54) IMAGE PROCESSING APPARATUS AND METHOD

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(21) Appl. No.: **09/757,654**

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Jan. 13, 2000 (JP) P2000-004942

Publication Classification

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(52) **U.S. Cl.** **348/222**; 348/241; 382/254; 382/275

(57) **ABSTRACT**

A digital camera acquires information about an optical system such as the arrangement of lenses in image capture, an aperture value, and the like to obtain a degradation function indicating a degradation characteristic of an image relative to the optical system. An image obtained is restored by using the degradation function. An area to be restored may be a whole or part of the image. Alternatively, the area to be restored may be reset and restored again on the basis of a restored image. The degradation function can also be obtained on the basis of subject movements in a plurality of continuously captured images. This enables proper image restoration without the use of a sensor for detecting a shake of an image capturing device.

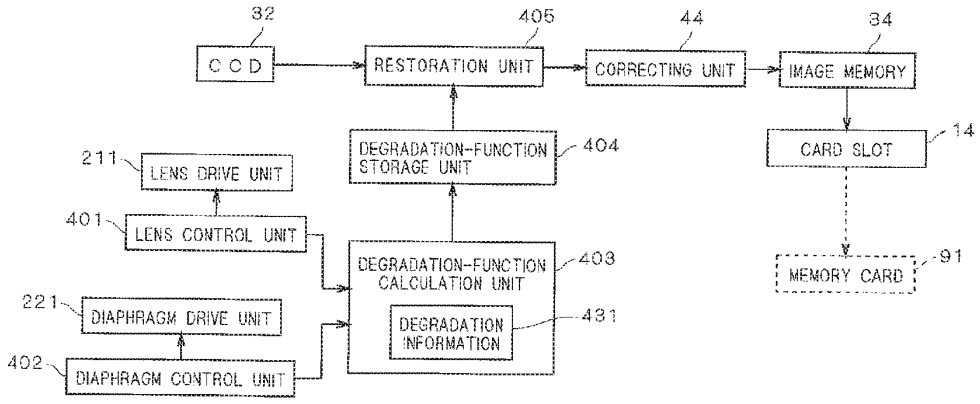


FIG. 1

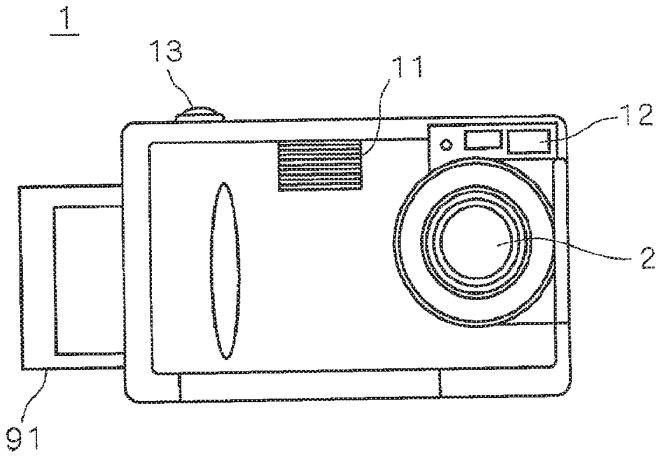


FIG. 2

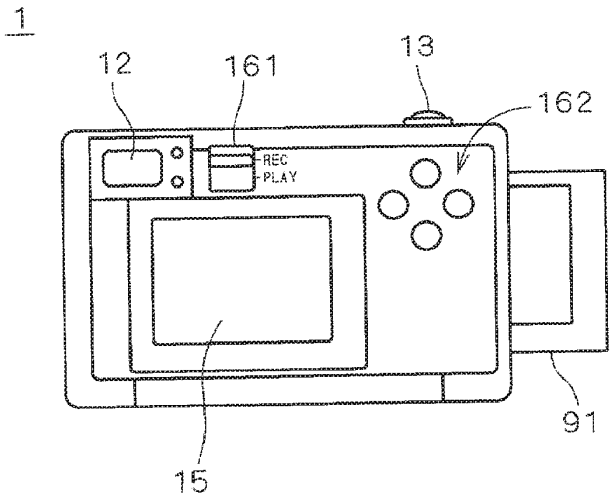


FIG. 3

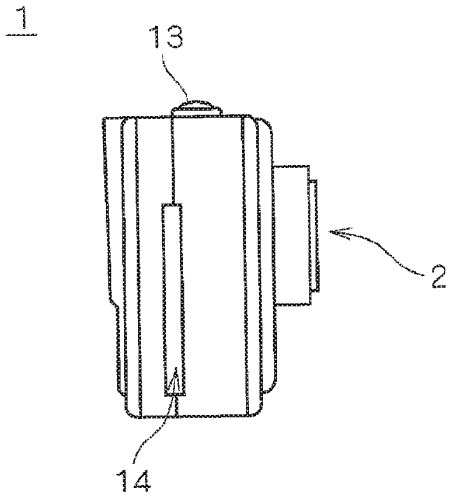


FIG. 4

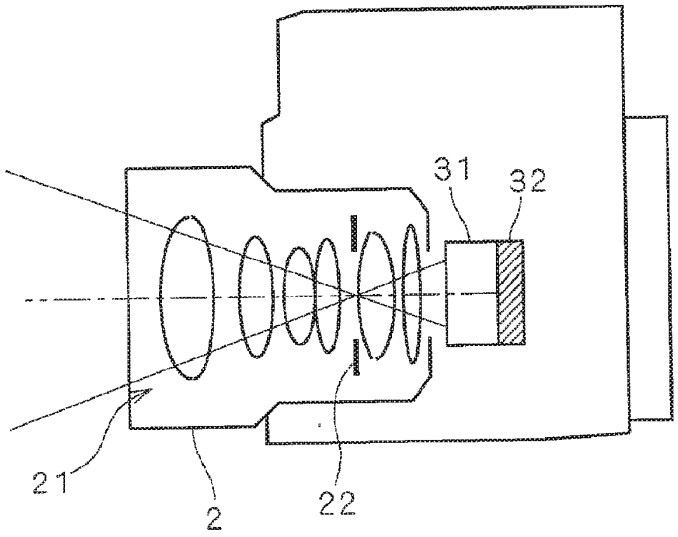
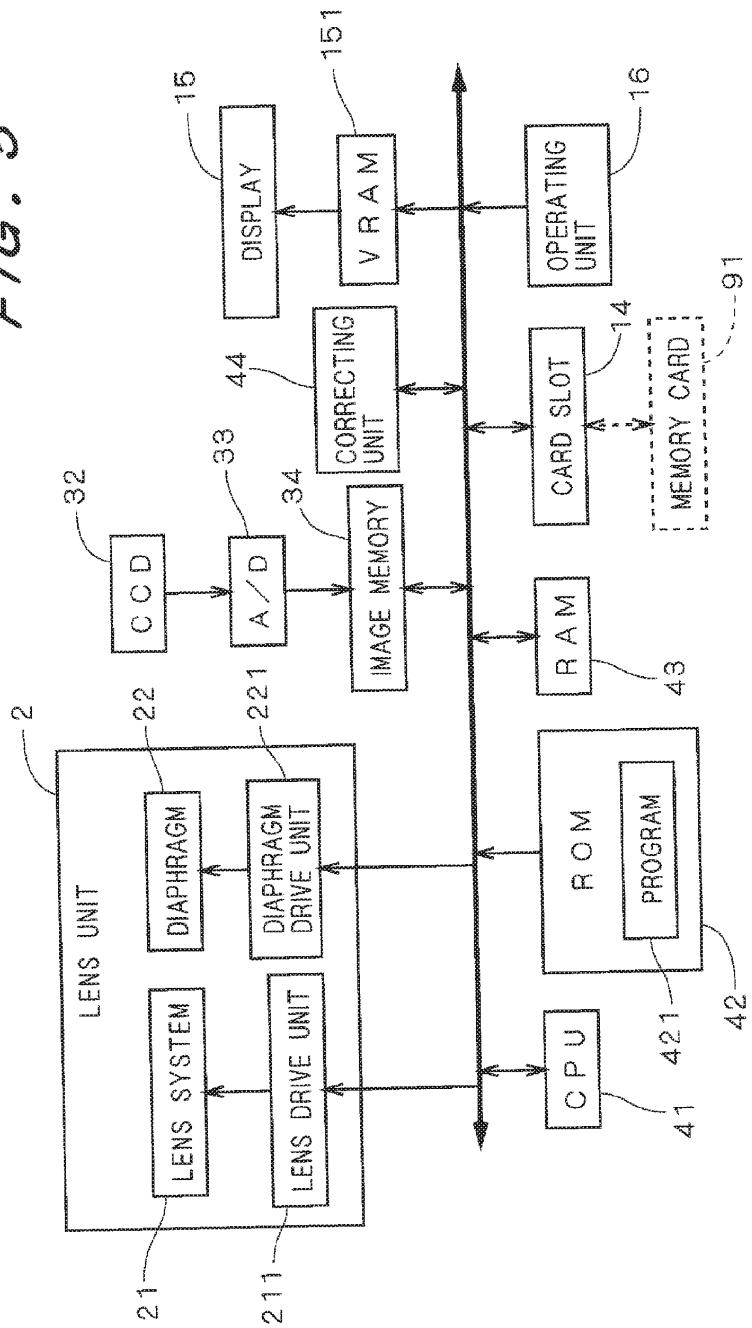


FIG. 5



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FIG. 6

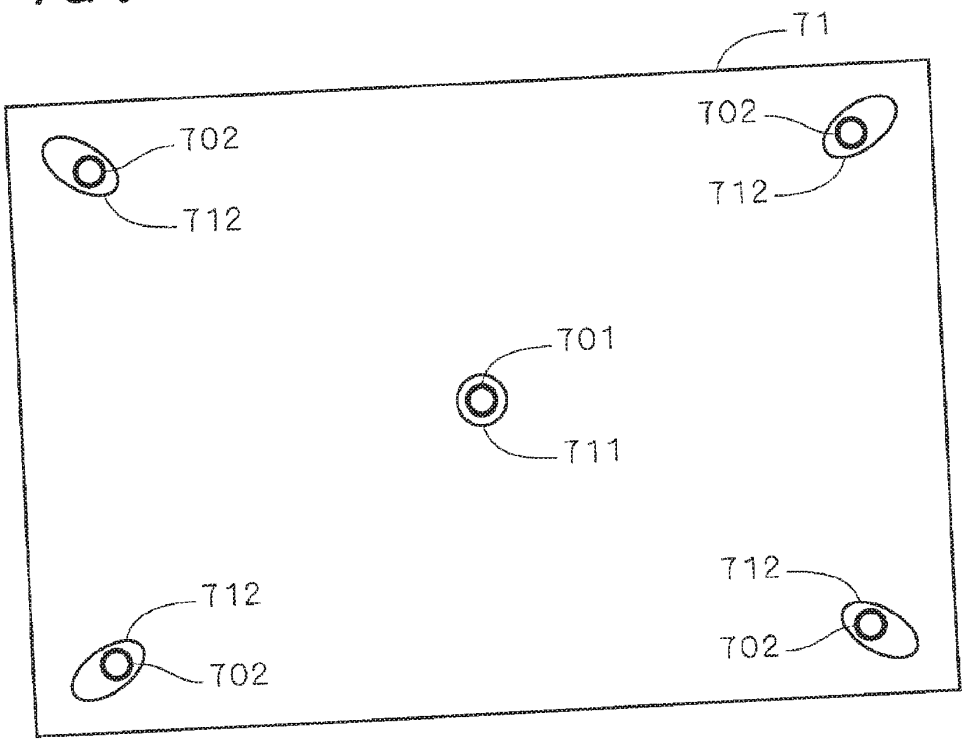


FIG. 7

0	0	0
0	1	0
0	0	0

FIG. 8

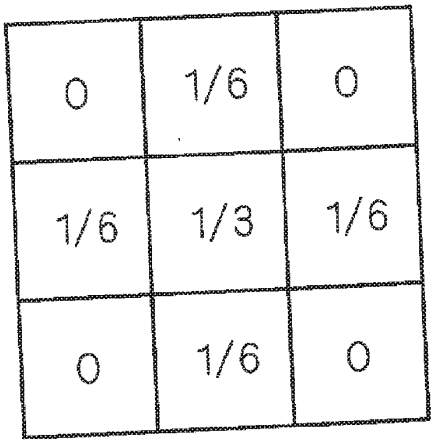


FIG. 9

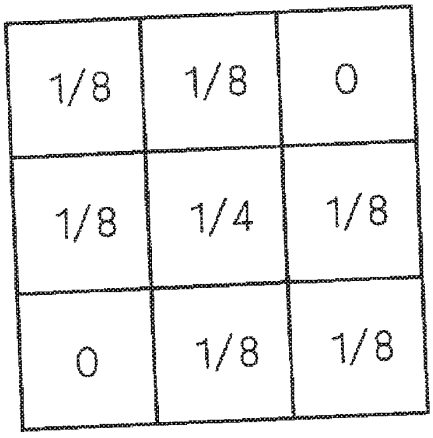


FIG. 10

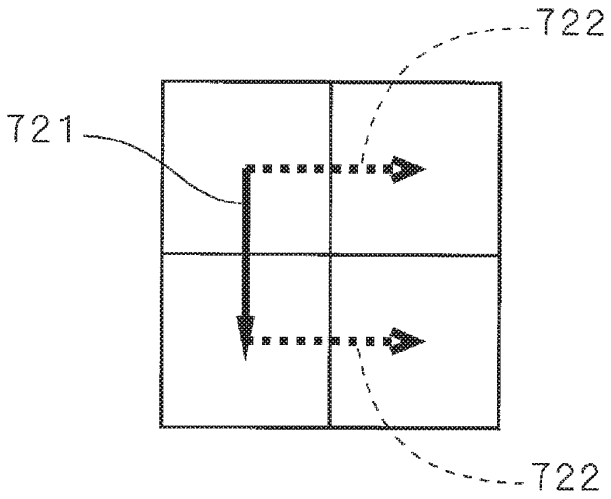


FIG. 11

0	0	0
0	1/4	1/4
0	1/4	1/4

FIG. 12

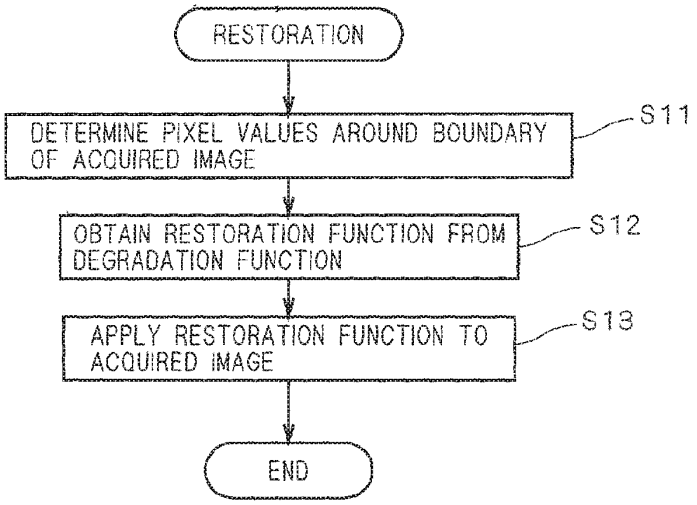

RESTORATION
DETERMINE PIXEL VALUES AROUND BOUNDARY OF ACQUIRED IMAGE
S11
OBTAIN RESTORATION FUNCTION FROM DEGRADATION FUNCTION
S12
APPLY RESTORATION FUNCTION TO ACQUIRED IMAGE
S13
END

FIG. 13

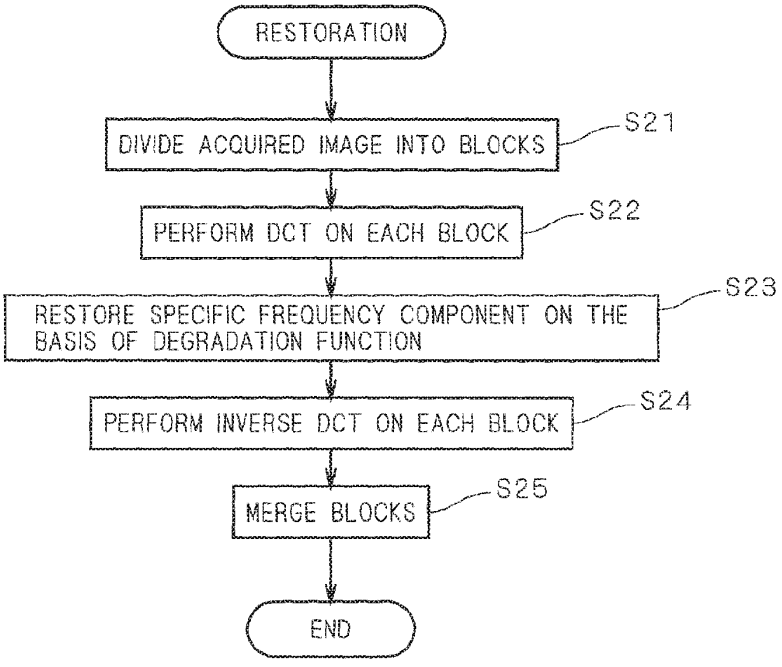

RESTORATION
DIVIDE ACQUIRED IMAGE INTO BLOCKS
S21
PERFORM DCT ON EACH BLOCK
S22
RESTORE SPECIFIC FREQUENCY COMPONENT ON THE BASIS OF DEGRADATION FUNCTION
S23
PERFORM INVERSE DCT ON EACH BLOCK
S24
MERGE BLOCKS
S25
END

FIG. 14

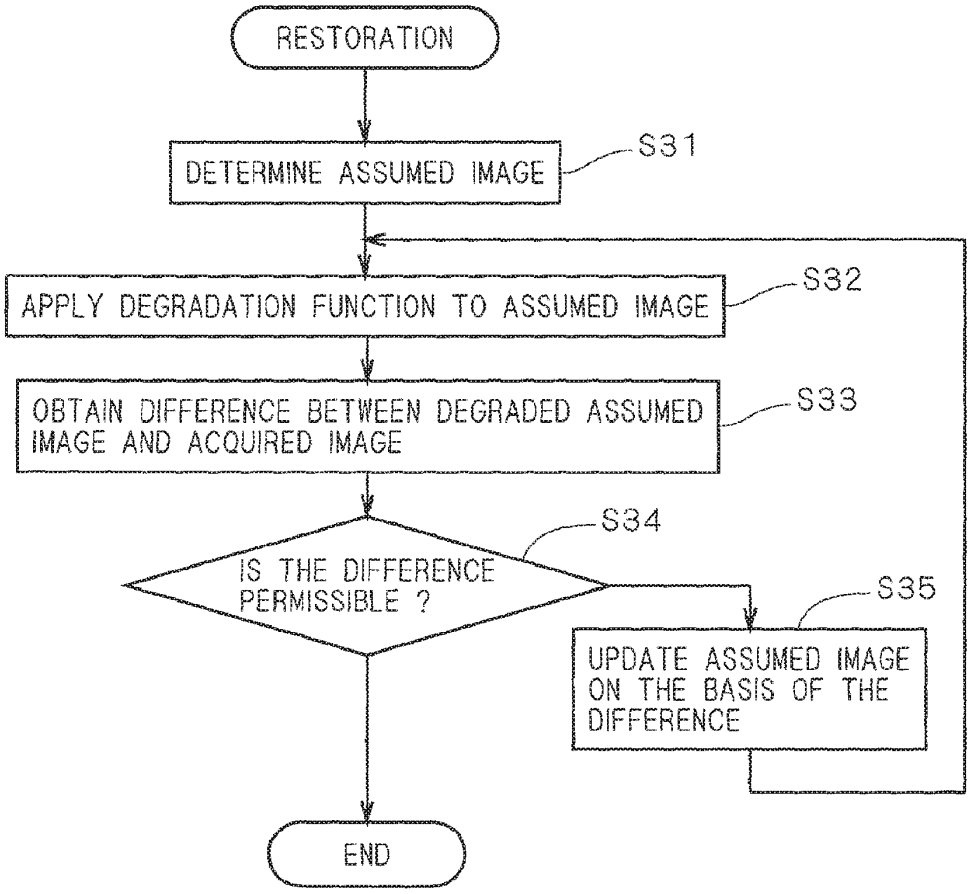
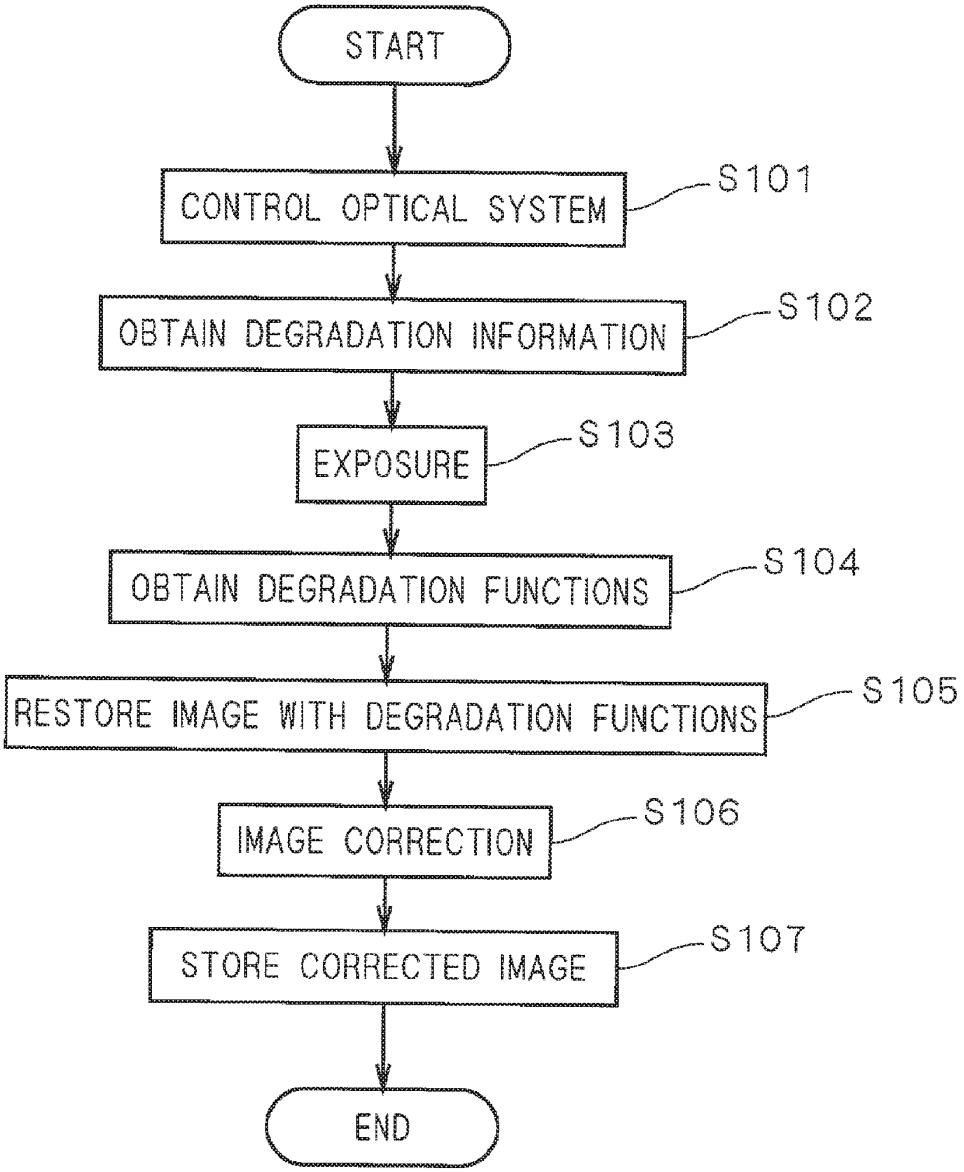

RESTORATION
DETERMINE ASSUMED IMAGE
S31
APPLY DEGRADATION FUNCTION TO ASSUMED IMAGE
S32
OBTAIN DIFFERENCE BETWEEN DEGRADED ASSUMED IMAGE AND ACQUIRED IMAGE
S33
IS THE DIFFERENCE PERMISSIBLE ?
S34
UPDATE ASSUMED IMAGE ON THE BASIS OF THE DIFFERENCE
S35
END

FIG. 15


START
CONTROL OPTICAL SYSTEM
S101
OBTAIN DEGRADATION INFORMATION
S102
EXPOSURE
S103
OBTAIN DEGRADATION FUNCTIONS
S104
RESTORE IMAGE WITH DEGRADATION FUNCTIONS
S105
IMAGE CORRECTION
S106
STORE CORRECTED IMAGE
S107
END

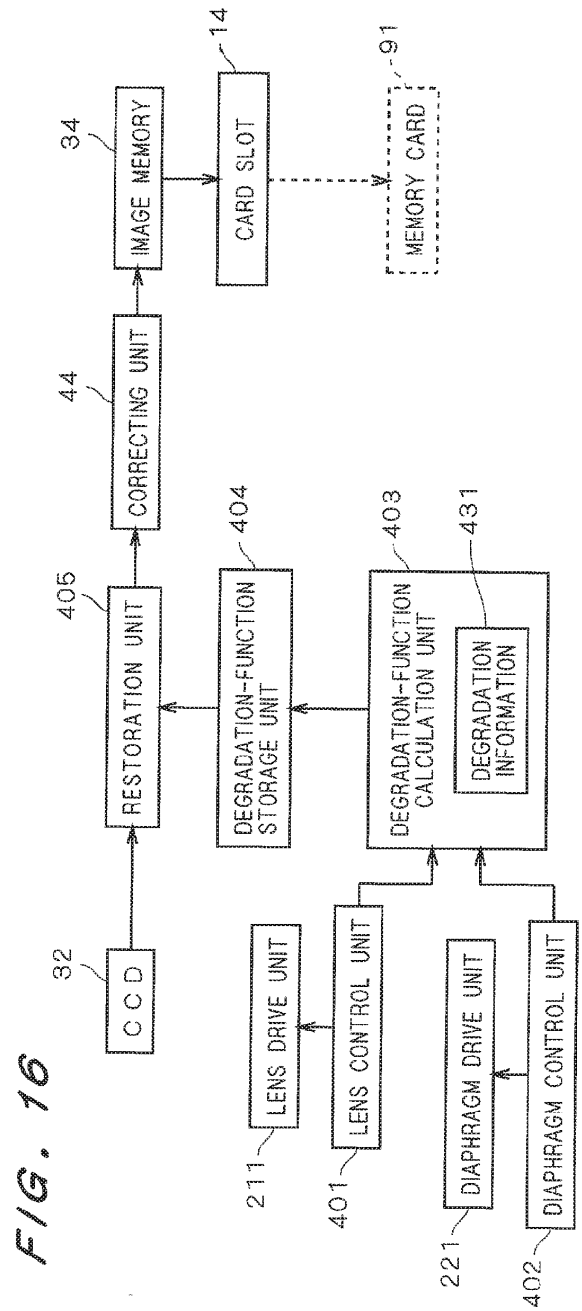


FIG. 16

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FIG. 17

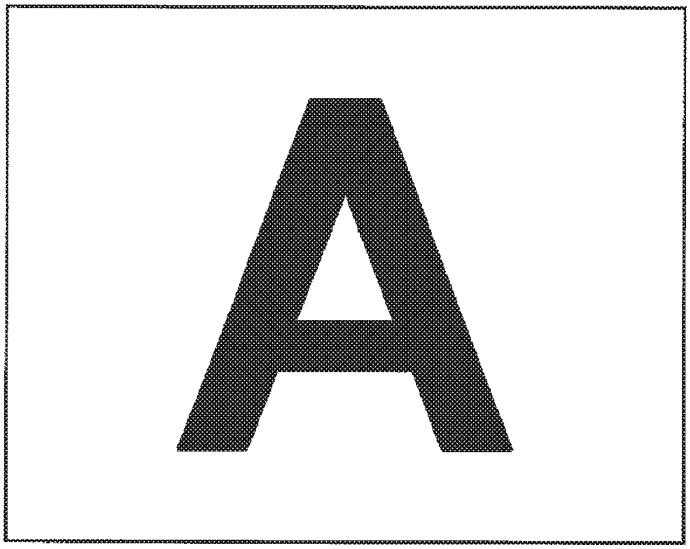


FIG. 18

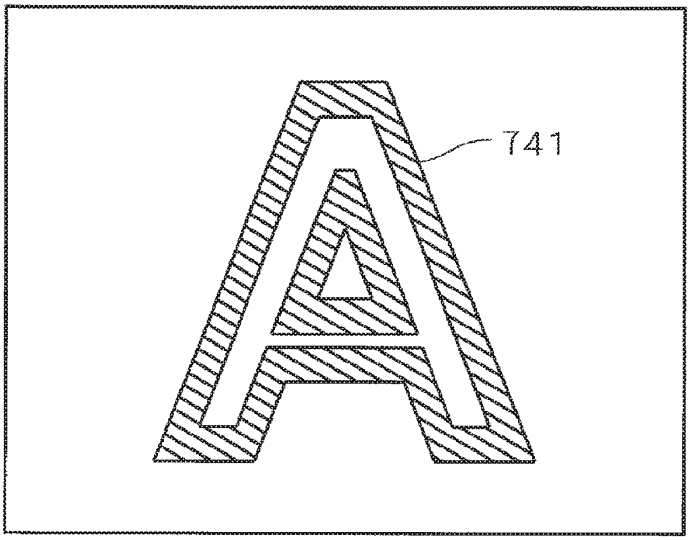
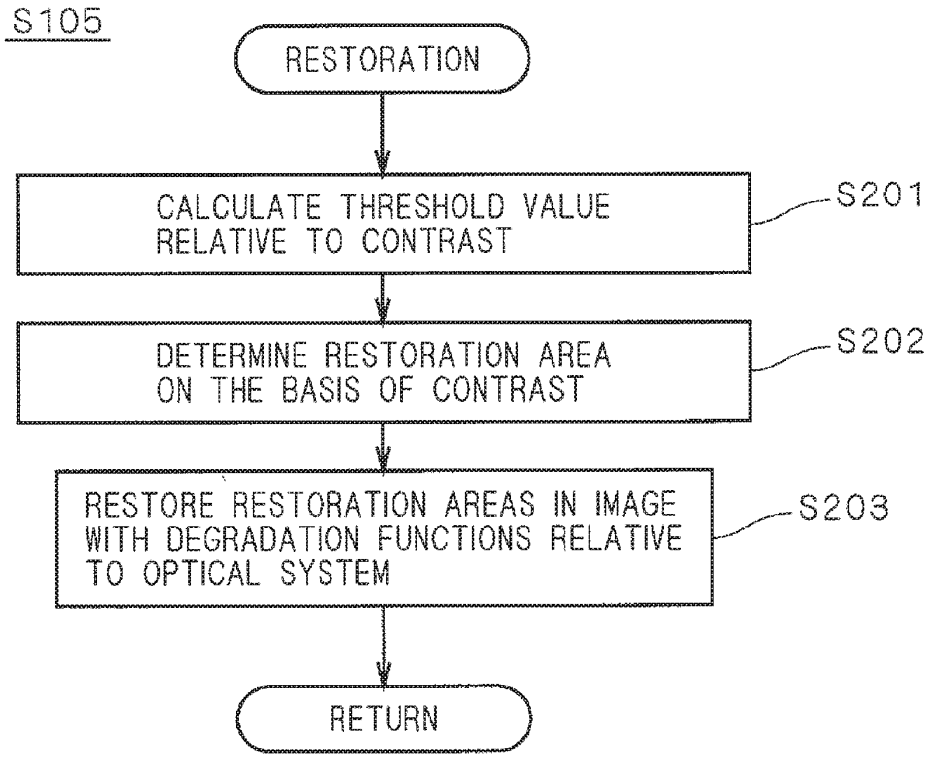


FIG. 19


S105
RESTORATION
CALCULATE THRESHOLD VALUE RELATIVE TO CONTRAST
S201
DETERMINE RESTORATION AREA ON THE BASIS OF CONTRAST
S202
RESTORE RESTORATION AREAS IN IMAGE WITH DEGRADATION FUNCTIONS RELATIVE TO OPTICAL SYSTEM
S203
RETURN

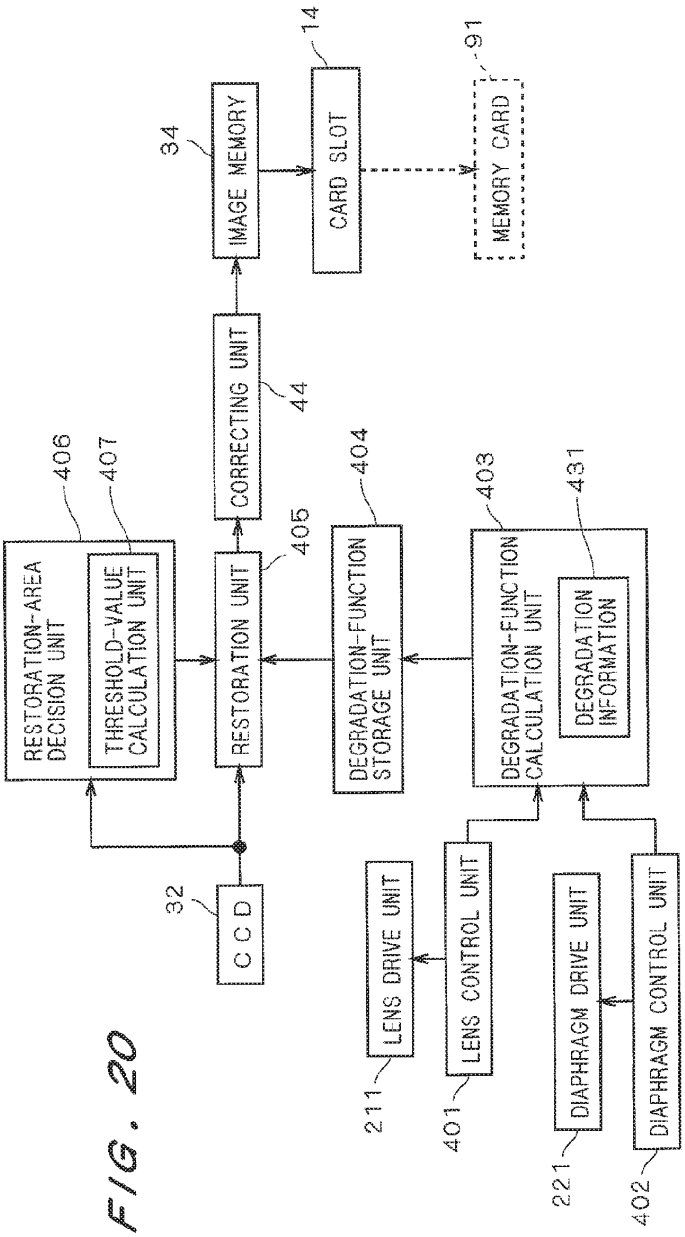


FIG. 20

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FIG. 21

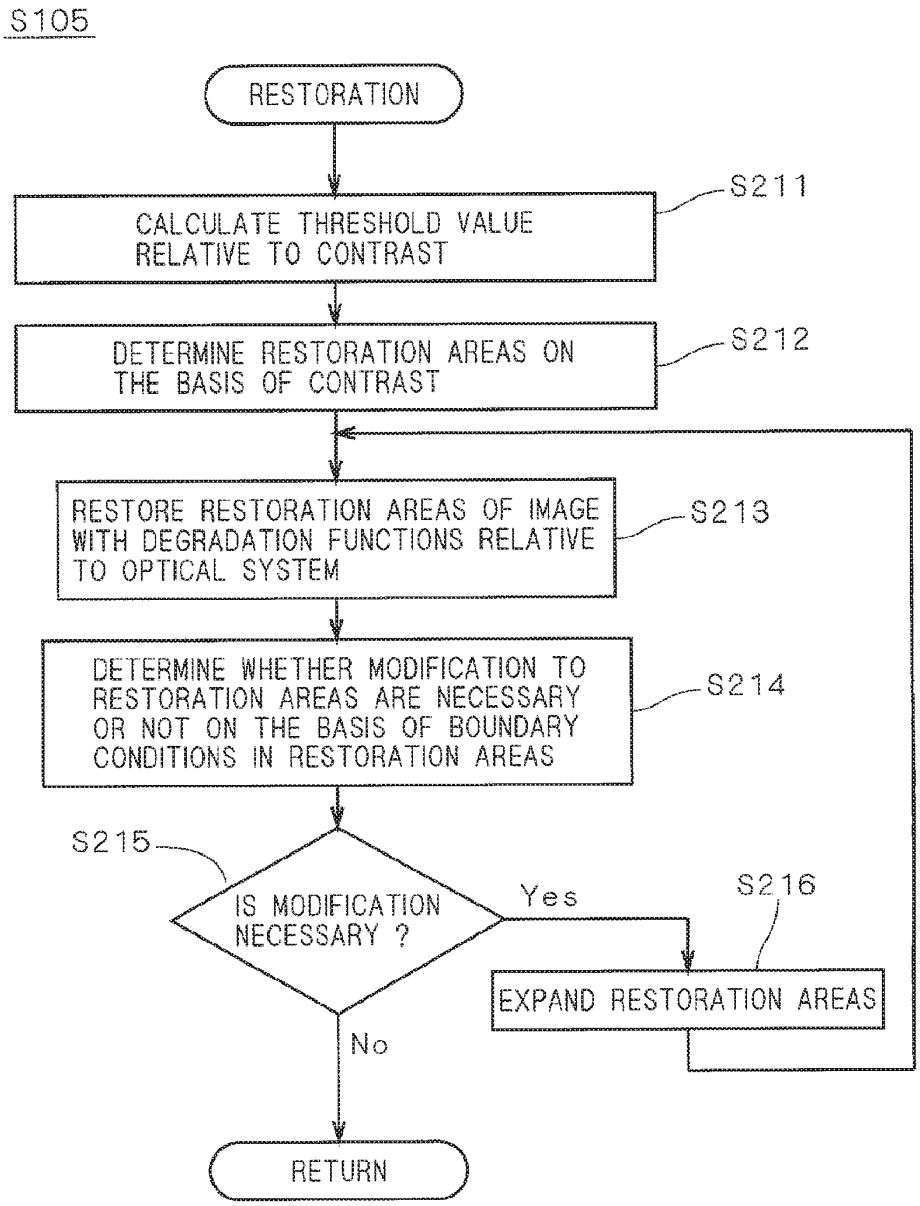
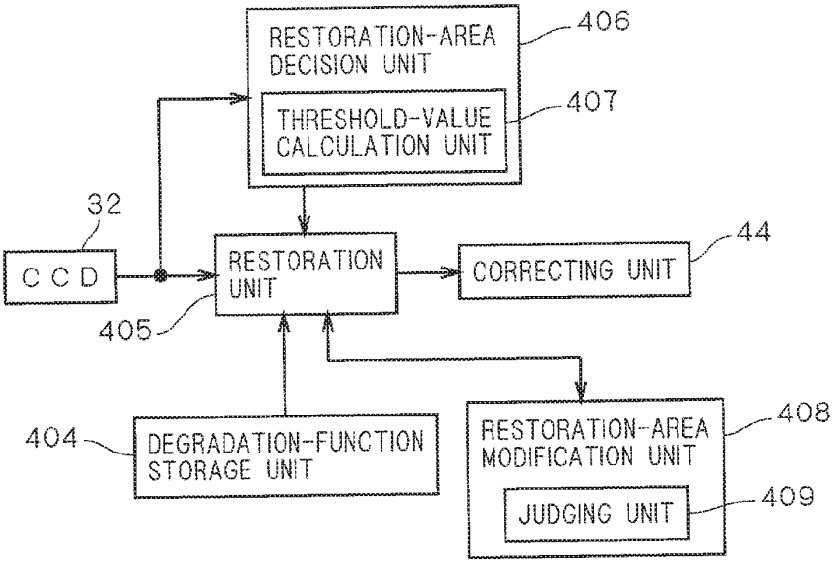

S105
RESTORATION
CALCULATE THRESHOLD VALUE RELATIVE TO CONTRAST
S211
DETERMINE RESTORATION AREAS ON THE BASIS OF CONTRAST
S212
RESTORE RESTORATION AREAS OF IMAGE WITH DEGRADATION FUNCTIONS RELATIVE TO OPTICAL SYSTEM
S213
DETERMINE WHETHER MODIFICATION TO RESTORATION AREAS ARE NECESSARY OR NOT ON THE BASIS OF BOUNDARY CONDITIONS IN RESTORATION AREAS
S214
S215
IS MODIFICATION NECESSARY ?
Yes
S216
EXPAND RESTORATION AREAS
No
RETURN

FIG. 22


RESTORATION-AREA DECISION UNIT
406
THRESHOLD-VALUE CALCULATION UNIT
407
32
CCD
RESTORATION UNIT
405
CORRECTING UNIT
44
404
DEGRADATION-FUNCTION STORAGE UNIT
RESTORATION-AREA MODIFICATION UNIT
408
JUDGING UNIT
409

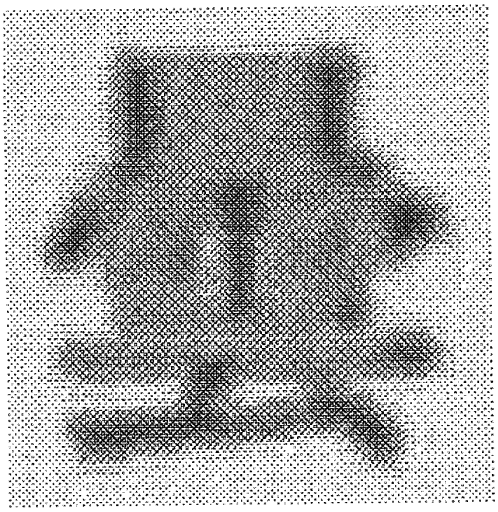


FIG. 23

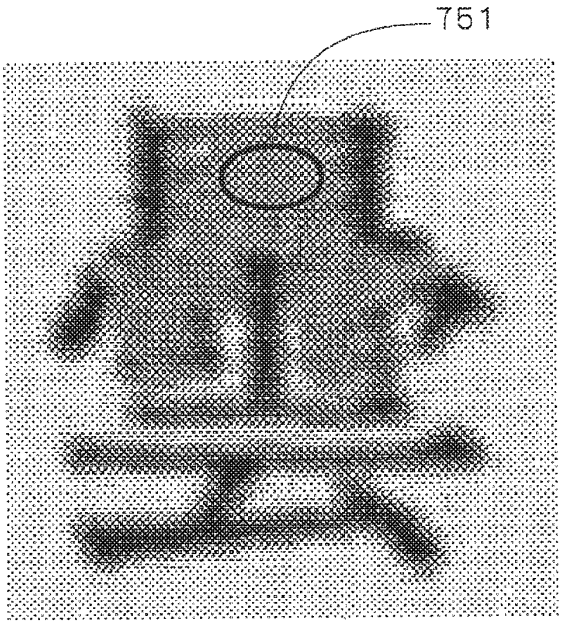


FIG. 24

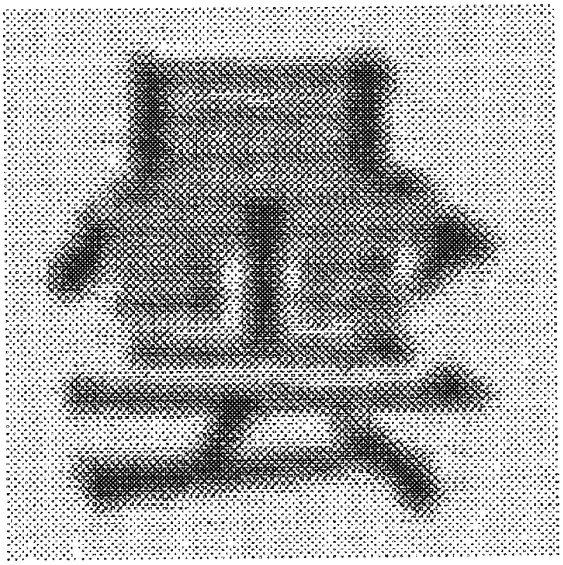


FIG. 25

FIG. 26

0	0	0	0	0
0	0	0	0	0
1/5	1/5	1/5	1/5	1/5
0	0	0	0	0
0	0	0	0	0

FIG. 27

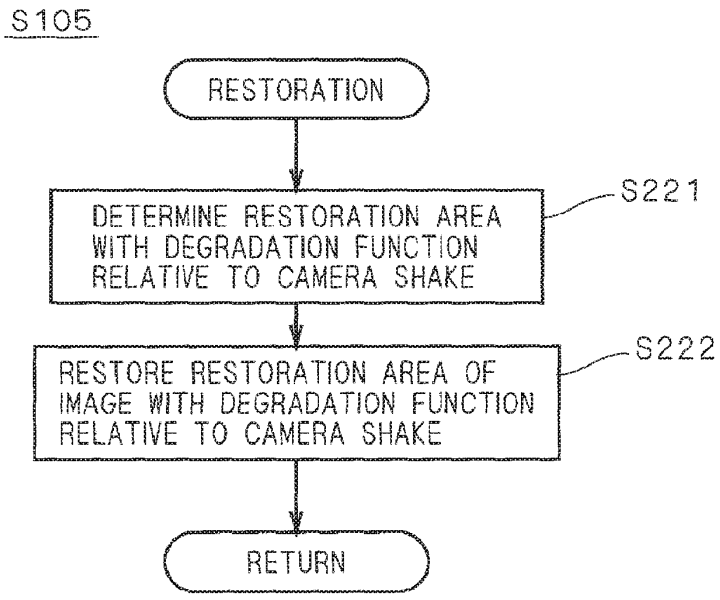
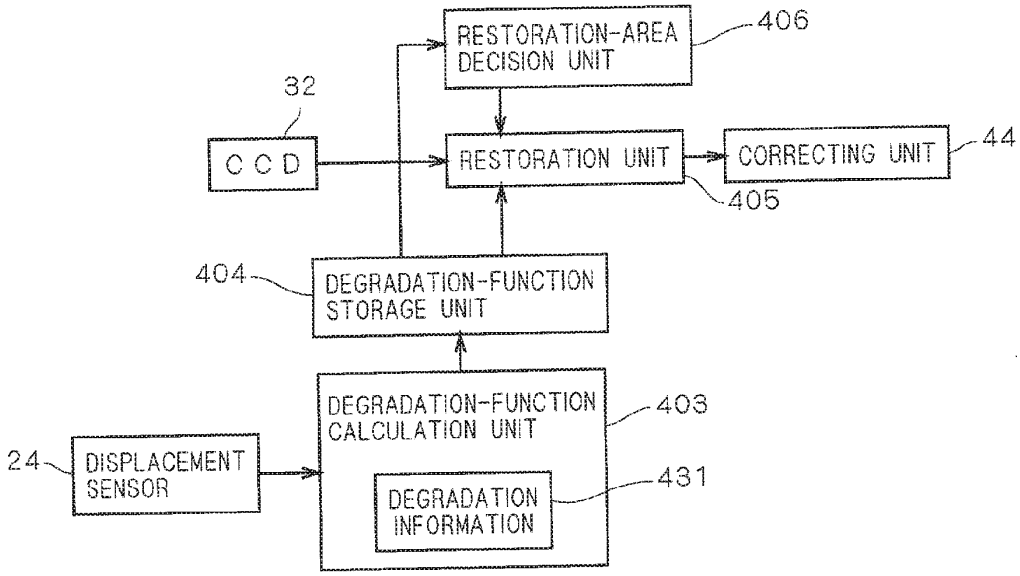


FIG. 28


RESTORATION-AREA DECISION UNIT
406
32
C C D
RESTORATION UNIT
CORRECTING UNIT
44
405
404
DEGRADATION-FUNCTION STORAGE UNIT
DEGRADATION-FUNCTION CALCULATION UNIT
403
24
DISPLACEMENT SENSOR
DEGRADATION INFORMATION
431

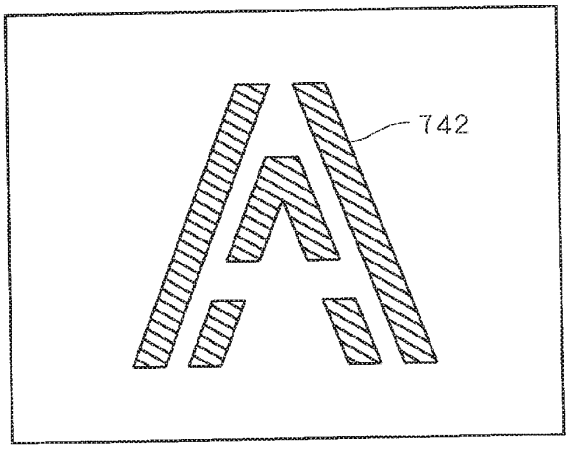

742

FIG. 29

FIG. 30

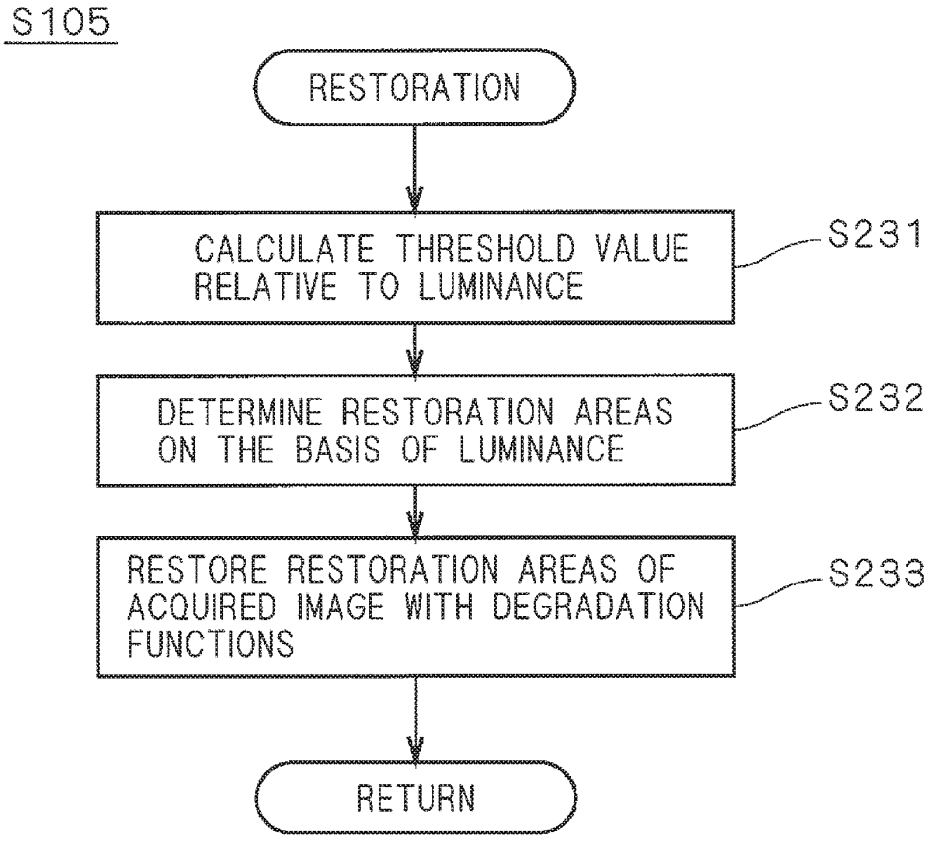

S105
RESTORATION
CALCULATE THRESHOLD VALUE RELATIVE TO LUMINANCE
S231
DETERMINE RESTORATION AREAS ON THE BASIS OF LUMINANCE
S232
RESTORE RESTORATION AREAS OF ACQUIRED IMAGE WITH DEGRADATION FUNCTIONS
S233
RETURN

FIG. 31

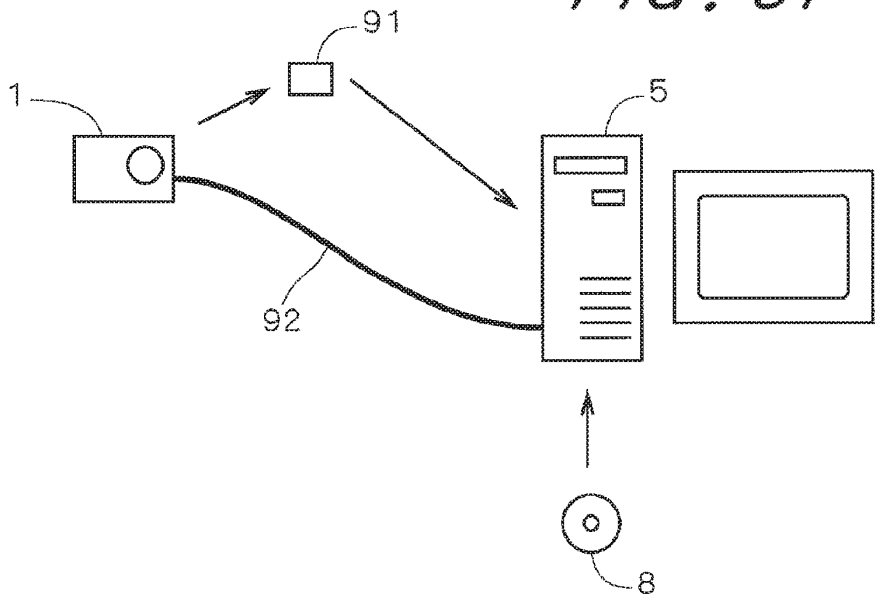

91
1
5
92
8

FIG. 32

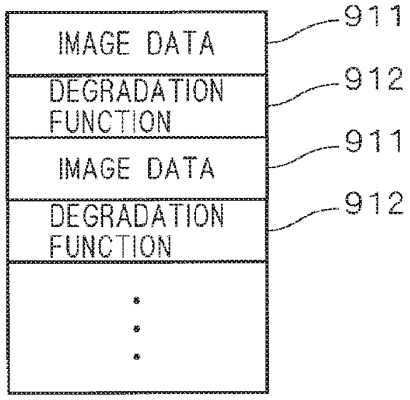

IMAGE DATA
911
DEGRADATION FUNCTION
912
IMAGE DATA
911
DEGRADATION FUNCTION
912

FIG. 33

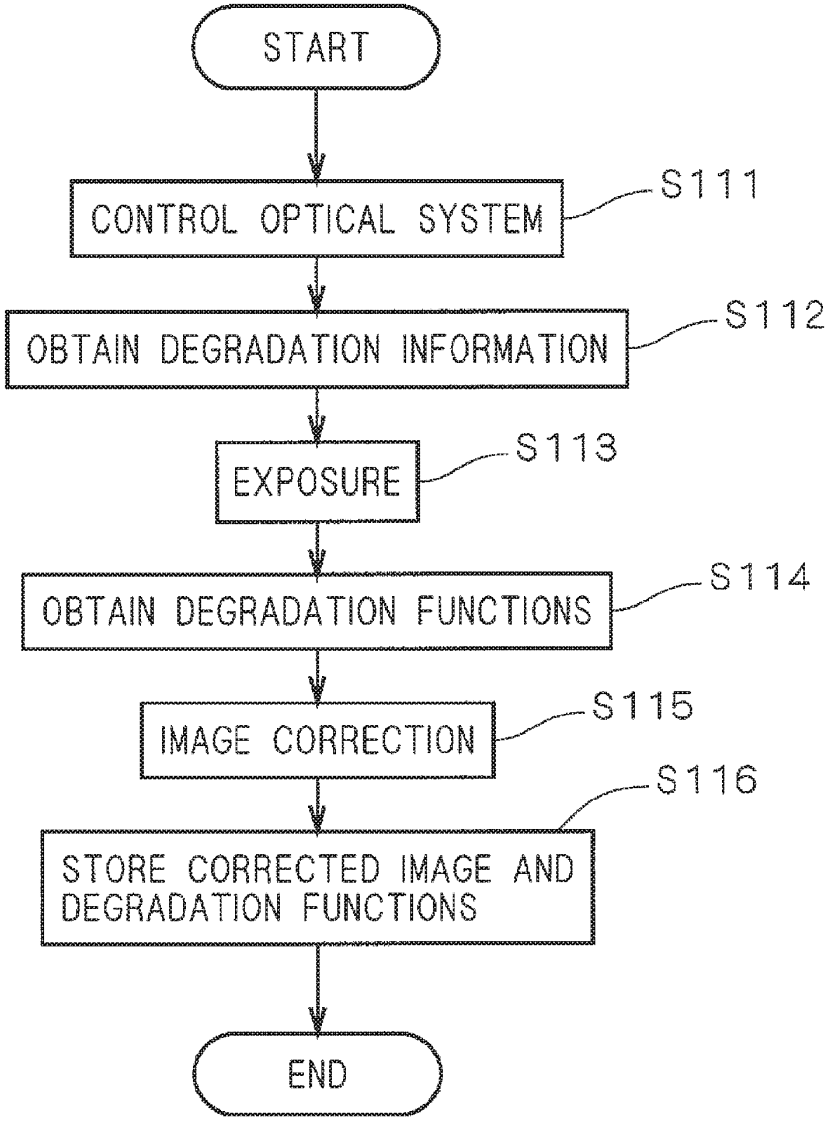

START
CONTROL OPTICAL SYSTEM
S111
OBTAIN DEGRADATION INFORMATION
S112
EXPOSURE
S113
OBTAIN DEGRADATION FUNCTIONS
S114
IMAGE CORRECTION
S115
STORE CORRECTED IMAGE AND DEGRADATION FUNCTIONS
S116
END

FIG. 34

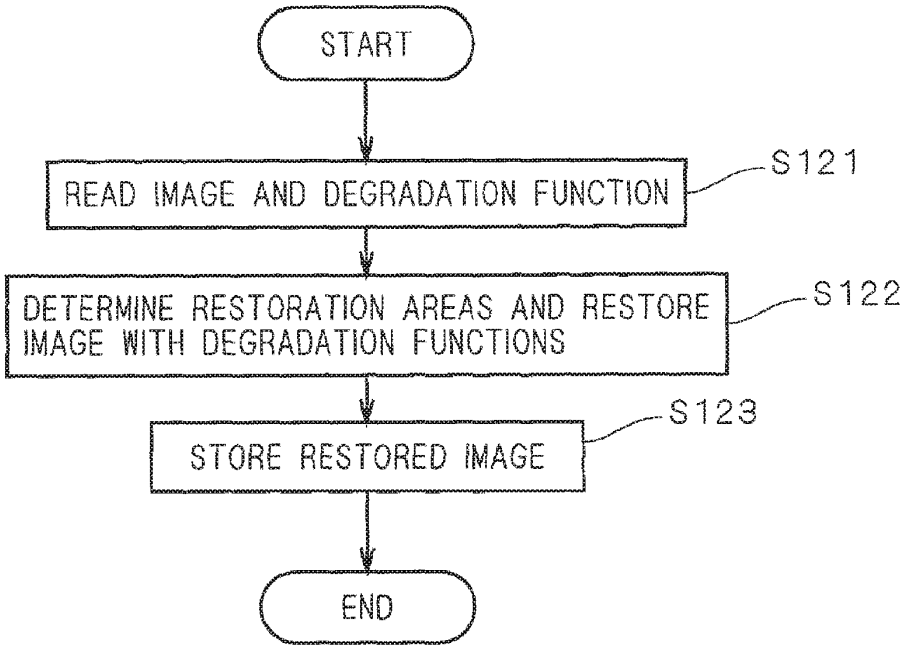

START
READ IMAGE AND DEGRADATION FUNCTION
S121
DETERMINE RESTORATION AREAS AND RESTORE IMAGE WITH DEGRADATION FUNCTIONS
S122
STORE RESTORED IMAGE
S123
END

FIG. 35

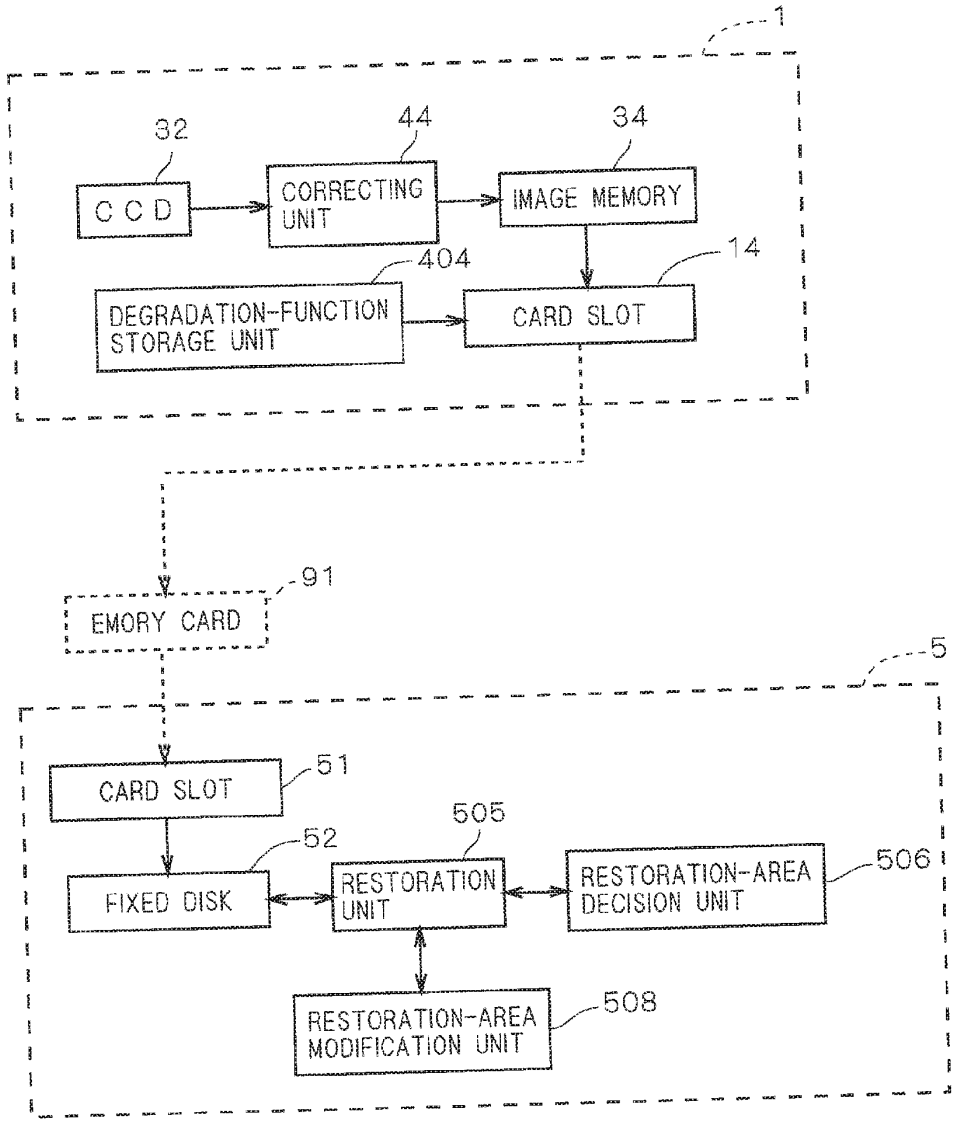

1
32
C C D
44
CORRECTING UNIT
34
IMAGE MEMORY
404
DEGRADATION-FUNCTION STORAGE UNIT
14
CARD SLOT
91
EMORY CARD
5
CARD SLOT
51
52
FIXED DISK
505
RESTORATION UNIT
RESTORATION-AREA DECISION UNIT
506
RESTORATION-AREA MODIFICATION UNIT
508

FIG. 36

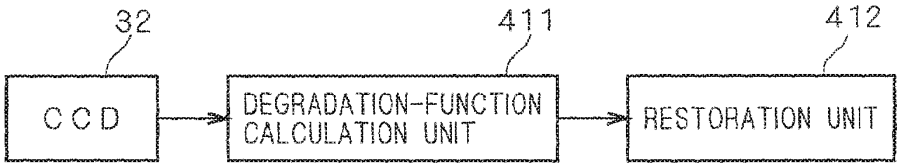

32
411
412
CCD
DEGRADATION-FUNCTION CALCULATION UNIT
RESTORATION UNIT

FIG. 37

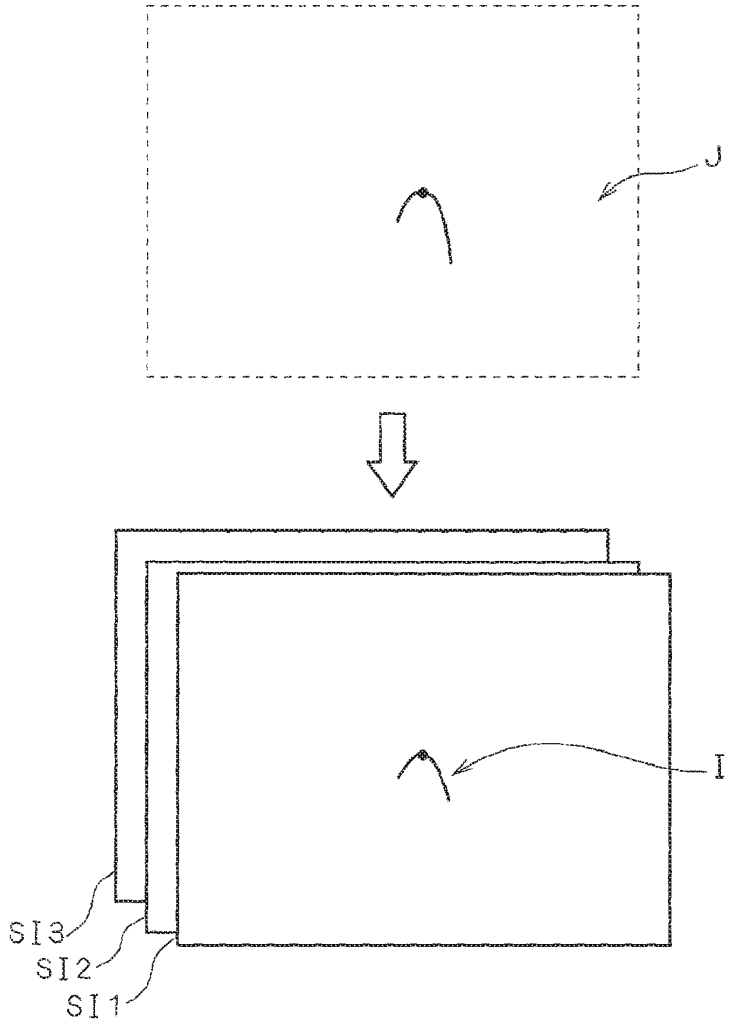

J
I
SI3
SI2
SI1

FIG. 38

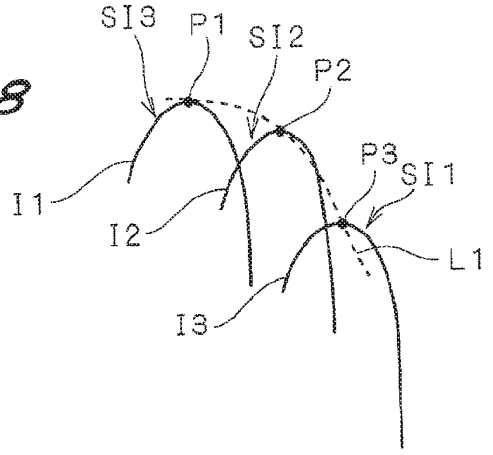


FIG. 39

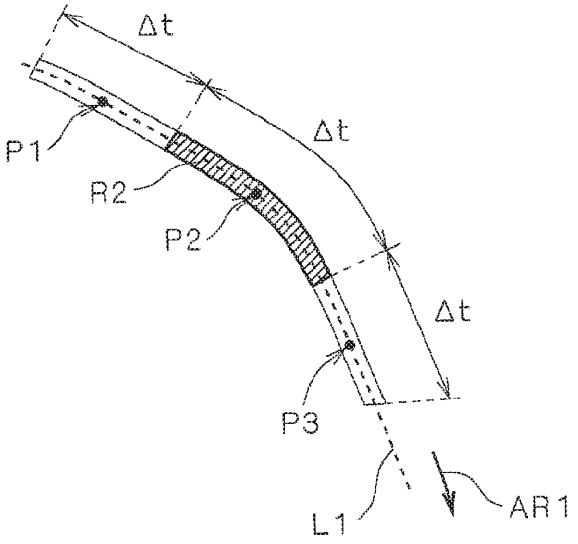


FIG. 40

0	0	0	0	0
$\frac{1}{5}$	$\frac{1}{5}$	0	0	0
0	0	$\frac{1}{5}$	0	0
0	0	0	$\frac{1}{5}$	0
0	0	0	0	$\frac{1}{5}$

FIG. 41

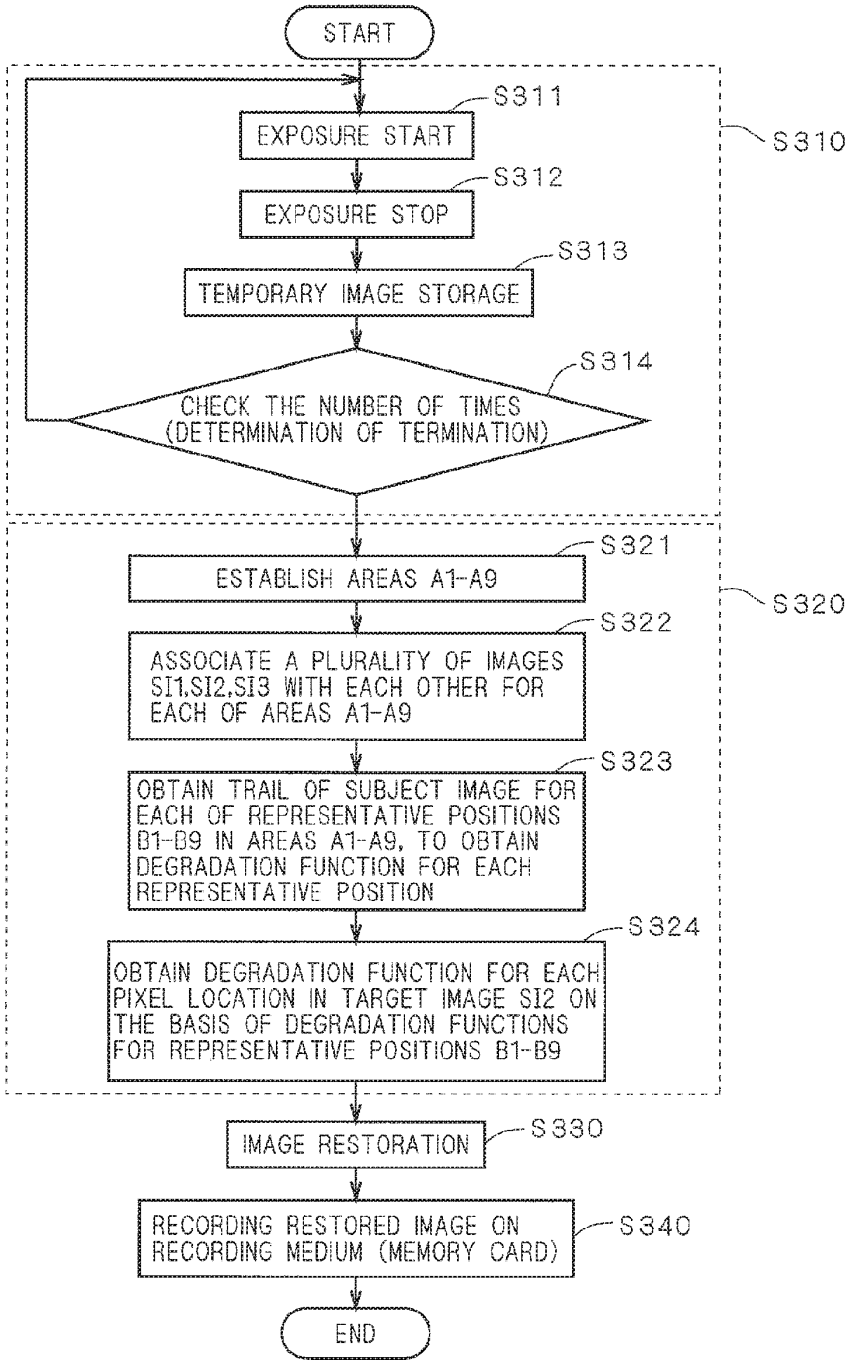

START
S311
EXPOSURE START
S312
EXPOSURE STOP
S313
TEMPORARY IMAGE STORAGE
S314
CHECK THE NUMBER OF TIMES (DETERMINATION OF TERMINATION)
S310
S321
ESTABLISH AREAS A1-A9
S322
ASSOCIATE A PLURALITY OF IMAGES SI1,SI2,SI3 WITH EACH OTHER FOR EACH OF AREAS A1-A9
S323
OBTAIN TRAIL OF SUBJECT IMAGE FOR EACH OF REPRESENTATIVE POSITIONS B1-B9 IN AREAS A1-A9, TO OBTAIN DEGRADATION FUNCTION FOR EACH REPRESENTATIVE POSITION
S324
OBTAIN DEGRADATION FUNCTION FOR EACH PIXEL LOCATION IN TARGET IMAGE SI2 ON THE BASIS OF DEGRADATION FUNCTIONS FOR REPRESENTATIVE POSITIONS B1-B9
S320
IMAGE RESTORATION
S330
RECORDING RESTORED IMAGE ON RECORDING MEDIUM (MEMORY CARD)
S340
END

FIG. 42

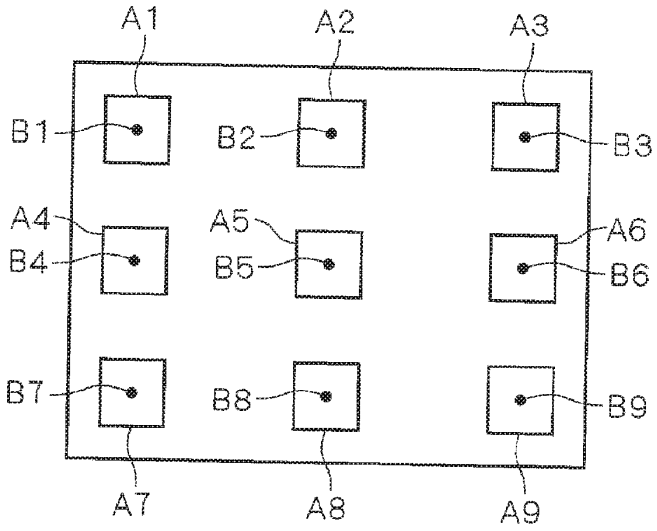
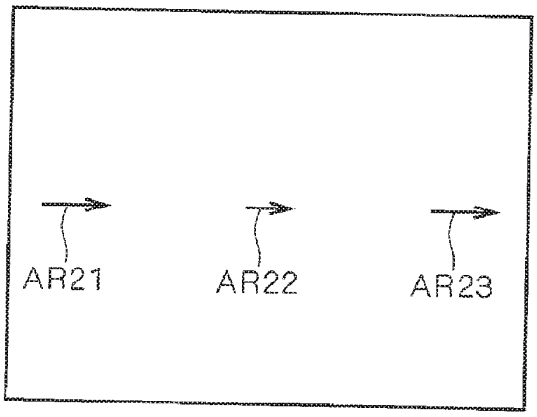


FIG. 43



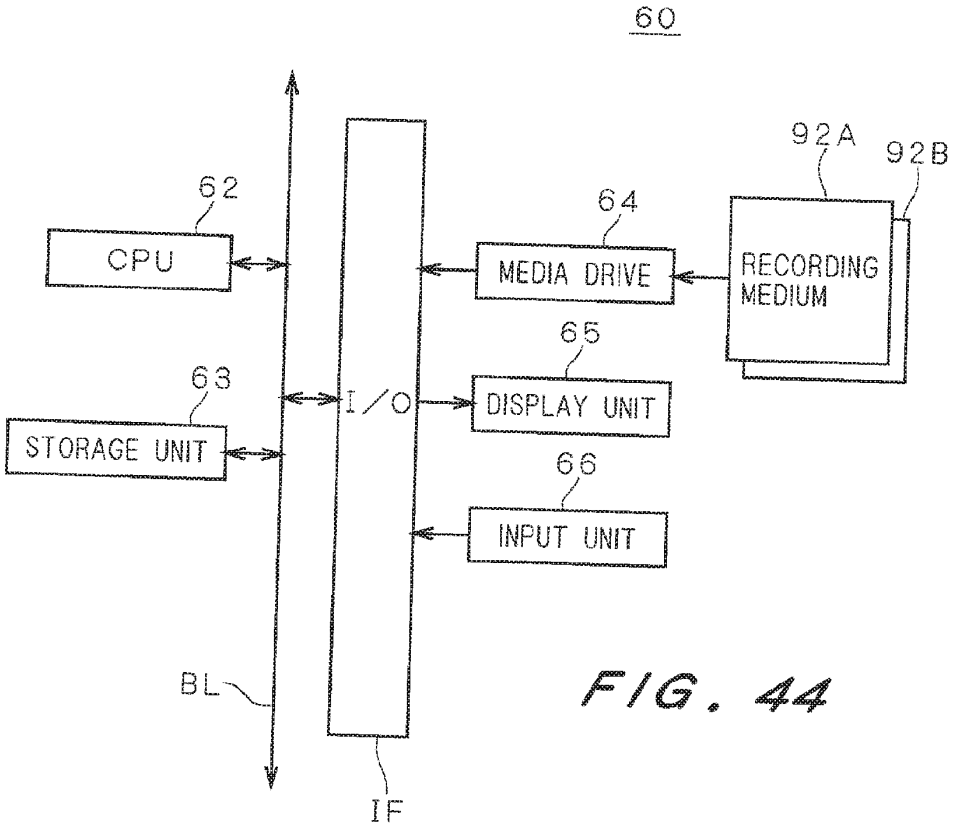

60
92A
92B
62
64
CPU
MEDIA DRIVE
RECORDING MEDIUM
65
63
I/O
DISPLAY UNIT
STORAGE UNIT
66
INPUT UNIT
BL
IF

FIG. 44

IMAGE PROCESSING APPARATUS AND METHOD

[0001] This application is based on applications Nos. 2000-4711, 2000-4941, and 2000-4942 filed in Japan, the entire contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to image processing techniques for restoring degraded image data obtained by image capture.

[0004] 2. Description of the Background Art

[0005] Conventionally, a variety of techniques have been proposed to restore a degraded image which is obtained as image data by the use of an array of light sensing elements which is typified by a CCD. Image degradation refers to degradation of an actually obtained image as compared with the ideal image which was supposed to be obtained from a subject. For example, an image captured by a digital camera suffers degradation from aberrations depending on an aperture value, a focal length, an in-focus lens position, and the like and from an optical low-pass filter provided for the prevention of spurious resolution.

[0006] Such a degraded image has conventionally been restored by modeling of image degradation for bringing the image close to the ideal image. Assuming for example that image degradation has come from the spread of incoming luminous fluxes according to a Gaussian distribution, the fluxes being supposed to enter each of the light sensing elements, image restoration is made by the application of a restoration function to the image or by the use of a filter (a so-called aperture compensation filter) for edge enhancement of the image.

[0007] The conventional image restoration techniques, however, take no account of actual causes of image degradation. Thus, it is frequently difficult to obtain an ideal image through the restoration.

[0008] Further, image degradation will not always occur in the whole image. For example when taking a subject with a geometrical pattern or a single-color background or when scanning a document for character recognition, an area that is not affected by degradation exists in an image. From this, restoration processing on the whole image can have an adverse effect on an area that does not require the restoration processing. For example, restoration processing on areas with edge or noise can cause ringing or noise enhancement, having an adverse effect on areas that do not require restoration.

[0009] On the other hand, an image capturing apparatus such as a digital camera may not be able to obtain ideal images because of its shake in image capture. Techniques for compensating for such image degradation due to shakes include a technique for correcting the obtained image with a shake sensor such as an acceleration sensor, and a technique for estimating shakes from a single image.

[0010] The above conventional techniques, however, have problems: for example, the former requires a special shake sensor and the latter has low precision in shake estimation.

SUMMARY OF THE INVENTION

[0011] An object of the present invention is to restore degraded images properly.

[0012] The present invention is directed to an image processing apparatus.

[0013] According to one aspect of the present invention, the image processing apparatus comprises: an obtaining section for obtaining image data generated by converting an optical image passing through an optical system into digital data; and a processing section for applying a degradation function based on a degradation characteristic of at least one optical element comprised in the optical system to the image data and restoring the image data by compensating for a degradation thereof. With the degradation function, image data can be restored properly according to the optical system.

[0014] According to another aspect of the present invention, the image processing apparatus comprises: a receiving section for receiving a plurality of image data sets generated by two or more consecutive image captures; a calculating section for calculating a degradation function on the basis of a difference between the plurality of image data sets; and a restoring section for restoring one of the plurality of image data sets by applying the degradation function. Thereby, one of the plurality of image data sets can be restored properly.

[0015] According to still another aspect of the present invention, the image processing apparatus comprises: a setting section for setting partial areas in a whole image, the partial areas being delimited according to contrast in the whole image; and a modulating section for modulating images comprised in the partial areas on the basis of a degradation characteristic of the whole image to restore the whole image. Thus, the partial areas to be restored can be determined properly according to contrast in the whole image. Alternatively, the partial areas may be determined on the basis of at least one degradation characteristic of the whole image or pixel values in the whole image.

[0016] According to still another aspect of the present invention, the image processing apparatus comprises: a setting section for setting areas to be modulated in a whole image; a restoring section for restoring the whole image by modulating images in the areas in accordance with a specified function; and an altering section for altering sizes of the areas in accordance with a restored whole image, wherein the restoring section again restores the whole image by modulating images in the areas whose sizes are altered by the altering section in accordance with the specified function. The alteration of the sizes of the areas to be restored enables more proper restoration of the whole image.

[0017] This invention is also directed to an image pick-up apparatus.

[0018] These and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] **FIG. 1** is a front view of a digital camera according to a first preferred embodiment;

[0020] **FIG. 2** is a rear view of the digital camera;

[0021] **FIG. 3** is a side view of the digital camera;

[0022] **FIG. 4** is a longitudinal cross-sectional view of a lens unit and its vicinity;

[0023] **FIG. 5** is a block diagram of a construction of the digital camera;

[0024] FIGS. **6** to **9** are explanatory diagrams of image degradation due to the lens unit;

[0025] **FIGS. 10 and 11** are explanatory diagrams of image degradation due to an optical low-pass filter;

[0026] **FIG. 12** is a flow chart of processing of a first image restoration method;

[0027] **FIG. 13** is a flow chart of processing of a second image restoration method;

[0028] **FIG. 14** is a flow chart of processing of a third image restoration method;

[0029] **FIG. 15** is a flow chart of the operation of the digital camera in image capture;

[0030] **FIG. 16** is a block diagram of functional components of the digital camera;

[0031] **FIG. 17** shows an example of an acquired image;

[0032] **FIG. 18** shows an example of restoration areas;

[0033] **FIG. 19** is a flow chart of restoration processing according to the second preferred embodiment;

[0034] **FIG. 20** is a block diagram of functional components of the digital camera;

[0035] **FIG. 21** is a flow chart of restoration processing according to a third preferred embodiment;

[0036] **FIG. 22** is a block diagram of part of functional components of a digital camera according to the third preferred embodiment;

[0037] **FIG. 23** shows an example of the acquired image;

[0038] **FIGS. 24 and 25** show examples of a restored image;

[0039] **FIG. 26** is an explanatory diagram of image degradation due to camera shake;

[0040] **FIG. 27** is a flow chart of restoration processing according to a fourth preferred embodiment;

[0041] **FIG. 28** is a block diagram of part of functional components of a digital camera according to the fourth preferred embodiment;

[0042] **FIG. 29** shows an example of the restoration areas;

[0043] **FIG. 30** is a flow chart of restoration processing according to a fifth preferred embodiment;

[0044] **FIG. 31** shows a whole configuration according to a sixth preferred embodiment;

[0045] **FIG. 32** is a schematic diagram of a data structure in a memory card;

[0046] **FIG. 33** is a flow chart of the operation of the digital camera in image capture;

[0047] **FIG. 34** is a flow chart of the operation of a computer;

[0048] **FIG. 35** is a block diagram of functional components of the digital camera and the computer;

[0049] **FIG. 36** is a block diagram of functional components of the digital camera **1**;

[0050] **FIG. 37** is a schematic diagram of continuously captured images SI1, SI2, and SI3 of a subject;

[0051] **FIG. 38** is a schematic diagram of a track L1 that a subject image describes in the images SI1, SI2, and SI3 due to camera shake;

[0052] **FIG. 39** is an enlarged view of representative points P1, P2, P3 of the subject image and their vicinity in the images SI1, SI2, SI3;

[0053] **FIG. 40** shows an example of a two-dimensional filter (degradation function);

[0054] **FIG. 41** is a flow chart of process operations of the digital camera **1**;

[0055] **FIG. 42** shows representative positions B1 to B9 and areas A1 to A9;

[0056] **FIG. 43** is a schematic diagram showing differences in the amount of camera shake among central and end areas;

[0057] **FIG. 44** is a schematic diagram of a computer **60**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

1. First Preferred Embodiment

1-1. Construction of Digital Camera

[0058] FIGS. **1** to **3** are external views of a digital camera **1** according to a first preferred embodiment of the present invention. **FIG. 1** is a front view; **FIG. 2** is a rear view; and **FIG. 3** is a left side view. **FIGS. 1 and 2** show how the digital camera **1** loads a memory card **91**, which is not shown in **FIG. 3**.

[0059] The digital camera **1** is principally similar in construction to previously known digital cameras. As shown in **FIG. 1, a** lens unit **2** for conducting light from a subject to a CCD and a flash **11** for emitting flash light to a subject are located on the front, and a viewfinder **12** for capturing a subject is located above the lens unit **2**.

[0060] Further, a shutter button **13** to be pressed in a shooting operation is located on the upper surface and a card slot **14** for loading the memory card **91** is provided in the left side surface.

[0061] On the back of the digital camera **1**, as shown in **FIG. 2**, there are a liquid crystal display **15** for display of images obtained by shooting or display of operating screens, a selection switch **161** for switching between recording and playback modes, a 4-way key **162** for a user to allow selective input, and the like.

[0062] **FIG. 4** is a longitudinal cross-sectional view of the internal structure of the digital camera **1** in the vicinity of the lens unit **2**. The lens unit **2** has a built-in lens system **21** comprised of a plurality of lens, and a built-in diaphragm **22**.

Behind the lens unit **2**, an optical low-pass filter **31** and a single-plate color CCD **32** with a two-dimensional array of light sensing elements are located in this order. That is, the lens system **21**, the diaphragm **22**, and the optical low-pass filter **31** constitute an optical system for conducting light from a subject into the CCD **32** in the digital camera **1**.

[0063] **FIG. 5** is a block diagram of prime components of the digital camera **1** relative to the operation thereof. In **FIG. 5**, the shutter button **13**, the selection switch **161**, and the 4-way key **162** are shown in one block as an operating unit **16**.

[0064] A CPU **41**, a ROM **42**, and a RAM **43** shown in **FIG. 5** control the overall operation of the digital camera **1**, and together with the CPU **41**, the ROM **42**, and the RAM **43**, a variety of components are connected as appropriate to a bus line. The CPU **41** performs computations according to a program **421** in the ROM **42**, using the RAM **43** as a work area, whereby the operation of each unit and image processing are performed in the digital camera **1**.

[0065] The lens unit **2** comprises, along with the lens system **21** and the diaphragm **22**, a lens drive unit **211** and a diaphragm drive unit **221** for driving the lens system **21** and the diaphragm **22**, respectively. The CPU **41** controls the lens system **21** and the diaphragm **22** as appropriate in response to output from a distance-measuring sensor and subject brightness.

[0066] The CCD **32** is connected to an A/D converter **33** and outputs a subject image, which is formed through the lens system **21**, the diaphragm **22**, and the optical low-pass filter **31**, to the A/D converter **33** as image signals. The image signals are converted into digital signals (hereinafter referred to as "image data") by the A/D converter **33** and stored in an image memory **34**. That is, the optical system, the CCD **32**, and the A/D converter **33** obtain a subject image as image data.

[0067] A correcting unit **44** performs a variety of image processing such as white balance control, gamma correction, noise removal, color correction, and color enhancement on the image data in the image memory **34**. The corrected image data is transferred to a VRAM (video RAM) **151**, whereby an image appears on the display **15**. By the user's operation, the image data is recorded as necessary on the memory card **91** through the card slot **14**.

[0068] The digital camera **1** further performs processing for restoration of degradation in the image data obtained, due to the influences of the optical system. This restoration processing is implemented by the CPU **41** performing computations according to the program **421** in the ROM **42**. Substantially, image processing (correction and restoration) in the digital camera **1** is performed on the image data, but in the following description, the "image data" to be processed is simply referred to as an "image" as appropriate.

1-2. Image Degradation due to Optical System

[0069] Next, image degradation in the digital camera **1** is discussed. The image degradation refers to a phenomenon that images obtained through the CCD **32**, the A/D converter **33**, and the like in the digital camera **1** are not ideal images. Such image degradation results from a spreading distribution of a luminous flux, which comes from one point on a subject, over the CCD **32** without converging to a single point thereon. In other words, a luminous flux which is supposed to be received by a single light sensing element (i.e., a pixel) of the CCD **32** in an ideal image, spreads to neighboring light sensing elements, thereby causing image degradation.

[0070] In the digital camera **1**, image degradation due to the optical system, which is primarily composed of the lens system **21**, the diaphragm **22**, and the optical low-pass filter **31**, is restored.

[0071] **FIG. 6** is an explanatory diagram of image degradation due to the lens unit **2**. The reference numeral **71** in **FIG. 6** designates a whole image. If an area designated by the reference numeral **701** shall be illuminated in an image which does not suffer degradation due to the influences of the optical system (hereinafter referred to as an "ideal image"), an area **711** larger than the area **701** is illuminated in an image actually obtained (hereinafter referred to as an "acquired image") in response to the focal length and the in-focus lens position (corresponding to the amount of travel for a zoom lens) in the lens system **21** and the aperture value of the diaphragm **22**. That is, a luminous flux which should ideally enter the area **701** of the CCD **32** spreads across the area **711** in practice.

[0072] The same can be said of the periphery of the image **71**. If an area designated by the reference numeral **702** shall be illuminated in the ideal image, a generally elliptical area enlarged as designated by the reference numeral **712** is illuminated in the acquired image.

[0073] FIGS. **7** to **9** are schematic diagrams for explaining image degradation due to the optical influence of the lens unit **2** at the level of light sensing elements. **FIG. 7** shows that without the influence of the lens unit **2** (i.e., in the ideal image), a luminous flux with light intensity **1** is received by only a light sensing element in the center of 3×3 light sensing elements. **FIGS. 8 and 9**, on the other hand, show how the influence of the lens unit **2** changes the state shown in **FIG. 7**.

[0074] **FIG. 8** shows, by way of example, the state near the center of the CCD **32**, where light with intensity 1/3 is received by a central light sensing element while light with intensity 1/6 is received by upper/lower and right/left light sensing elements adjacent to the central light sensing element. That is, a luminous flux which is supposed to be received by the central light sensing element spreads therearound by the influence of the lens unit **2**. **FIG. 9** shows, by way of example, the state in the periphery of the CCD **32**, where light with intensity 1/4 is received by a central light sensing element while light with intensity 1/8 is received by neighboring light sensing elements, spreading from top left to bottom right.

[0075] Such a degradation characteristic of the image can be expressed as a function (i.e., a two-dimensional filter based on point spread) that converts each pixel value in the ideal image into a distribution of pixel values as illustrated in **FIGS. 8 and 9**; therefore, it is called a degradation function (or degradation filter).

[0076] A degradation function indicating the degradation characteristic due to the influence of the lens unit **2** can previously be obtained for every position of a light sensing element (i.e., for every pixel location) on the basis of the focal length and the in-focus lens position in the lens system

21 and the aperture value of the diaphragm 22. From this, the digital camera 1, as will be described later, obtains information about the arrangement of lenses and the aperture value from the lens unit 2 to obtain a degradation function for each pixel location, thereby achieving a restoration of the acquired image on the basis of the degradation functions.

[0077] The degradation function relative to the lens unit 2 is generally a nonlinear function using, as its parameters, the focal length, the in-focus lens position, the aperture value, two-dimensional coordinates in the CCD 32 (i.e., 2D coordinates of pixels in the image), and the like. For convenience's sake, FIGS. 7 to 9 contain no mention of the color of the image; however for color images, a degradation function for each of R, G, B colors or a degradation function which is a summation of the degradation functions for such colors is obtained. For simplification of the process, chromatic aberration may be ignored to make degradation functions for R, G, B colors equal to each other.

[0078] FIG. 10 is a schematic diagram for explaining degradation due to the optical low-pass filter 31 at the level of light sensing elements of the CCD 32. The optical low-pass filter 31 is provided for preventing spurious resolution by setting a band limit using birefringent optical materials. For a single-plate color CCD, as shown in FIG. 10, light which is supposed to be received by the upper left light sensing element is first distributed between the upper and lower left light sensing elements as indicated by an arrow 721, and then between the upper right and left light sensing elements and between the lower right and left light sensing elements as indicated by arrows 722.

[0079] In a single-plate color CCD, two light sensing elements on the diagonal out of four light sensing elements adjacent to each other, are provided with green (G) filters and the remaining two light sensing elements are provided with red (R) and blue (B) filters, respectively. R, G, B values of each pixel are obtained by interpolation with reference to information obtained from its neighboring pixels. In the single-plate color CCD, however, there are green pixels twice as much as red or blue pixels; therefore, the use of data from the CCD without any modification results in the creation of an image whose green resolution is higher than red and blue resolutions. Accordingly, high-frequency components, which cannot be obtained with the light sensing elements provided with R or B filters, appear in a subject image as spurious resolution.

[0080] From this reason, the optical low-pass filter 31 having the property as illustrated in FIG. 10 is provided on the front of the CCD 32. However, the influence of this optical low-pass filter 31 causes degradation of high-frequency components, which are obtained with the green light sensing elements, in an image.

[0081] FIG. 11 illustrates the distribution of a luminous flux which were supposed to be received by a central light sensing element, in the presence of the optical low-pass filter 31 having the property as illustrated in FIG. 10. That is, it schematically shows the characteristic of a degradation function relative to the optical low-pass filter 31. As shown in FIG. 11, the optical low-pass filter 31 distributes a luminous flux which is supposed to be received by a central light sensing element among 2×2 light sensing elements. From this, the digital camera 1, as will be described later, prepares a degradation function relative to the optical low-pass filter 31 beforehand, thereby achieving a restoration of the acquired image on the basis of the degradation function.

[0082] In the process of restoration using the degradation function relative to the optical low-pass filter 31, a luminance component is obtained from R, G, B values of each pixel after interpolation and this luminance component is restored. As an alternative to the restoration technique described above, G components may be restored after interpolation and interpolation using restored G components may be performed for R and B components.

[0083] While in the foregoing description the degradation function is obtained for each pixel, a summation of degradation functions for a plurality of pixels or for all pixels (i.e., a transformation matrix corresponding to degradation of a plurality of pixels) may be used.

1-3. Image Restoration

[0084] Next, three concrete examples of restoration of the acquired image with the degradation function are mentioned. The digital camera 1 can adopt any of the following three image restoration methods.

[0085] FIG. 12 is a flow chart of processing of a first image restoration method. The first image restoration method is for obtaining a restoration function from a degradation function and applying the restoration function to the acquired image for restoration.

[0086] Consider a degraded image which is obtained by applying a degradation function to each pixel in the ideal image. Since the degradation function has the function of using each pixel value to alter its neighboring pixel values, the degraded image is larger in size than the ideal image. Here, if the ideal image and the acquired image are the same in size, the degraded image from which peripheral pixels are deleted can be considered as the acquired image. Therefore, when obtaining a restoration function for inverse transformation of the degradation function, there is no information about the outside (i.e., the outer periphery) of an area to be processed and therefore a proper restoration function cannot be obtained.

[0087] In the first image restoration method, virtual pixels are first provided outside the area to be processed and pixel values of those virtual pixels are determined as appropriate (step S11). For example, pixel values on the inner side of the boundary of the acquired image are used as-is as pixel values on the outer side of the boundary. From this, it can be assumed that a vector Y which is an array of pixel values in an after-modification acquired image and a vector X which is an array of pixel values in the ideal image satisfy the following equation:

$$HX=Y \tag{1}$$

[0088] where a matrix H is the degradation function to be applied to the whole ideal image (hereinafter referred to as an "image degradation function") which is obtained by summation of degradation functions for all pixels.

[0089] Then, an inverse matrix H^{-1} of the matrix H, which is an image degradation function, is obtained as a restoration function for image restoration (step S12), and the vector X is obtained from the following equation:

$$X=H^{-1}Y \tag{2}$$

[0090] That is, the restoration function is applied to the after-modification acquired image for image restoration (step S13).

[0091] FIG. 13 is a flow chart of processing of a second image restoration method. Since the degradation function generally has the characteristic of reducing a specific frequency component in the ideal image, the second image restoration method makes a restoration of a specific frequency component in the acquired image for image restoration.

[0092] First, the acquired image is divided into blocks each consisting of a predetermined number of pixels (step S21) and a two-dimensional Fourier transform (i.e., discrete cosine transform (DCT)) is performed on each block, thereby to convert each block into frequency space (step S22).

[0093] Then, a reduced frequency component is restored on the basis of the characteristic of the degradation function (step S23). More specifically, each Fourier-transformed block is divided by a Fourier-transformed degradation function, then inversely Fourier-transformed (inverse DCT) (step S24) and those restored blocks are merged to obtain a restored image (step S25).

[0094] FIG. 14 is a flow chart of processing of a third image restoration method. The third image restoration method is for assuming a before-degradation image (hereinafter, the image assumed is referred to as an "assumed image") and updating the assumed image by an iterative method, thereby to obtain a before-degradation image.

[0095] First, the acquired image is used as an initial assumed image (step S31). Then, the degradation function (precisely, the matrix or image degradation function H) is applied to the assumed image (step S32) and a difference between an image obtained and the acquired image is found (step S33). The assumed image is then updated on the basis of the difference (step S35).

[0096] More specifically, on the basis of the vector Y representing the acquired image and the vector X representing the assumed image, a vector X that satisfies the following equation with the minimum value is obtained as an after-modification assumed image:

$$[Y-HX]^T[W][Y-HX] \quad (3)$$

[0097] where W is the weighing matrix (or may be the unit matrix).

[0098] After that, the update of the assumed image is repeated until the difference between the acquired image and the degraded assumed image comes within permissible levels (step S34). The assumed image eventually obtained becomes a restored image.

[0099] That is, a sum of the squares of differences between each pixel value in the acquired image and a corresponding pixel value in the assumed image (or a sum of the loaded squares) is obtained as a difference between the vector Y representing the acquired image and the vector HX representing the after-degradation assumed image, and simultaneous equations of one dimension, Y=HX, is solved by the iterative method. Thereby, the vector X with the minimum difference is obtained. A more detailed description of the third image restoration method is given for example in an article entitled "RESTORATION OF A SINGLE SUPER-RESOLUTION IMAGE FROM SEVERAL BLURRED, NOISY AND UNDER-SAMPLED MEASURED IMAGES" by M. Elad and A. Feuer, IEEE Trans., On Image Processing, Vol. 6, No. 12, pp. 1646-1658, December, 1997. Of course, various other techniques can be used for the details of the iterative method.

[0100] The use of the third image restoration method enables more proper image restoration than the use of the first and second image restoration methods, but the digital camera 1 may use any of the first to third image restoration methods or it may also use any other method.

1-4. Operation of Digital Camera

[0101] So far, the construction of the digital camera 1, the degradation function indicating degradation of the acquired image, and the image restoration using the degradation function have been described. Next, the operation of the digital camera 1 which performs the image restoration using the degradation function is discussed.

[0102] FIG. 15 is a flow chart of the operation of the digital camera 1 in image capture, and FIG. 16 is a block diagram of functional components of the digital camera 1 relative to a shooting operation thereof. In FIG. 16, a lens control unit 401, a diaphragm control unit 402, a degradation-function calculation unit 403, a degradation-function storage unit 404, and a restoration unit 405 are functions achieved by the CPU 41, the ROM 42, the RAM 43, and the like with the CPU 41 performing computations according to the program 421 in the ROM 42.

[0103] Upon the press of the shutter button 13, the digital camera 1 controls the optical system to form a subject image on the CCD 32 (step S101). More specifically, the lens control unit 401 gives a control signal to the lens drive unit 211 to control the arrangement of a plurality of lenses which constitute the lens system 21. Further, the diaphragm control unit 402 gives a control signal to the diaphragm drive unit 221 to control the diaphragm 22.

[0104] On the other hand, information about the arrangement of lenses and the aperture value are transmitted from the lens control unit 401 and the diaphragm control unit 402 to the degradation-function calculation unit 403 as degradation information 431 for obtaining a degradation function (step S102). Then, exposures are performed (step S103) and the subject image obtained with the CCD 32 and the like is stored as image data in the image memory 34. Subsequent image processing is performed on the image data stored in the image memory 34.

[0105] The degradation-function calculation unit 403 obtains a degradation function for each pixel from the degradation information 431 received from the lens control unit 401 and the diaphragm control unit 402, with consideration given to the influences of the lens system 21 and the diaphragm 22 (step S104). The degradation functions obtained are stored in the degradation-function storage unit 404. The degradation-function storage unit 404 also prepares a degradation function relative to the optical low-pass filter 31 beforehand.

[0106] Alternatively, in step S104, a degradation function may separately be obtained for each component or each characteristic of the lens unit 2 and then a degradation

function considering the whole optical system may be obtained. For example, a degradation function relative to the lens system **21**, a degradation function relative to the diaphragm **22**, and a degradation function relative to the optical low-pass filter **31** may separately be prepared. The degradation function relative to the lens system **21** may be divided into a degradation function relative to the focal length and a degradation function relative to the in-focus lens position.

[0107] For simplification of a computation for obtaining a degradation function for each pixel, degradation functions for representative pixels may be obtained in an image and then degradation functions for the other pixels may be obtained by interpolation with the degradation functions for the representative pixels.

[0108] After the degradation functions are obtained, the restoration unit **405** performs previously described restoration processing on the acquired image (step **S105**). This restores degradation of the acquired image due to the influences of the optical system. More specifically, image restoration using the degradation function relative to the optical low-pass filter **31** and image restoration using the degradation function relative to the lens unit **2** are performed.

[0109] In the image restoration using the degradation function relative to the optical low-pass filter **31**, a luminance component and other color components are obtained from R, G, B values of each pixel in an after-interpolation acquired image, and this luminance component is restored. The luminance component and the color components are then brought back into the R, G, B values.

[0110] In the image restoration using the degradation function relative to the lens unit **2**, on the other hand, R, G, B values of each pixel in the acquired image are individually restored in consideration of color aberration. For simplification of the process, of course only the luminance component may be processed to simplify the restoration of image degradation due to the optical low-pass filter **31** and the lens unit **2**.

[0111] Alternatively, image degradation due to the optical low-pass filter **31** and that due to the lens unit **2** may be restored at the same time. That is, an image may be restored after a degradation function for the whole optical system is obtained.

[0112] The restored image is then subjected to a variety of image processing such as white balance control, gamma correction, noise removal, color correction, and color enhancement in the correcting unit **44** (step **S106**) and image data corrected is stored in the image memory **34**. The image data in the image memory **34** is further stored as appropriate into the memory card **91** through the card slot **14** (step **S107**).

[0113] As above described, for restoration of image degradation due to the influences of the optical system, the digital camera **1** uses the degradation functions indicating degradation characteristics due to the optical system. This enables proper restoration of the acquired image.

2. Second Preferred Embodiment

[0114] While the whole image is restored in the first preferred embodiment, a digital camera **1** according to a second preferred embodiment makes restoration of only predetermined restoration areas. Here, the digital camera **1** of the second preferred embodiment has the same configuration as shown in FIGS. **1** to **5** and performs the same fundamental operation as shown in **FIG. 12**; therefore, the same reference numerals are used as appropriate for the description thereof.

[0115] When the first image restoration method shown in **FIG. 12** restores only restoration areas, pixel values only in the restoration areas are used as vectors X and Y in the above equation (2) for obtaining a restoration function which converts the vector Y into the vector X. This reduces the amount of processing below that in restoration of the whole image. Further, it is easy to obtain a proper restoration function because many pixel values around the restoration area are already known.

[0116] When the second image restoration method shown in **FIG. 13** restores only restoration areas, only the restoration areas are divided into blocks for processing. This reduces the amount of processing below that in restoration of the whole image.

[0117] When the third image restoration method shown in **FIG. 14** restores only restoration areas, only the restoration areas of the assumed image are updated. This improves the stability of a convergence of solutions in repeated computations on the restoration areas.

[0118] Next, as a way of determining restoration areas with the digital camera **1**, a technique using contrast to determine restoration areas is discussed. Herein, the term "contrast" refers to a difference in pixel value between a pixel to be a target (hereinafter referred to as a "target pixel") and its neighboring pixels.

[0119] Any kind of techniques can be used for obtaining the contrast of each pixel in the acquired image. For example, a sum total of pixel value differences between a target pixel and its neighboring pixels (e.g., eight adjacent pixels or 24 neighboring pixels) can be used. In another alternative, a sum total of the squares of pixel value differences between a target pixel and its neighboring pixels or a sum total of the ratios of pixel values therebetween may be used as contrast.

[0120] After the contrast of each pixel is obtained, it is compared with a predetermined threshold value and areas of pixels with higher contrast values than the threshold value are determined as restoration areas. The higher the exposure level (i.e., the brightness of the whole image) and the noise level, the higher the threshold value.

[0121] With such a technique, for example, a diagonally shaded area designated by the reference numeral **741** in **FIG. 18** is determined as a restoration area of the acquired image shown in **FIG. 17**.

[0122] **FIG. 19** is a flow chart of the operation of the digital camera **1** in image restoration, the operation corresponding to step **S105** of **FIG. 15**. **FIG. 20** is a block diagram of functional components of the digital camera **1** relative to a shooting operation thereof. The construction of **FIG. 20** is such that a restoration-area decision unit **406** is added to the construction of **FIG. 16**. The restoration-area decision unit **406** is a function achieved by the CPU **41**, the

ROM **42**, the RAM **43**, and the like with the CPU **41** performing computations according to the program **421** in the ROM **42**.

[**0123**] In the second preferred embodiment, after the degradation functions are obtained as in the first preferred embodiment, the restoration-area decision unit **406** determines restoration areas and the restoration unit **405** performs previously described restoration processing on the restoration areas of the acquired image (step **S105**). This restores degradation of only the restoration areas of the acquired image due to the influences of the optical system. More specifically, image restoration using the degradation function relative to the optical low-pass filter **31** and image restoration using the degradation function relative to the lens unit **2** are performed on the restoration areas.

[**0124**] In the process of image restoration, as shown in **FIG. 19**, a threshold-value calculation unit **407** calculates a threshold value for use in determination of the restoration areas (step **S201**), and the restoration-area decision unit **406** determines the restoration areas by comparing the contrast of each pixel with the threshold value (step **S202**). Then, image restoration is performed on the restoration areas by using any of the previously described image restoration methods, using the degradation functions relative to the optical system (step **S203**).

[**0125**] As has been described, the digital camera **1** restores image degradation of only the restoration areas due to the influences of the optical system, by the use of degradation functions which indicate degradation characteristics due to the optical system. This minimizes an adverse effect on non-degraded areas, such as the occurrence of ringing or increase of noise, thereby enabling proper restoration of the acquired image.

3. Third Preferred Embodiment

[**0126**] Now, another restoration technique that can be used for the digital camera **1** of the second preferred embodiment is discussed as a third preferred embodiment. Here, a digital camera **1** of the third preferred embodiment has the same configuration as shown in FIGS. **1** to **5** and performs the same fundamental operation as shown in **FIG. 15**; therefore, the same reference numerals are used as appropriate for the description thereof.

[**0127**] **FIG. 21** shows the details of step **S105** of **FIG. 15** in the operation of the digital camera **1** according to the third preferred embodiment. **FIG. 22** is a block diagram of functional components of the digital camera **1** around the restoration unit **405**. The construction of the digital camera **1** is such that a restoration-area modification unit **408** is added to the construction of **FIG. 20**. The restoration-area modification unit **408** is a function achieved by the CPU **41**, the ROM **42**, the RAM **43**, and the like, and the other functional components are similar to those in **FIG. 20**.

[**0128**] In the digital camera **1** of the third preferred embodiment, for restoration of the acquired image, the threshold-value calculation unit **407** calculates a threshold value relative to contrast from the acquired image obtained by the CCD **32** (step **S211**) and the restoration-area decision unit **406** determines areas of pixels with higher contrast values than the threshold value as restoration areas (step **S212**), both as in the second preferred embodiment. Further, the restoration unit **405** restores the restoration areas of the image by using degradation functions stored in the degradation-function storage unit **404** (step **S213**).

[**0129**] **FIG. 23** shows an example of the acquired image, and **FIG. 24** shows a result of image restoration using the restoration area determined by contrast. When the restoration areas are determined by contrast, an area that has completely lost its shape has low contrast and is thus not included in the restoration areas. That is, the degradation functions, which have the property of erasing or decreasing a specific frequency component, can cause for example an area which should have a stripped pattern in the ideal image to have almost no contrast in the acquired image. In **FIG. 24**, the reference numeral **751** designates such an area that was supposed to be restored but not restored because it was judged as a non-restoration area.

[**0130**] In the presence of such an area that was supposed to be restored but not restored, a restoration area which is located in contact with that area will generally have widely varying pixel values with respect to a direction along the boundary therebetween. The digital camera **1** therefore checks on the conditions of pixel values (i.e., variations in pixel values) around non-restoration areas of the restored image, and when there are variations in pixel values on the outer periphery of any non-restoration area, a judging unit **409** judges that the restoration area is in need of modification (or the size of the restoration area needs to be altered) (step **S214**).

[**0131**] Whether a non-restoration area is an area to be restored or not may be determined by focusing attention on a divergence of pixel values near the boundary of the adjacent restoration areas during restoration processing using the iterative method.

[**0132**] When the restoration areas are in need of modification (step **S215**), the restoration-area modification unit **408** makes a modification to reduce the non-restoration area concerned, i.e., to expand the restoration areas (step **S216**). Then, the restoration unit **405** performs restoration processing again on the modified restoration areas (step **S213**). The process then returns to the decision step (i.e., step **S214**). Thereafter, the modification to the restoration areas and the restoration processing are repeated as required (steps **S213**-**S216**). **FIG. 25** shows a result of image restoration performed with modifications to the restoration areas, wherein proper restoration is made on the area **751** shown in **FIG. 24**.

[**0133**] Here, the restoration processing after the expansion of the restoration areas may be performed either on an image after previous restoration processing or an initial image (i.e., the acquired image).

[**0134**] As above described, the restoration areas are modified or expanded according to the conditions near the boundaries of non-restoration areas, whereby non-restoration areas that are supposed to be restored can be eliminated. This enables proper image restoration. The restored image is subjected to image correction in the correcting unit **44** and stored in the image memory **34** as in the first preferred embodiment.

4. Fourth Preferred Embodiment

[**0135**] While the techniques for restoring image degradation due to the optical system have been described in the first

to third preferred embodiments, this fourth preferred embodiment provides, as a way of restoring image degradation due to other causes, a digital camera **1** that restores image degradation due to camera shake in image capture. The fundamental construction of this digital camera **1** is nearly identical to that of FIGS. **1** to **5**. Although only correction for camera shake will be discussed in the fourth preferred embodiment, the restoration of image degradation due to the optical system may of course be performed at the same time.

[0136] **FIG. 26** is an explanatory diagram of image degradation due to camera shake. **FIG. 26** shows 5×5 light sensing elements on the CCD **32**, illustrating that a light flux with intensity 1, which was supposed to be received by the leftmost light sensing element in the middle row, spreads to the right because of camera shake, i.e., spreads over light sensing elements in the middle row from left to right with intensity 1/5. In other words, a degradation function for a point image which has a distribution due to degradation is shown.

[0137] The digital camera **1** of the fourth preferred embodiment is configured to be able to obtain a degradation function relative to camera shake with a displacement sensor and make proper restoration of the acquired image by using the degradation function.

[0138] **FIG. 27** shows the details of step **S105** in the overall operation of the digital camera **1** shown in **FIG. 15**, and **FIG. 28** is a block diagram of functional components around the restoration unit **405**. The digital camera **1** of the fourth preferred embodiment differs from that of the second preferred embodiment (**FIG. 20**) in that it comprises a displacement sensor **24** for sensing the direction and amount of camera shake (i.e., a sensor for obtaining displacement with an acceleration sensor) and in that the degradation function is also transferred from the degradation-function storage unit **404** to the restoration-area decision unit **406**. The other functional components are identical to those of the second preferred embodiment.

[0139] In the fourth preferred embodiment, the digital camera **1** controls the optical system for image capture as shown in **FIG. 15** (steps **S101**, **S103**). At this time, information from the displacement sensor **24** is transmitted to the degradation-function calculation unit **403** as the degradation information **431** which indicates degradation of the acquired image (step **S102**). Then, the degradation-function calculation unit **403** calculates a degradation function having the property as illustrated in **FIG. 26** on the basis of the degradation information **431** (step **S104**) and transfers the same to the degradation-function storage unit **404**.

[0140] Following this, the determination of restoration areas and the restoration of the acquired image are performed (step **S105**). More specifically, as shown in **FIG. 27**, the restoration-area decision unit **406** determines restoration areas on the basis of the degradation function relative to camera shake which was received from the degradation-function storage unit **404** (step **S221**) and the restoration unit **405** restores the restoration areas of the image by using this degradation function (step **S222**).

[0141] In the acquired image which suffers degradation having the degradation characteristic illustrated in **FIG. 26**, when there are no variations in pixel values in the ideal image with respect to horizontal directions, no degradation will occur even if there are variations in pixel values in the ideal image with respect to vertical directions. For example, with the degradation function having the degradation characteristic of **FIG. 26**, no image degradation will occur when a horizontally extending straight line is captured. In this case, the restoration-area decision unit **406** determines, as a restoration area, only an area of pixels with higher contrast values than a predetermined threshold value with respect to the vertical directions (i.e., the direction of camera shake) on the basis of the degradation function.

[0142] In this way of determining the restoration areas on the basis of the degradation function, a diagonally shaded area **742** in **FIG. 29** for example is determined as a restoration area of the acquired image shown in **FIG. 17**.

[0143] After the determination of the restoration areas and the restoration of the acquired image are completed, image correction is performed as in the first preferred embodiment (step **S106**), and the corrected image is transferred as appropriate from the image memory **34** to the memory card **91**.

[0144] As previously described, the determination of the restoration areas may be performed on the basis of the degradation function (e.g., by deriving a predetermined arithmetic expression from the degradation function). Further, the degradation function relative to camera shake in the above description may be any other degradation function. For example, by referring to a frequency characteristic of the degradation function, an areas that have lost a predetermined frequency component or areas with a so-called "double-line effect" may be determined as restoration areas. Further, the restoration areas may be modified as in the second preferred embodiment.

5. Fifth Preferred Embodiment

[0145] Next, another technique for determining restoration areas that can be used in the second preferred embodiment is described as a fifth preferred embodiment. The construction and fundamental operation of the digital camera **1** are identical to those of FIGS. **1** to **5**, **15**, and **20**; therefore, the same reference numerals are used for the description thereof. The digital camera **1** according to the fifth preferred embodiment can also be used for restoration of image degradation due to a variety of causes other than the optical system.

[0146] **FIG. 30** is a flow chart of restoration processing (step **S105** of **FIG. 15**) according to the fifth preferred embodiment. In the fifth preferred embodiment, the restoration areas are determined on the basis of luminance. More specifically, a predetermined threshold value is calculated on the basis of brightness of the acquired image (step **S231**) and areas with luminance of the predetermined threshold value or less are determined as restoration areas (step **S232**).

[0147] Then, as in the second preferred embodiment, restoration processing is performed on the restoration areas by using the degradation functions relative to the optical system (step **S233**).

[0148] As above described, the fifth preferred embodiment performs the determination of restoration areas on the basis of luminance. From this, for example a white background in an image can certainly be determined as a non-restoration

area. This properly prevents the occurrence of ringing around a main subject and noise enhancement in the background during restoration processing on the whole image.

[0149] The above description is specifically given with the digital camera. For a scanner which obtains a character image for character recognition, proper character recognition can be achieved.

[0150] While in the above description an area with luminance of a predetermined threshold value or less is determined as a restoration area, an area with luminance of a predetermined threshold value or more may of course be determined as a restoration area depending on background brightness. Further, when the background brightness is already known, an area with luminance within a prescribed range may be determined as a restoration area.

[0151] When the background takes on a predetermined color as in an identification photograph, an area with color within a prescribed range may be determined as a restoration area. In this fashion, the use of pixel values (including luminance) in determining restoration areas allows proper determination, thereby enabling proper image restoration.

[0152] Also in this fifth preferred embodiment, the restoration areas may be modified as in the third preferred embodiment.

6. Sixth Preferred Embodiment

[0153] **FIG. 31** illustrates a sixth preferred embodiment. While image restoration is performed in the digital camera **1** in the first to fifth preferred embodiments, it is performed in a computer **5** in this sixth preferred embodiment. That is, data transfer between the digital camera **1** with no image restoration capability and the computer **5** is made possible by the use of the memory card **91** or a communication cable **92**, whereby images obtained by the digital camera **1** are restored in the computer **5**.

[0154] Restoration processing by the computer **5** may be any restoration processing described in the first to fifth preferred embodiments, but in the following description, restoration of image degradation due to the optical system and modifications to the restoration areas are performed as in the third preferred embodiment.

[0155] The digital camera **1** of the sixth preferred embodiment is identical to that of the first preferred embodiment (i.e., the third preferred embodiment) except that it does not perform image restoration. In the following description, therefore, like or corresponding parts are denoted by the same reference numerals as in the first preferred embodiment. Further, data from the digital camera **1** may be outputted through any desired output device such as the card slot **14** or an output terminal, but in the following description, the memory card **91** is used for data transfer from the digital camera **1** to the computer **5**.

[0156] The computer **5** comes preinstalled with a program for restoration processing through a recording medium **8** such as a magnetic disk, an optical disk, and a magneto-optic disk. In the computer **5**, the CPU performs processing according to the program using a RAM as a work area, whereby image restoration is performed in the computer **5**.

[0157] **FIG. 32** is a schematic diagram of recorded-data structures in the memory card **91**. The digital camera **1** captures an image as image data in the same manner as the previously-described digital cameras **1**, and at the same time, obtains (or previously has stored) degradation functions indicating degradation characteristics that the optical system gives to the image. Such image data **911** and degradation functions **912** are outputted in combination to the memory card **91**.

[0158] **FIG. 33** is a flow chart of the operation of the digital camera **1** according to the sixth preferred embodiment in image capture, and **FIG. 34** is a flow chart of the operation of the computer **5**. **FIG. 35** is a block diagram of functional components of the digital camera **1** and the computer **5** relative to restoration processing. In **FIG. 35**, only part of the functional components is shown. function components of the digital camera **1** for use in recording image data and degradation functions on the memory card **91**; and functional components of the computer **5** including a card slot **51** for reading out data from the memory card **91**, a fixed disk **52**, a restoration unit **505**, a restoration-area decision unit **506**, and a restoration-area modification unit **508**, the units **505**, **506**, **508** being achieved by the CPU, the RAM, and the like. Referring now to FIGS. **33** to **35**, the operations of the digital camera **1** and the computer **5** of the sixth preferred embodiment are discussed.

[0159] In image capture by the digital camera **1**, the lens control unit **401** and the diaphragm control unit **402** exercise control over the optical system (step S111 of **FIG. 33**) and information about the optical system is obtained as the degradation information **431** (step S112), both as in the second preferred embodiment (cf. **FIG. 20**). Then, exposure is performed on the CCD **32** (step S113), whereby a captured image is obtained as image data.

[0160] The degradation-function calculation unit **403** obtains a degradation function on the basis of the degradation information **431** about the lens unit **2** (step S114) and transfers the same to the degradation-function storage unit **404**. As in the second preferred embodiment, the degradation-function storage unit **404** has previously stored the degradation function relative to the optical low-pass filter **31**. On the other hand, the image obtained is subjected to image correction in the correcting unit **44** and stored in the image memory **34** (more correctly, image correction is made on the image data in the image memory **34**) (step S115).

[0161] The digital camera **1** then, as shown in **FIG. 35**, outputs the image data corresponding to a corrected image and the degradation functions to the memory card **91** through the card slot **14** (step S116).

[0162] After the image data and the degradation functions are stored in the memory card **91**, the memory card **91** is loaded in the card slot **51** of the computer **5**. The computer **5** then reads the image data and the degradation functions into the fixed disk **52** thereby to prepare necessary data for restoration processing (step S121 of **FIG. 34**).

[0163] Then, the restoration-area decision unit **506** determines restoration areas on the basis of the image described by the image data, and the restoration unit **505** and the restoration-area modification unit **508** repeat previously described restoration processing using the degradation functions and modifications to the restoration areas, respectively (step S122). These operations are similar to those in the restoration processing of the third preferred embodiment shown in **FIG. 21**.

[0164] After the completion of image restoration, the restored image is stored in the fixed disk **52** (step S123).

[0165] As above described, the digital camera **1** of the sixth preferred embodiment outputs the image data and the degradation functions to the outside, and the computer **5** performs the determination of the restoration areas and the restoration processing using the degradation functions. That is, the digital camera **1** does not have to perform restoration processing. This accelerates time between the start of image capture and the storage of image data as compared with that in the third preferred embodiment (especially when an image captured has a large number of pixels).

7. Modifications to First to Sixth Preferred Embodiments

[0166] In the aforementioned preferred embodiments, images obtained by the digital camera **1** are restored. However, it is to be understood that the preferred embodiments are not limited thereto and various modifications may be made therein.

[0167] For example, while the aforementioned preferred embodiments give descriptions of degradation functions including the degradation function relative to the lens unit **2**, the degradation function relative to the optical low-pass filter **31**, and the degradation function relative to camera shake, any other kind of degradation functions may be obtained (or may be prepared beforehand). Further, as in the case of a 3 CCD digital camera **1** that uses only the degradation function relative to the lens unit **2** or the degradation function relative to the diaphragm **22**, only a specific kind of degradation may be restored by the use of only one kind of degradation function.

[0168] As previously described, there is no need to obtain degradation functions for all pixels. For example, after obtaining degradation functions for representative pixels (i.e., light sensing elements) by using an LUT or the like, degradation functions for the other pixels may be obtained by interpolation. When degradation functions for all pixels are constant like the degradation function relative to the optical low-pass filter **31**, it is sufficient to prepare only one degradation function in the ROM **42** beforehand.

[0169] That is, the use of at least one degradation function of at least one kind enables proper restoration of a specific kind of degradation.

[0170] In the aforementioned preferred embodiments, the calculation of degradation functions and image restoration are performed by the CPU, the ROM, and the RAM in the digital camera **1** or in the computer **5**. Here all or part of the following components may be constructed by a purpose-built electric circuit: the lens control unit **401**, the diaphragm control unit **402**, the degradation-function calculation unit **403**, the restoration unit **405**, the restoration-area decision unit **406**, and the restoration-area modification unit **408**, all in the digital camera **1**; and the restoration unit **505**, the restoration-area decision unit **506**, and the restoration-area modification unit **508**, all in the computer **5**.

[0171] The program **421** for image restoration by the digital camera **1** may previously be installed in the digital camera **1** through a recording medium such as the memory card **91**.

[0172] Further, the preferred embodiments are not limited to restoration of images obtained by the digital camera **1** but may also be used for restoration of images obtained by any other image capturing device, such as an electron microscope or a film scanner, which uses an array of light sensing elements to obtain images. Of course, the array of light sensing elements is not limited to a two-dimensional array but may be a one-dimensional array.

[0173] The techniques for determining or modifying restoration areas are also not limited to those described in the above preferred embodiments, but a variety of techniques may be adopted. For example, restoration areas may be determined on the basis of a distribution of or variations in space frequency in the acquired image, or a non-restoration area which is surrounded by the restoration areas may be forcefully changed to a restoration area.

[0174] Further, two kinds of threshold values may be obtained for determination of restoration areas. In this case, after an image is divided into three kinds of areas, namely restoration areas, half-restoration areas, and non-restoration areas, by the use of the two threshold values, pixels in the half-restoration areas are updated to an average of before- and after-restoration pixel values (or to a weighted average). This erases clearly defined boundaries between the restoration areas and non-restoration areas.

8. Seventh Preferred Embodiment

[0175] A digital camera **1** according to a seventh preferred embodiment has the same configuration as shown in FIGS. **1** to **5** and performs the same fundamental operation as shown in **FIG. 15**. **FIG. 36** shows main functional components of the digital camera **1**. A degradation-function calculation unit **411** and a restoration unit **412** are functions achieved by the CPU **41** and the like performing a program recorded on the ROM **42**.

[0176] The degradation-function calculation unit **411**, when focusing attention on a target image which is included in a plurality of images continuously captured by the CCD **32**, obtains from the plurality of images a track of a subject image in the target image, which is caused by a shake of the digital camera **1** in image capture. Thereby, at least one degradation function indicating a degradation characteristic of the target image due to camera shake is obtained.

[0177] The restoration unit **412** restores the target image, using at least one degradation function obtained by the above degradation-function calculation unit **411**.

[0178] The concrete operations of the degradation-function calculation unit **411** and the restoration unit **412** will be described later.

[0179] Referring now to FIGS. **37** to **40**, the principle of image restoration is discussed. **FIG. 37** shows a plurality of images (three images) SI1, SI2, and SI3 continuously captured for a predetermined subject J. The following description gives the case where restoration processing is performed on the image SI2, i.e., the image SI2 is a target image of restoration processing.

[0180] **FIGS. 37 and 38** show that an image (subject image) I of the subject J captured in actual space has different position coordinates in the three images SI1, SI2, SI3 because of a shake of the digital camera **1** in image

capture. In **FIG. 37**, the subject images I in the images SI1, SI2, SI3 are aligned so that the images SI1, SI2, and SI3 are misaligned. In **FIG. 38**, the frames (not shown) of the three images SI1, SI2, and SI3 are aligned so that the subject images I in the images SI1, SI2, and SI3 are misaligned. **FIG. 38** also shows a track L1 that the subject images I in the images SI1, SI2, and SI3 describe because of "camera shake". That is the movement of the subject image I is shown in **FIG. 38**, wherein subject images corresponding to the images SI1, SI2, and SI3 are indicated by I1, I2, and I3, respectively.

[0181] **FIG. 39** is an enlarged view illustrating representative points P1, P2, and P3 of, respectively, the subject images I in the images SI1, SI2, and SI3, and their vicinity. The representative points P1, P2, and P3 are corresponding points representing the same position on the subject in the images SI1, SI2, and SI3.

[0182] As shown in **FIG. 39, a** shake of the digital camera **1** in image capture takes place in the direction of the arrow AR1 along the broken line L1. In other words, the broken line L1 indicates a track of the subject image which is produced by a shake of the digital camera **1** in image capture. Such a track of the subject image can be calculated by appropriate interpolation (linear or spline interpolation) to pass the track through the representative points P1, P2, and P3.

[0183] Here movements of a captured image are caused by travel of a subject image with respect to the CCD **32** during exposure, and image degradation due to such image movements is caused by a distribution of a light beam, which is given from a single point on the subject, onto the track of travel of the subject image without the light beam converging to a single point on the CCD **32**. This, in other words, means that a pixel at a predetermined position in a target image receives light from a plurality of positions on the track of travel of the subject image. For example, a pixel value at a position P2 in the target image SI2 is obtained by summation of light that has been given during an exposure time Δt from an area R2 (a diagonally-shaded area in **FIG. 39**) which is defined in the vicinity of the position P2 along the track L1 of the subject image.

[0184] As for such degradation of the target image due to camera shake, therefore, a degradation function indicating a degradation characteristic can be expressed as a two-dimensional filter based on point spread. Here, the track L1 of the subject image in the target image SI2 is expressed as a two-dimensional filter of a predetermined size (i.e., 5×5) by using spline interpolation.

[0185] **FIG. 40** shows an example of such a two-dimensional filter. It is understood that a pixel at a predetermined position in the target image SI2 is obtained by applying the degradation function, which is expressed as such a two-dimensional filter, to an ideally captured image (hereinafter referred to as an "ideal image") which suffers no image degradation due to camera shake and the like. This can be expressed by the following equation:

$$q(i,j)=\sum_{k,l}\{w(k,l)\cdot p(i+k,j+l)\} \qquad (4)$$

-continued

$$\begin{pmatrix} -2\le k\le +2 \\ -2\le l\le +2 \end{pmatrix}$$

[0186] where q(i, j) indicates a pixel value with position coordinates (i, j) in the target image SI2; p(i+k, j+1) indicates a pixel value with position coordinates (i+k, j+1) in the ideal image; and w(k, 1) indicates each weighing coefficient in the two-dimensional filter. Referring to the two-dimensional filter of **FIG. 40**, five positions along the track L1 take on a value of "1/5", and thus pixel values P corresponding to those five positions each are multiplied by 1/5 and added up, whereby pixel values q are obtained.

[0187] As expressed by Equation (4), the pixel value with the predetermined position coordinates (i, j) in the target image SI2 can be expressed by a value which is obtained by weighing pixel values in the vicinity of the position coordinates (i, j) in the ideal image with a predetermined weighing coefficient. Thus, the two-dimensional filter as the above weighing coefficient expresses a track of the subject image in the target image SI2.

[0188] Expressed differently, the pixel value with the position coordinates (i, j) in the target image is obtained as the amount of light which has been accumulated during the exposure time Δt at a pixel with the predetermined position coordinates (i, j) in the CCD **32**. This amount of light can be obtained by summation of light received from a plurality of positions on a subject along the movement of the subject. That is, the target image SI2 can be considered as an image which is degraded by the application of a degradation function, which is expressed as the above two-dimensional filter, to the "ideal image".

[0189] The above degradation function is for use with the predetermined position coordinates (i, j), but more simply, the same two-dimensional filter may be used as a degradation function for all positions, assuming that such degradation occurs at all the positions. Further, degradation may be expressed in more detail by obtaining the above two-dimensional filter for every position coordinates in an image. In this fashion, at least one degradation function, which indicates the degradation characteristic of the target image due to a shake of an image capturing device, can be obtained.

[0190] With such a degradation function for every pixel, restoration processing can be performed. Examples of techniques that can be used in this restoration processing include: (1) the technique for obtaining a restoration function with assumed boundary conditions; (2) the technique for restoring a specific frequency component; and (3) the technique for updating an assumed image by the iterative method. Those techniques have been discussed above.

[0191] Now, the detailed operations of the CCD **32**, the degradation-function calculation unit **411**, the restoration unit **412**, and the like are discussed with reference to **FIG. 41**.

[0192] **FIG. 41** is a flow chart of processing. As shown in **FIG. 41**, the CCD **32** continuously captures a plurality of images SI1, SI2, and SI3 in step S**310** and the degradation-function calculation unit **411** obtains a track of a subject

image in the target image SI2 from the plurality of images SI1, SI2, and SI3 in step S320. Thereby, at least one degradation function which indicates a degradation characteristic of the target image SI2 due to a shake of the digital camera 1 is obtained. In step S330, the restoration unit 412 restores the target image SI2 by using at least one degradation function obtained in step S320. The followings are more detailed descriptions of the processing of steps S310 to S330.

[0193] First, the processing of step S310 is described. In this step, exposures are performed for a predetermined very short time Δt (e.g., 1/6 second) between exposure start (step S311) and exposure stop (step S312), whereby the CCD 32 forms a subject image. The image SI1 formed in this way as digital image signals is then temporarily stored in the RAM 43 (step S313, see FIG. 5). Step S314, which makes a determination of the termination of processing, determines whether or not the same operation (shooting operation) is repeated three times. When the number of times the above shooting operation is carried out is less than three, the process returns to step S311 for another shooting operation to capture an image SI2 or SI3, and then goes to the next step S320 after recognizing a three-time repetition of the shooting operation. Through the processing of step S310, the plurality of continuously captured images SI1, SI2, and SI3 are obtained.

[0194] Next, the processing of step S320 is discussed. In this step, a degradation functions for each of a plurality of representative positions (nine representative positions) B1 to B9 (cf. FIG. 42) is obtained and then a degradation function for every position is obtained on the basis of the degradation functions for the representative positions B1 to B9.

[0195] First, areas A1 to A9 (cf. FIG. 42) including, respectively, the representative positions B1 to B9 are established in step S321. This establishment of the areas A1 to A9 is made in the target image SI2. With respect to the vertical direction, the areas A1 to A3 are located in the upper portion of the image, the areas A4 to A6 in the middle portion, and the areas A7 to A9 in the lower portion. With respect to the horizontal direction, on the other hand, the areas A1, A4, A7 are located in the left-side portion of the image, the areas A2, A5, A8 in the middle portion, and the areas A3, A6, A9 in the right-side portion. The representative positions B1 to B9 are in the center of the areas A1 to A9, respectively.

[0196] In step S322, the plurality of images (three images) SI1, SI2, and SI3 are associated with each other for each of the areas A1 to A9. That is, what position each of the areas A1 to A9 established in the image SI2 takes in the other images SI1 and SI3 is determined. To establish this correspondences, techniques such as matching and a gradient method can be used.

[0197] After establishing such image correspondences, a track L1 (cf. FIG. 39) of the subject image in the target image SI2 is obtained in step S323. This track L1 can be obtained for each of the representative positions B1 to B9 in the areas A1 to A9 which were associated in the images SI1, SI2, and SI3. Then, a two-dimensional filter (cf. FIG. 40) is obtained for each of the representative positions B1 to B9 on the basis of the corresponding track L1. These two-dimensional filters are degradation functions for the representative positions B1 to B9.

[0198] After the degradation functions for the plurality of representative positions B1 to B9 are obtained, degradation functions for all pixel locations in the target image SI2 are obtained in the next step S324 on the basis of the nine degradation functions for the representative positions B1 to B9. The degradation function for each pixel location can be determined by, for example, reflecting relative positions of each pixel and the representative positions B1 to B9 in the image on the basis of the plurality of degradation functions (nine degradation functions) for the plurality of representative positions (nine representative positions) B1 to B9. This determination may be made by further reflecting shooting information such as an optical focal length and a distance to the subject. In this fashion, a plurality of degradation functions can be obtained in accordance with pixel locations. This provides more detailed degradation functions, which for example can accommodate nonlinear variations according to pixel locations with flexibility.

[0199] More specifically, when camera shake occurs in the horizontal direction during image capture and the like using a wide-angle lens as shown in FIG. 43, the amount of camera shake in left/right end portions of an image becomes greater than that in the middle portion because of lens aberration and the like (the lengths of the arrows AR21 to AR23 in FIG. 43 schematically represent the amounts of camera shake at the respective locations). In such a case, independent degradation functions are obtained for respective position coordinates in the X direction (or horizontal direction) in the image. This allows high-precision degradation-function representation, thereby enabling high-precision image restoration. In this fashion, even if degradation functions vary according to position coordinates in the image, the preferred embodiment is applicable on the basis of, for example, differences in optical properties of lenses and the like.

[0200] As above described, a degradation function for every pixel location can be calculated on the basis of a plurality of degradation functions (nine degradation functions) calculated for the plurality of areas (nine areas) A1 to A9.

[0201] The aforementioned description is given on the premise that each pixel location has a different degradation function, but more simply, as above described, one degradation function obtained for a single representative position may be regarded as a degradation function for all pixel positions.

[0202] In step S330, restoration processing is performed with the degradation functions obtained in step S320. This restoration processing may adopt any of the image restoration methods shown in FIGS. 12 to 14 or it may adopt any other method.

[0203] In step S340, a restored image obtained in step S330 is recorded on a recording medium such as a memory card using a semiconductor memory. The recording medium may be any medium other than a memory card, e.g., it may be a magnetic disk or an optical magnetic disk.

[0204] While in the seventh preferred embodiment, the plurality of images SI1, SI2, and SI3 each are captured during the same amount of very short exposure time Δt, this embodiment is not limited thereto. For example, the exposure time to capture the images SI1 and SI3 before and after the target image SI2 may be shorter than that to capture the target image SI2. In this case, camera shake is reduced and

positional accuracy is improved in the images SI1 and SI3; therefore, a more accurate track L1 of the subject image can be obtained in the above step **S320**. That is, more proper restoration of the target image SI2 is made possible by ensuring a sufficient amount of exposure time for the target image SI2 while shortening the exposure time for the images SI1 and SI3 before and after the target image SI2.

[0205] While in the seventh preferred embodiment, the plurality of images SI1, SI2, and SI3 each include the same number of pixels; for example, the numbers of pixels in the images SI1 and SI3 before and after the target image SI2 may be smaller than that in the target image SI2 (i.e., the images SI1 and SI3 may appear jagged). Even in this case, the track L1 of the subject image ensures a predetermined level of positional accuracy.

[0206] As above described, the target image SI2 to be restored and the other images SI1, SI3 may be captured under different shooting conditions (exposure time, pixel resolution, etc.) For example, the images SI1 and SI3 may be live view images. Here the "live view image" refers to an image that is displayed in real time on a display monitor on the back of the digital camera.

[0207] While in the seventh preferred embodiment, the two-dimensional filters are 5×5 in size, they may be of any other size (3×3, 7×7, etc.). Further, the two-dimensional filters are not necessarily the same in size but may be of different sizes for a proper representation of the track at each pixel location.

[0208] While in the seventh preferred embodiment, three continuously captured images are used to obtain degradation functions, for example, with two continuously captured images, the above track L1 may be obtained by interpolation between two points and estimation of subsequent travel of the track. As another alternative, N ($\geqq$4) continuously captured images may be used. In this case, the aforementioned operations (calculation of degradation functions and restoration) should be performed on each of (N− 2) images as a target image, excluding the first and the last images (a total of two images). At this time, if a track to connect N ($\geqq$4) points is obtained by spline interpolation or the like, a more accurate track of the subject image can be obtained. Further, averaging or the like with the (N−2) restored images obtained allows a further reduction in the influence of noise. In this case, averaging of pixels should preferably be carried out after images are associated with each other in consideration of the amount of travel in each image due to camera shake or the like in image capture.

[0209] While in the seventh preferred embodiment, the images SI1 and SI3 for modification are captured separately before and after the target image SI2, they may be replaced by live view images.

[0210] While the digital image capturing devices described in the seventh preferred embodiment are for capturing still images, they may be devices for capturing dynamic images. That is, the aforementioned processing is also applicable to digital image capturing devices for capturing dynamic images, in which case, in obtaining a still image from a dynamic image, a target image due to camera shake or the like in image capture can be restored with high precision without the use of any specific shake sensor. For example, degradation of a dynamic image, which is comprised of a plurality of continuously captured frame images, can be restored by using at least one of the plurality of frame images as a target image. From this, even with degradation of a dynamic image due to camera shake in image capture, the aforementioned processing can achieve the same effect.

[0211] The aforementioned restoration processing is also applicable in a case where, in obtaining a still image from a dynamic image, not a shake of a digital image capturing device but a movement of a subject itself causes image degradation in accordance with a track of the subject image in a target image as above described. For example, when only part of dynamic images is degraded by the "movement" of the subject itself, a desirable still image can be obtained by performing the aforementioned processing only on that part of the dynamic images which suffers the "movement".

[0212] While in the seventh preferred embodiment, image capture of a plurality of images and image restoration are performed as a sequence of operations and restored images obtained are stored in a recording medium; for example, with a recording medium or the like storing a plurality of captured images (before-restoration images) and degradation functions at predetermined positions, restoration processing on a target image may be performed separately after the completion of a sequence of shooting operations. Or, with a recording medium or the like storing only a plurality of captured images (before-restoration images), the calculation of degradation functions and the image restoration may be performed separately. In those cases, even if the calculation of degradation functions and/or the image restoration require enormous amounts of time, the length of time until the completion of image storage can be shortened. This reduces the load of processing during image capture on the CPU in the digital camera **1**, thereby enabling higher-speed continues shooting operations and the like.

[0213] The aforementioned operations (calculation of degradation functions and image restoration) are not necessarily performed in a digital image capturing device such as the digital camera **1**. Instead, a computer system may be used to perform similar operations on the basis of a plurality of images continuously captured by such a digital image capturing device.

[0214] **FIG. 44** is a schematic diagram of a hardware configuration of such a computer system (hereinafter referred to simply as a "computer"). A computer **60** comprises a CPU **62**, a storage unit **63** including a semiconductor memory, a hard disk, and the like, a media drive **64** for fetching information from a variety of recording media, a display unit **65** including a monitor and the like, and an input unit **66** including a keyboard, a mouse, and the like.

[0215] The CPU **62** is connected through a bus line BL and an input/output interface IF to the storage unit **63**, the media drive **64**, the display unit **65**, the input unit **66**, and the like. The media drive **64** fetches information which is recorded on a transportable recording medium such as a memory card, a CD-ROM, a DVD (digital versatile disk), and a flexible disk.

[0216] The computer **60** loads a program from a recording medium **92**A for recording the program, thereby to have a variety of functions such as the aforementioned degradation-function calculating and restoring functions. A plurality of images continuously captured by a digital image capturing

device such as the digital camera **1** are loaded in this computer **60** via a recording medium **92B** such as a memory card.

[**0217**] The computer **60** then performs the aforementioned calculation of degradation functions and restoration of a target image, thereby achieving the same functions as above described.

[**0218**] While the invention has been shown and described in detail, the foregoing description is in all aspects illustrative and not restrictive. It is therefore understood that numerous modifications and variations can be devised without departing from the scope of the invention.

What is claimed is:

1. An image processing apparatus comprising:

an obtaining section for obtaining image data generated by converting an optical image passing through an optical system into digital data; and

a processing section for applying a degradation function based on a degradation characteristic of at least one optical element comprised in said optical system to said image data and restoring said image data by compensating for a degradation thereof.

2. The image processing apparatus according to claim 1, wherein

said degradation function depends on a position of each pixel.

3. The image processing apparatus according to claim 1, wherein

said degradation function is based on a focal length, an in-focus lens position and an aperture value.

4. The image processing apparatus according to claim 3, wherein

said degradation function is generated from conditions of a lens system and a diaphragm in said optical system.

5. The image processing apparatus according to claim 1, wherein

said degradation function corresponds to a plurality of pixels.

6. The image processing apparatus according to claim 1, wherein

said processing section processes part of said image data, said part of said image data being determined on the basis of a difference between a pixel value of each pixel and pixel values of pixels adjacent to said each pixel.

7. The image processing apparatus according to claim 1, wherein

said processing section processes part of said image data, said part of said image data being determined on the basis of said degradation function.

8. The image processing apparatus according to claim 1, wherein

said processing section processes part of said image data, said part of said image data being determined on the basis of pixel values in said image data.

9. An image pick-up apparatus comprising:

a generating section for generating image data by converting an optical image passing through an optical system into digital data; and

an outputting section for outputting said image data out of said apparatus together with information for restoring said image data, said information including a degradation function based on a degradation characteristic of at least one optical element comprised in said optical system.

10. An image processing apparatus comprising:

a receiving section for receiving a plurality of image data sets generated by two or more consecutive image captures;

a calculating section for calculating a degradation function on the basis of a difference between said plurality of image data sets; and

a restoring section for restoring one of said plurality of image data sets by applying said degradation function.

11. The image processing apparatus according to claim 10, wherein

said one of said plurality of image data sets is restored without a sensor which detects a shake of an image capturing device.

12. The image processing apparatus according to claim 10, wherein

said degradation function is generated as a two-dimensional filter on the basis of a track of a subject on images of said plurality of image data sets.

13. The image processing apparatus according to claim 10, wherein

said degradation function is generated for each of representative positions on one of images of said plurality of image data sets.

14. The image processing apparatus according to claim 10, wherein

any other image data set than said one of said plurality of image data sets is generated by a shorter-time image capture than said one of said plurality of image data sets.

15. The image processing apparatus according to claim 10, wherein

any other image than an image of said one of said plurality of image data sets has less pixels than said image of said one of said plurality of image data sets.

16. The image processing apparatus according to claim 10, wherein

any other image than an image of said one of said plurality of image data sets is a live view image.

17. An image pick-up apparatus comprising:

a generating section for generating a plurality of image data sets generated by two or more consecutive image pick-upping;

a calculating section for calculating a degradation function on the basis of a difference between said plurality of image data sets to restore one of said plurality of image data sets; and

an outputting section for outputting said one of said plurality of image data sets out of said apparatus together with said degradation function so as to restore said one of said plurality of image data sets with said degradation function.

18. The image pick-up apparatus according to claim 17, wherein

said image pick-up apparatus is portable.

19. An image processing apparatus comprising:

a setting section for setting partial areas in a whole image, said partial areas being delimited according to contrast in said whole image; and

a modulating section for modulating images comprised in said partial areas on the basis of a degradation characteristic of said whole image to restore said whole image.

20. An image processing apparatus comprising:

a setting section for setting partial areas in a whole image on the basis of at least one degradation characteristic of said whole image; and

a modulating section for modulating images comprised in said partial areas on the basis of said at least one degradation characteristic to restore said whole image.

21. The image processing apparatus according to claim 20, wherein

said at least one degradation characteristic is derived from a shake of an image capturing device, said whole image being captured by said image capturing device.

22. An image processing apparatus comprising:

a setting section for setting partial areas in a whole image on the basis of a distribution of pixel values in said whole image; and

a modulating section for modulating images comprised in said partial areas on the basis of a degradation characteristic of said whole image to restore said whole image.

23. The image processing apparatus according to claim 22, wherein

said setting section sets said partial areas on the basis of a distribution of brightness in said whole image.

24. An image processing apparatus comprising:

a setting section for setting areas to be modulated in a whole image;

a restoring section for restoring said whole image by modulating images in said areas in accordance with a specified function; and

an altering section for altering sizes of said areas in accordance with a restored whole image, wherein

said restoring section again restores said whole image by modulating images in said areas whose sizes are altered by said altering section in accordance with said specified function.

25. The image processing apparatus according to claim 24, wherein

said setting section sets said areas according to contrast in said whole image.

26. The image processing apparatus according to claim 24, wherein

said setting section sets said areas on the basis of at least one degradation characteristic of said whole image.

27. The image processing apparatus according to claim 24, wherein

said setting section sets said areas on the basis of a distribution of pixel values in said whole image.

28. The image processing apparatus according to claim 24, wherein

said altering section alters said sizes of said areas in accordance with a distribution of pixel values around areas not to be modulated.

* * * * *

Electronic Acknowledgement Receipt

EFS ID:	38322387
Application Number:	13691805
International Application Number:	
Confirmation Number:	6244
Title of Invention:	Digital imaging system for correcting video image aberrations
First Named Inventor/Applicant Name:	Neal Solomon
Customer Number:	21186
Filer:	Garrett M. Hall/Jamie Johnson
Filer Authorized By:	Garrett M. Hall
Attorney Docket Number:	5311.001US3
Receipt Date:	16-JAN-2020
Filing Date:	02-DEC-2012
Time Stamp:	22:12:56
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Non Patent Literature	0052_b_rzolympus_e1_canon0064059.pdf	23123069 2f860527895 62f69b5db80ec78f2c2c9a4b909d4	no	91

Warnings:

Information:					
2	Non Patent Literature	0053_olympus_e300_canon0064241.pdf	22137828 c27fad2a9aeb79b02e0d627c746fa58ba5b1f261	no	212
Warnings:					
Information:					
3	Non Patent Literature	0054_olympus_e330_canon0064453.pdf	19987292 76ae6e973e8ba2aa34f22882426ce24773a01f6d	no	196
Warnings:					
Information:					
4	Non Patent Literature	0055_a_rzphotoshop_cs2_canon0062668_part1.pdf	15625765 6de6f5b4eaee293d127bba5bda83b4a8be4ff203	no	86
Warnings:					
Information:					
5	Non Patent Literature	0055_b_rzphotoshop_cs2_canon0062668_part1.pdf	23799852 f05422289f40f983fd211fd9fc2c902da22205e9	no	77
Warnings:					
Information:					
6	Non Patent Literature	0056_b_rzphotoshop_cs2_canon0062668_part2.pdf	22654464 f38e835223287c0c117ec820afc3f427ba1481dc	no	81
Warnings:					
Information:					
7	Non Patent Literature	0056_rzphotoshop_cs2_canon0062668_part2.pdf	22354391 b0c017ee62705698857cda0002111d0f6c6a2f91	no	82
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Information:					
8	Non Patent Literature	0057_a_rzphotoshop_cs2_canon0062668_part3.pdf	18617223 ef597f0c0aacc8afa3fe3957787b60ccb359f533	no	88
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9	Non Patent Literature	0057_b_rzphotoshop_cs2_canon0062668_part3.pdf	17097319 e4cd827d7b1eb48125a53e7ef00fdf59034b21fe	no	75
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10	Non Patent Literature	0058_a_rzphotoshop_cs2_canon0062668_part4.pdf	20940674 d645511302877ee776673965893a2cfa91bd6db2	no	82
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11	Non Patent Literature	0058_b_rzphotoshop_cs2_canon0062668_part4.pdf	22294312 2b188661748a7d70379773f605309be5a229fc8e	no	81
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12	Non Patent Literature	0059_a_rzphotoshop_cs2_canon0062668_part5.pdf	17998120 3ce6d9fca0a4b46d95d49fd4c6cedc213dbabd3b	no	55
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13	Non Patent Literature	0059_b_rzphotoshop_cs2_canon0062668_part5-2.pdf	14292846 4a4153dcd32431117a9a32aadef1547bd7d718ac	no	56
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Information:					
14	Non Patent Literature	0059_c_rzphotoshop_cs2_canon0062668_part5.pdf	15862792 c37b278629722d8f346afa8ea4e7042fc8688095	no	52
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Information:					
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Information:					

16	Non Patent Literature	0061_us5905530_canon0062546.pdf	14508215 9d4594ce77101a7d519de031ae302aa978b2e469	no	71
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Information:					
17	Non Patent Literature	0062_us_7590305_canon0064843.pdf	5793908 4ebde57ad468da419938c15b00d57c6d28d07abd	no	23
Warnings:					
Information:					
18	Non Patent Literature	0063_us_7738015_canon0064866.pdf	6313845 8716402ba189cd201abd177aff91aef38786253f	no	23
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Information:					
19	Non Patent Literature	0064_us_7936392_canon0062617.pdf	11544636 3a5f3d13b654877d02913adfc4b389b3619320f5	no	51
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Information:					
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Warnings:					
Information:					
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Information:					
22	Non Patent Literature	0067_us20040150732_canon0062455.pdf	7543837 4675b2a3217625d10601e3f7634d8eb86ab43d3f	no	31
Warnings:					
Information:					

23	Non Patent Literature	0068_us20040207733_canon0062486.pdf	14110591 c21ab36e7a6cf48294d6ad08885ccc47726d1ed2	no	60
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Information:					
24	Non Patent Literature	0069_wo2005093653a1_canon0064889_original.pdf	25463602 2fece0e208b2e0062ae1919623283 09e23c4c96c	no	128
Warnings:					
Information:					
25	Non Patent Literature	0070_zuiko_digital_1445_mm_f35_canon0065019.pdf	1497489 ef56ec1009d7487b3692f1a7678f4b509a9831e9	no	2
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26	Non Patent Literature	0071_zuiko_digital_50_mm_f20_canon0065017.pdf	1838265 80cc2709b4f81d218f6ebe91ab6eb5d430ac8aaa	no	2
Warnings:					
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27	Non Patent Literature	0072_canon_invalidity_contentions_2019.pdf	294902 1418d4e8580c711f6c28376672c250cfd008c7a6	no	32
Warnings:					
Information:					
28	Non Patent Literature	0022_gl2imen.pdf	4594525 fe34a421f6810c707f7929b40660854f750f46d7	no	163
Warnings:					
Information:					
		Total Files Size (in bytes):	408197362		

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

US005905530A

United States Patent [19]

Yokota et al.

[11] Patent Number: 5,905,530

[45] Date of Patent: May 18, 1999

[54] **IMAGE PICKUP APPARATUS**

[75] Inventors: **Hideo Yokota**; **Hiroyuki Hamano**; **Masaharu Suzuki**; **Yasuhiro Tamekuni**; **Takashi Kato**, all of Kanagawa-ken; **Katsumi Azusawa**, Saitama-ken; **Hidekage Sato**, Kanagawa-ken, all of Japan

[73] Assignee: **Canon Kabushiki Kaisha**, Tokyo, Japan

[21] Appl. No.: **08/598,140**

[22] Filed: **Feb. 7, 1996**

Related U.S. Application Data

[63] Continuation of application No. 08/103,091, Aug. 6, 1993, abandoned.

[30] **Foreign Application Priority Data**

Aug. 24, 1992	[JP]	Japan	4-223994
Nov. 18, 1992	[JP]	Japan	4-331204
Nov. 18, 1992	[JP]	Japan	4-331205
Dec. 11, 1992	[JP]	Japan	4-352358
Dec. 11, 1992	[JP]	Japan	4-352359

[51] **Int. Cl.**[6] **H04N 5/262**; H04N 5/217; H04N 5/232

[52] **U.S. Cl.** **348/240**; 348/241; 348/347; 348/358; 348/369; 396/76; 396/87

[58] **Field of Search** 348/207, 345, 348/347, 333, 240, 241, 151, 169, 187, 231, 360, 578, 222, 224, 228, 358, 369; 354/400, 402; 369/680, 708; 358/906, 909.1; 396/72, 76, 77, 79, 80, 82, 85, 87; H04N 5/225, 5/232, 5/335, 5/262, 5/217

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4316286	6/1992	Japan	H04N 5/232

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Rebiai et al. Image Distortion from Zoom Lenses: Modeling and Digital Correction, Jul. 3–7, 1992, IBC Conf. Publ. No. 358 PTO 93–2414 Translation of JPI–238283.

Primary Examiner—Wendy Garber
Assistant Examiner—Ngoc-Yen Vu
Attorney, Agent, or Firm—Fitzpatrick, Cella, Harper & Scinto

[57] **ABSTRACT**

An image pickup apparatus is disclosed which is provided with a distortional-aberration memorizing element for memorizing distortional-aberration information about an objective lens, a state-of-objective-lens detecting circuit for detecting a state of the objective lens, an image correcting circuit for reading out distortional-aberration information about distortional aberration occurring during photography from the distortional-aberration memorizing element on the basis of information supplied from the state-of-objective-lens detecting circuit, and electrically correcting a distortion of an image due to the objective lens with a predetermined image height in a photographed image selected as a datum.

1 Claim, 48 Drawing Sheets

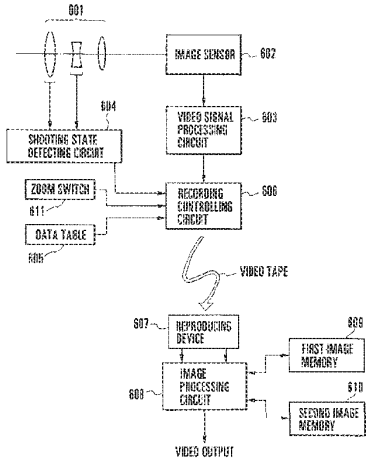
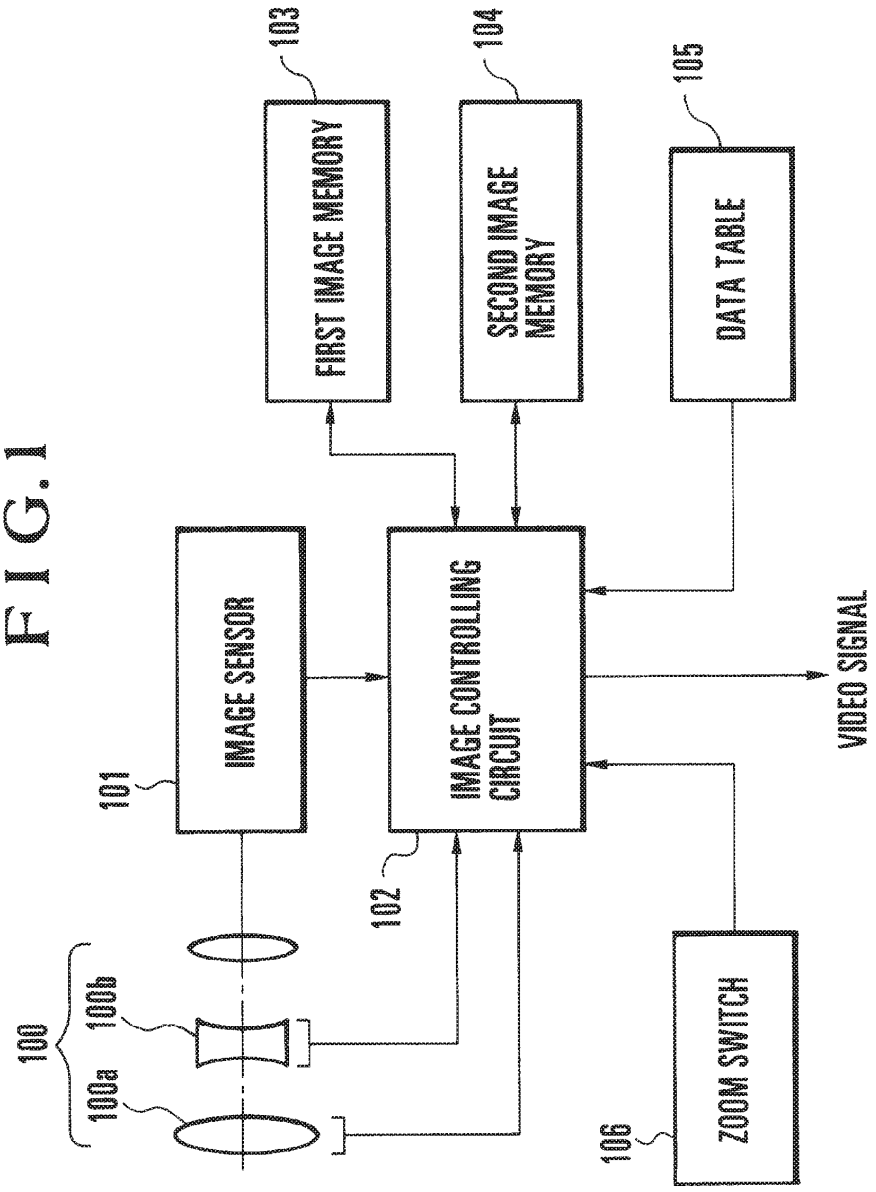


FIG. 1



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FIG.2

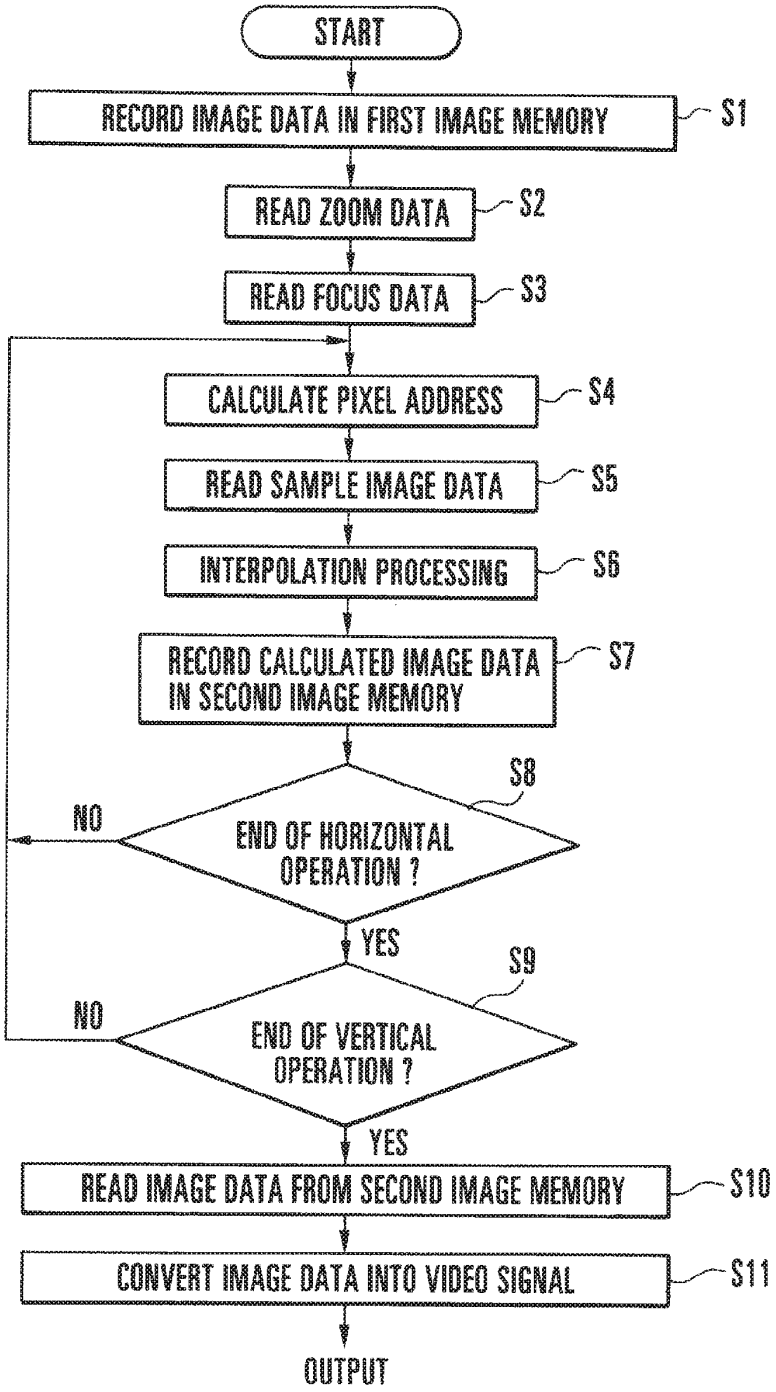

START
RECORD IMAGE DATA IN FIRST IMAGE MEMORY
S1
READ ZOOM DATA
S2
READ FOCUS DATA
S3
CALCULATE PIXEL ADDRESS
S4
READ SAMPLE IMAGE DATA
S5
INTERPOLATION PROCESSING
S6
RECORD CALCULATED IMAGE DATA IN SECOND IMAGE MEMORY
S7
S8
END OF HORIZONTAL OPERATION ?
NO
YES
S9
END OF VERTICAL OPERATION ?
NO
YES
READ IMAGE DATA FROM SECOND IMAGE MEMORY
S10
CONVERT IMAGE DATA INTO VIDEO SIGNAL
S11
OUTPUT

FIG.3

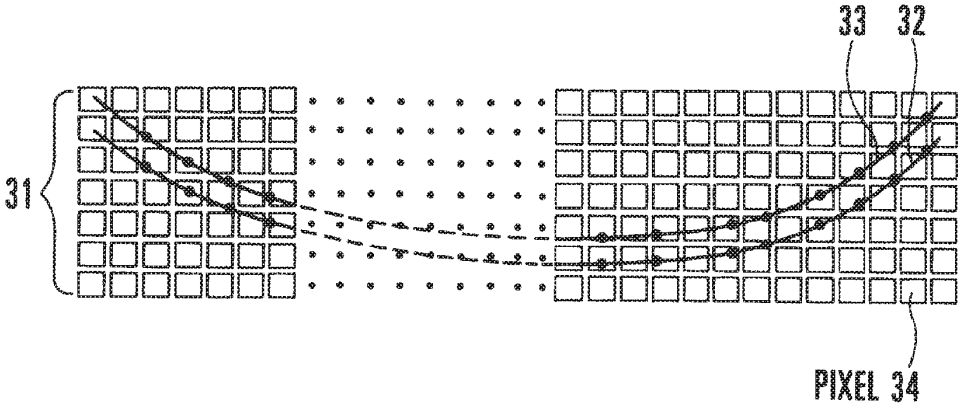


FIG.4

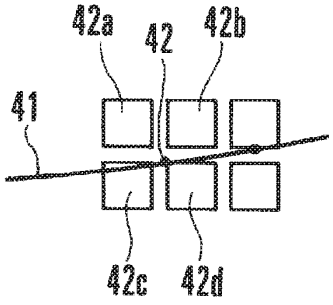
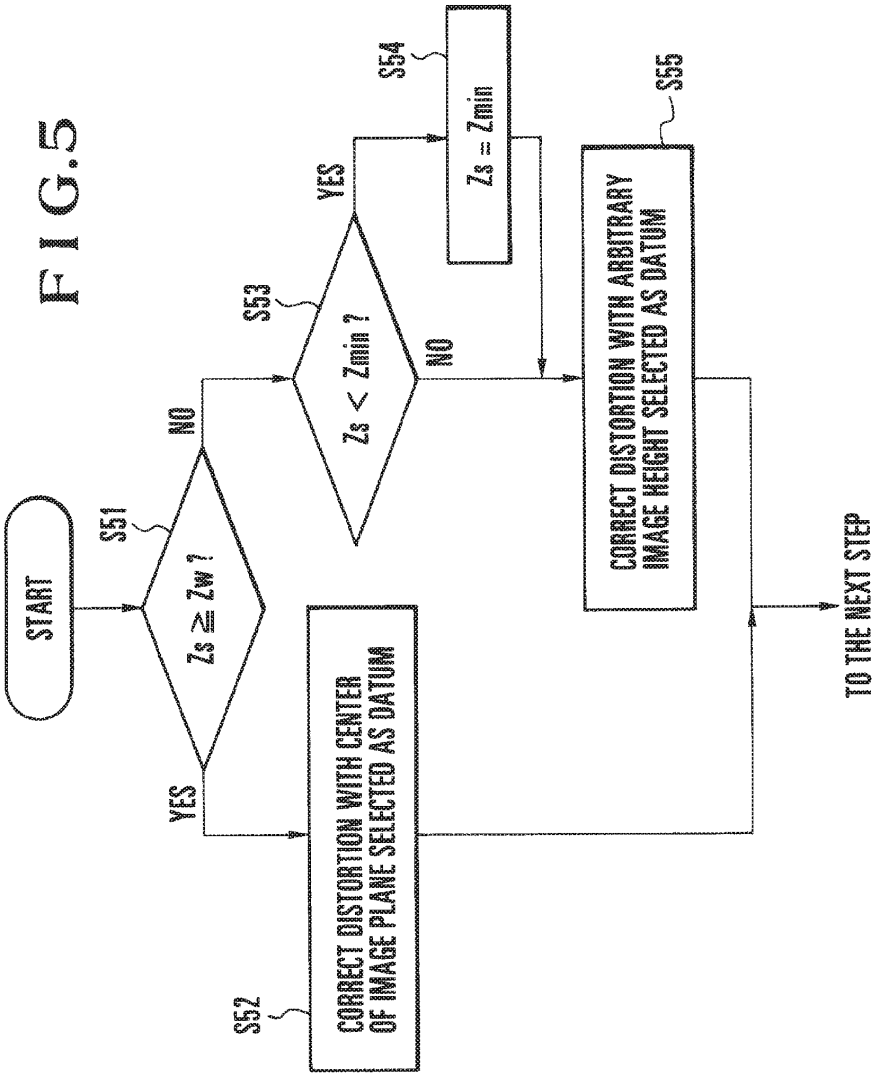


FIG.5



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FIG.6(a) FIG.6(b) FIG.6(c)

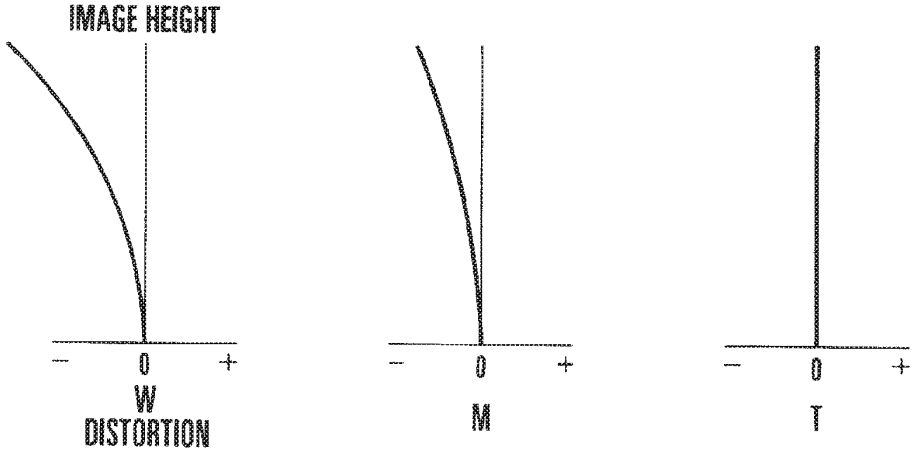


FIG.7

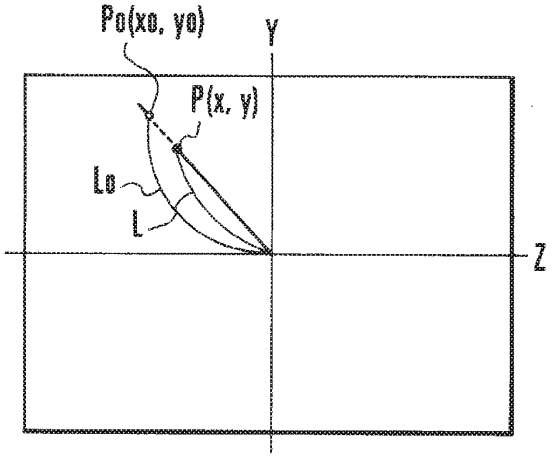


FIG.8

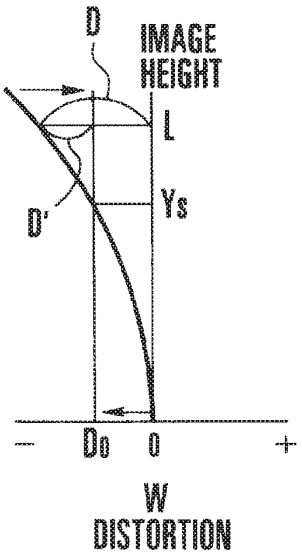

D
IMAGE HEIGHT
L
Ys
D'
−
D0
0
+
W
DISTORTION

FIG.9

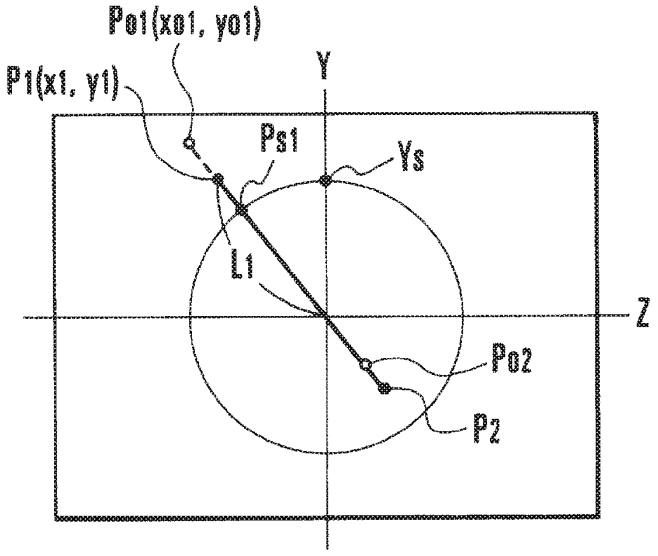

Po1(xo1, yo1)
P1(x1, y1)
Y
Ps1
Ys
L1
Z
Po2
P2

FIG.10

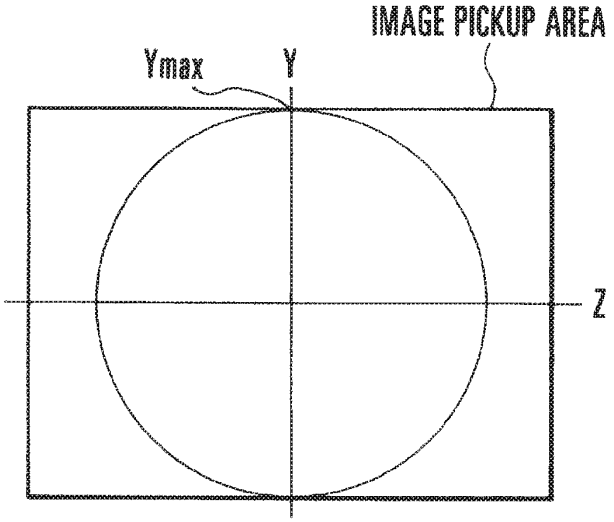

IMAGE PICKUP AREA
Ymax
Y
Z

FIG.11

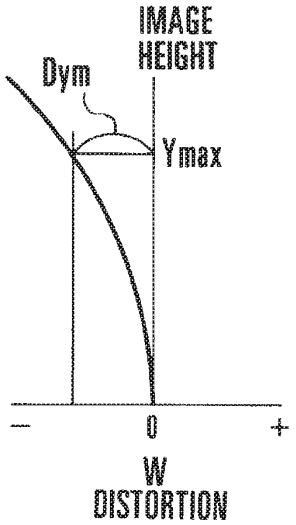
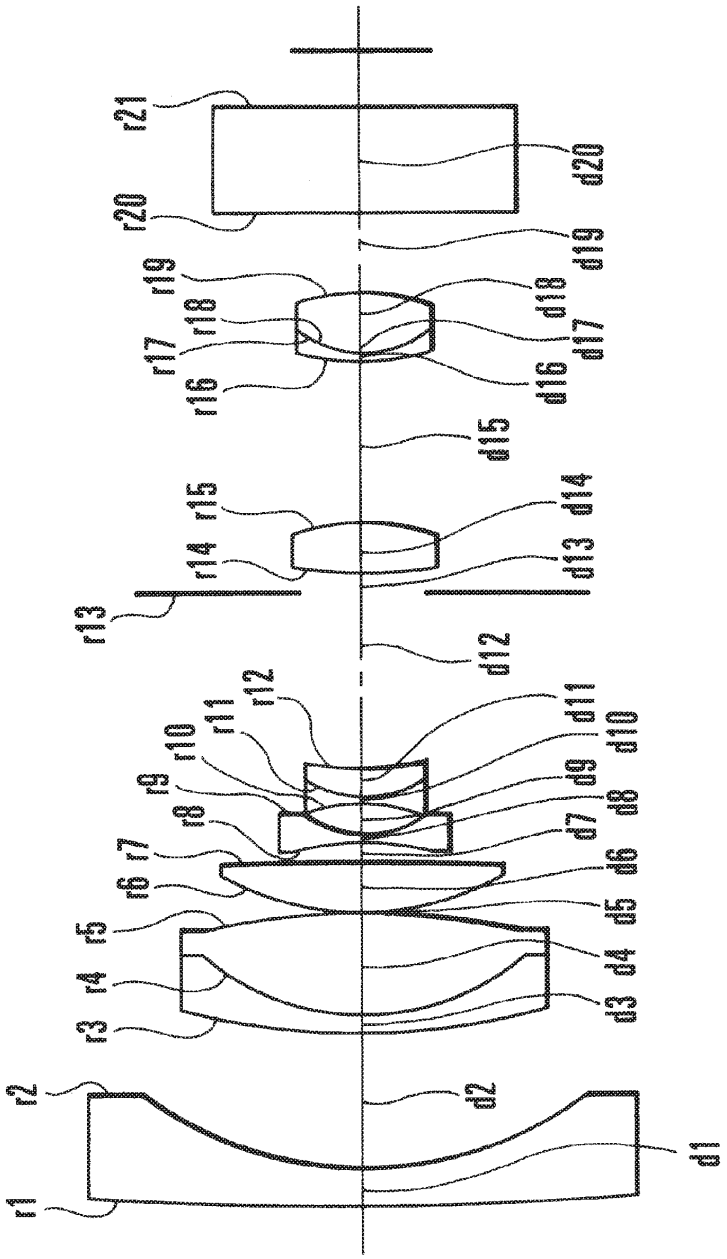

IMAGE HEIGHT
Dym
Ymax
−
0
+
W
DISTORTION

FIG. 12



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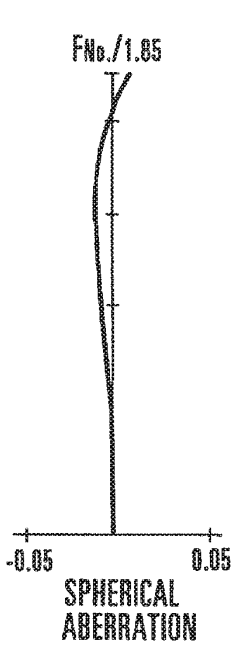


FIG.13(a)

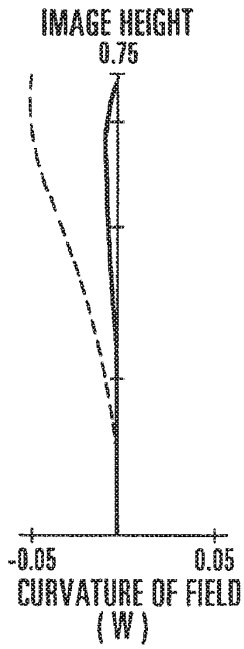


FIG.13(b)

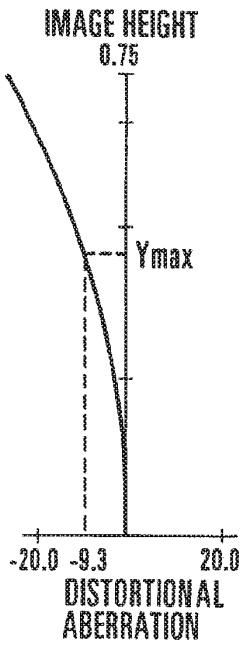


FIG.13(c)

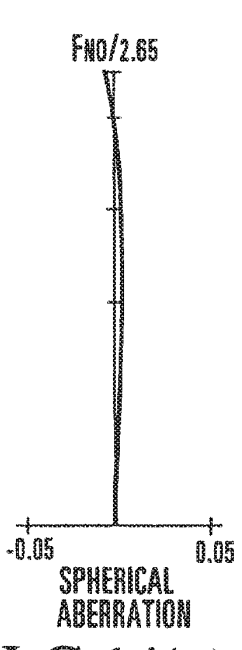


FIG.14(a)

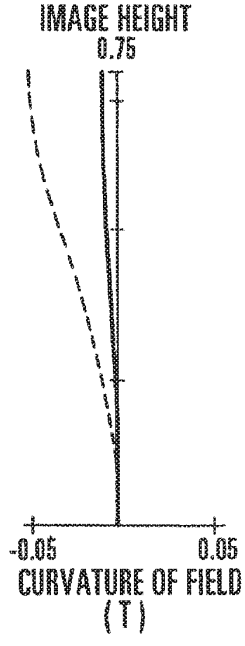


FIG.14(b)

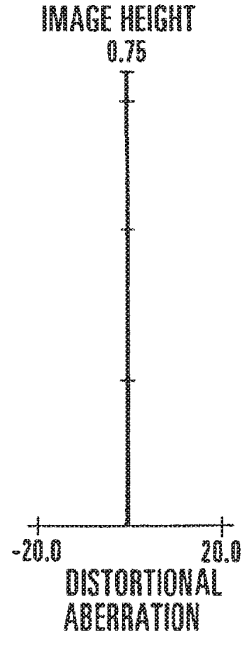


FIG.14(c)

FIG.15(a)

< NUMERICAL EXAMPLE >

F=1～5.66 FNO=1:1.85 ～2.65 IMAGE HEIGHT 0.75

r 1=	99.5653	d 1=	0.4977	n 1=	1.60311	v 1=	60.7
r 2=	5.7183	d 2=	1.9912				
r 3=	9.6933	d 3=	0.2986	n 2=	1.80518	v 2=	25.4
r 4=	3.9454	d 4=	1.4931	n 3=	1.58913	v 3=	61.3
r 5=	-14.0451	d 5=	0.0498				
r 6=	4.3647	d 6=	0.6968	n 4=	1.80400	v 4=	46.6
r 7=	193.8973	d 7=	VARIABLE				
r 8=	-7.1644	d 8=	0.1244	n 5=	1.88300	v 5=	40.8
r 9=	1.4701	d 9=	0.5147				
r10=	-3.3919	d10=	0.1244	n 6=	1.51742	v 6=	52.4
r11=	1.5737	d11=	0.4106	n 7=	1.84666	v 7=	23.8
r12=	6.6811	d12=	VARIABLE				
r13=	0.0000 (STOP)	d13=	0.2986				
* r14=	9.9724	d14=	0.7217	n 8=	1.58313	v 8=	59.4
r15=	-3.6206	d15=	VARIABLE				
r16=	3.0913	d16=	0.1244	n 9=	1.84666	v 9=	23.8
r17=	1.5845	d17=	0.0105				
r18=	1.6097	d18=	0.9332	n10=	1.58313	v10=	59.4
* r19=	-3.7395	d19=	VARIABLE				
r20=	0.0000	d20=	1.6175	n11=	1.51633	v11=	64.2
r21=	0.0000						

* ASPHERIC

CANON0062556

FIG.15(b)

VARIABLE SEPARATION	FOCAL LENGTH		
	1.00	2.55	5.66
d 7	0.32	1.99	2.97
d 12	2.68	1.01	0.03
d 15	2.46	1.53	0.99
d 19	1.24	2.18	2.71

FIG.15(c)

ASPHERIC COEFFICIENT

SURFACE	B	C	D
r 14	-9.4890×10^{-3}	-9.5313×10^{-4}	-3.5873×10^{-5}
r 19	-1.5696×10^{-3}	-1.4025×10^{-3}	-9.1864×10^{-5}

CANON0062557

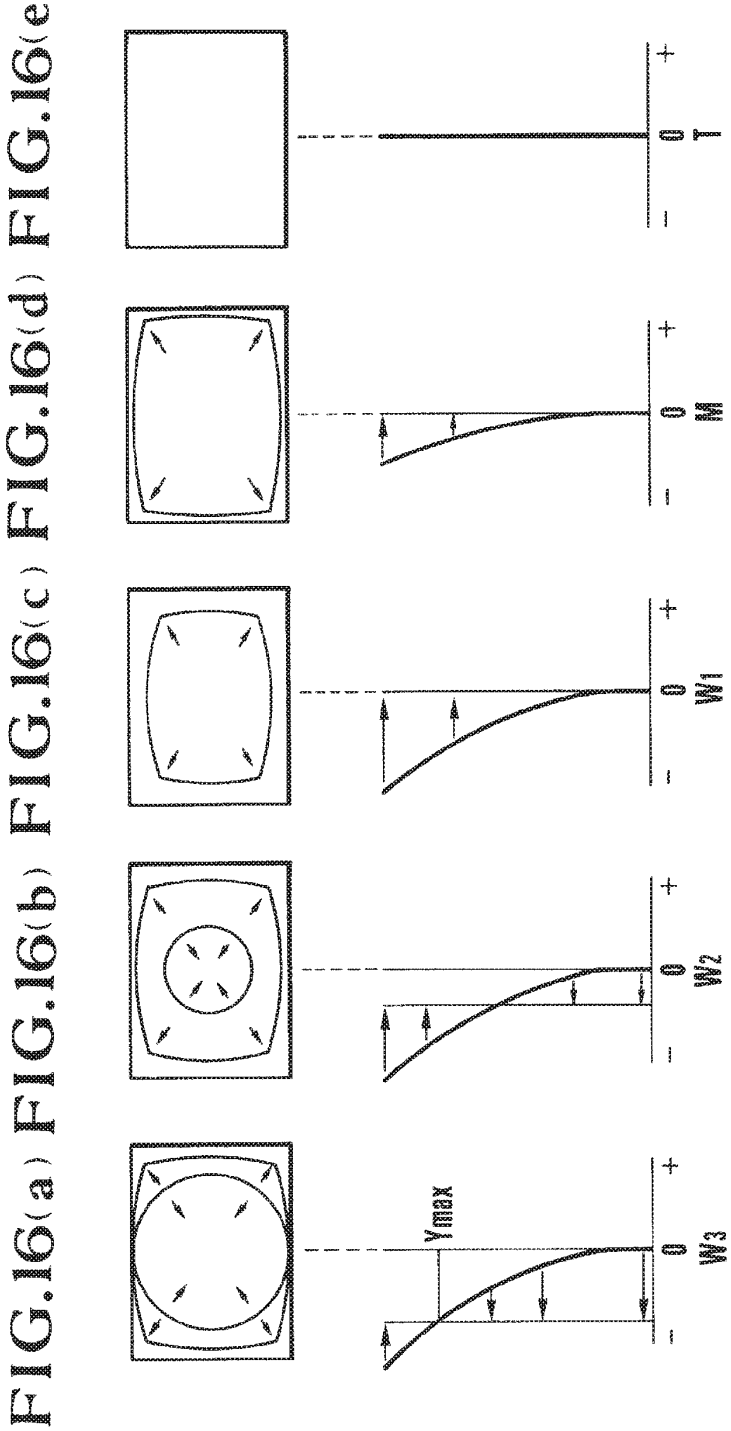


FIG.16(a) FIG.16(b) FIG.16(c) FIG.16(d) FIG.16(e)

FIG.17

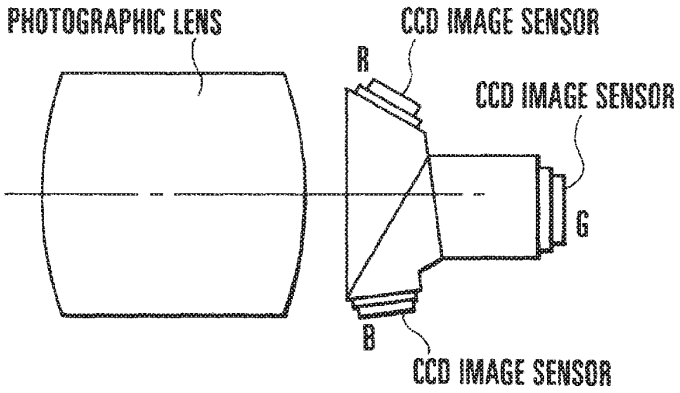


FIG.18(a) FIG.18(b) FIG.18(c)

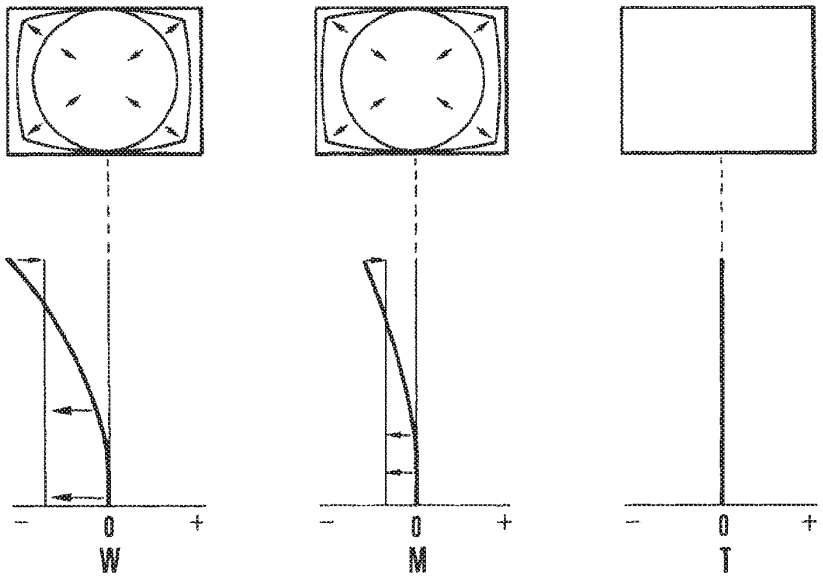
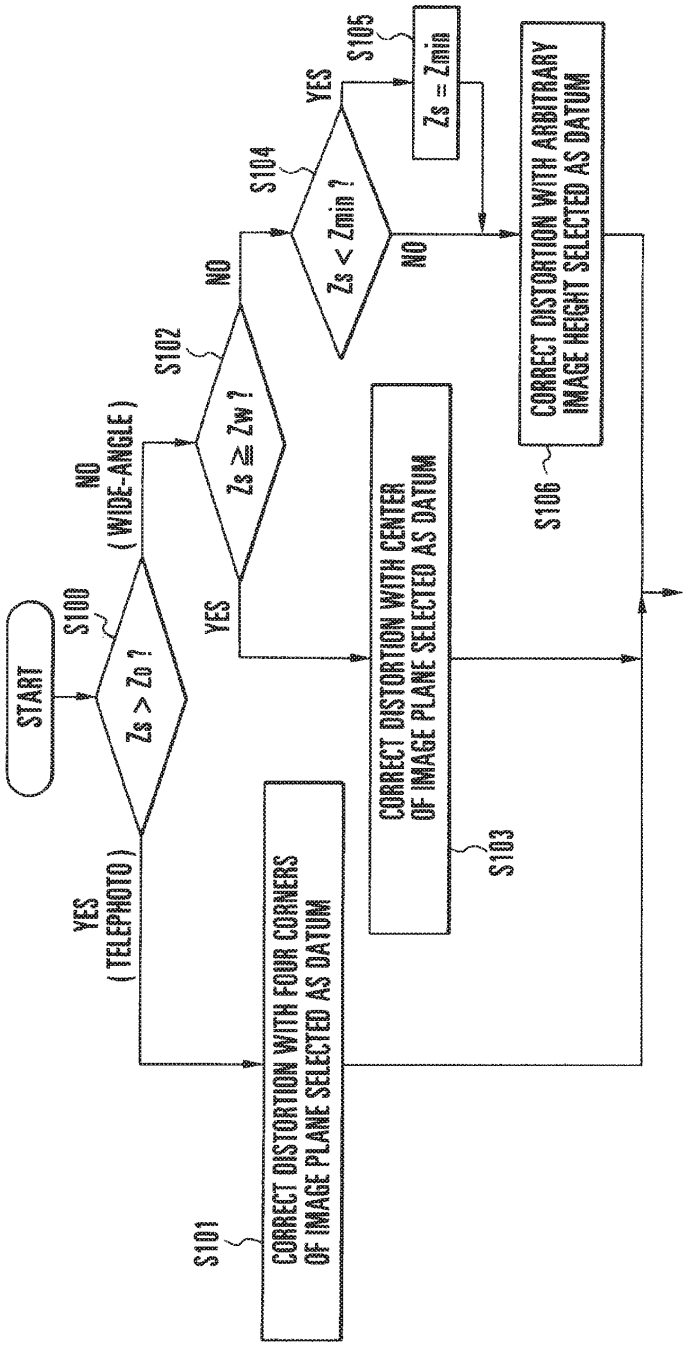


FIG.19



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FIG.20

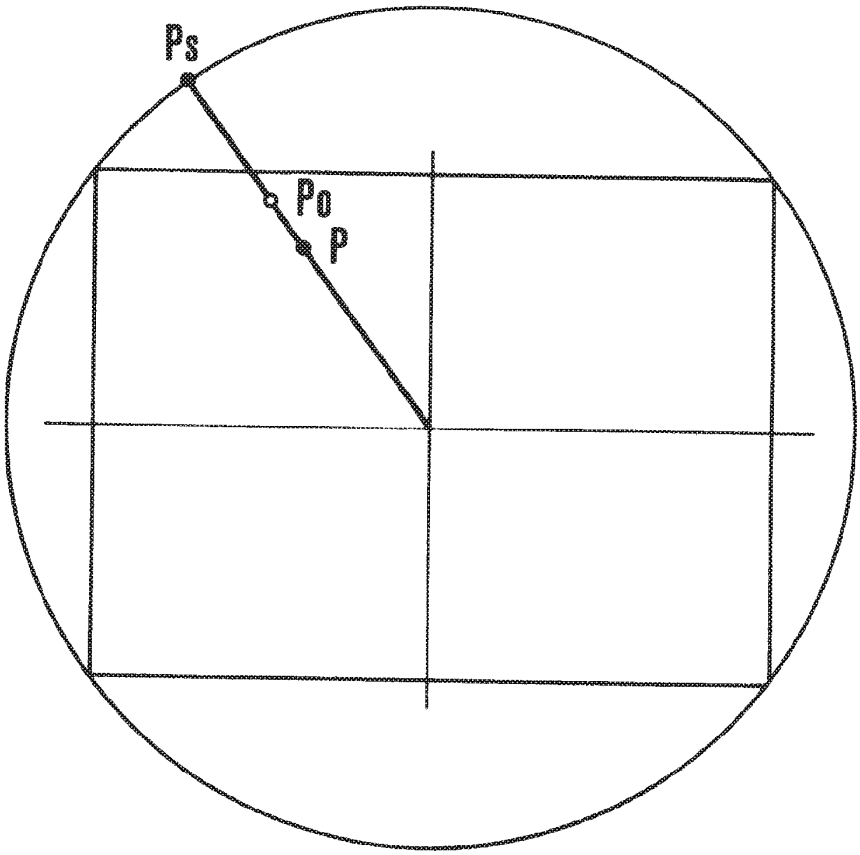


FIG.21

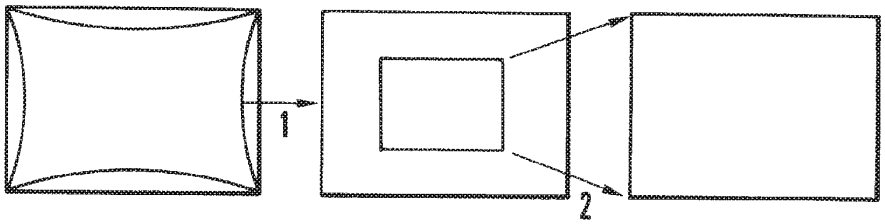


FIG.22

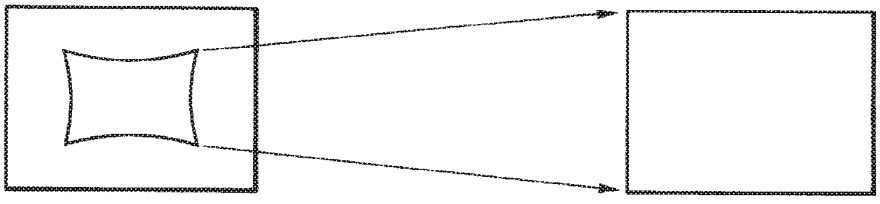


FIG.23

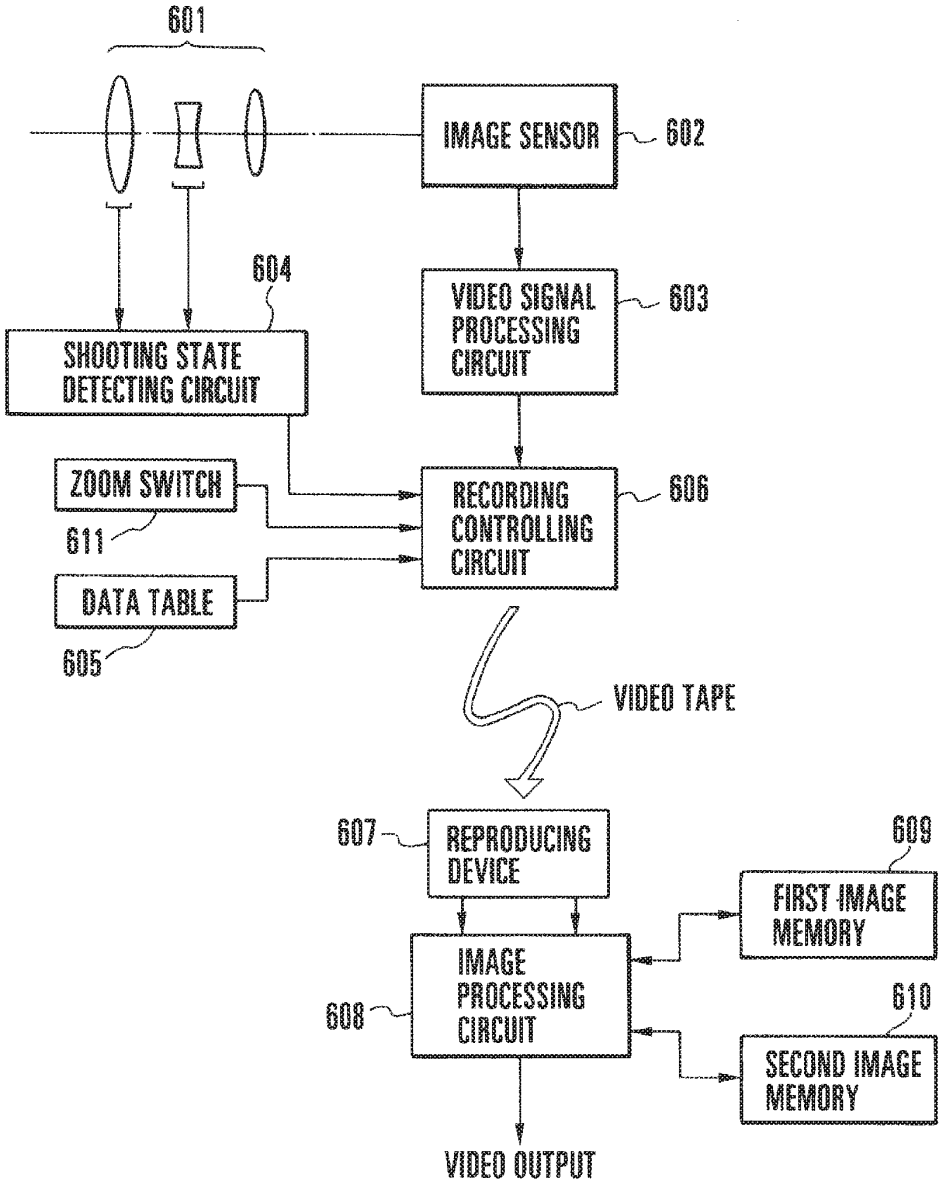

601
IMAGE SENSOR
602
604
VIDEO SIGNAL PROCESSING CIRCUIT
603
SHOOTING STATE DETECTING CIRCUIT
ZOOM SWITCH
611
RECORDING CONTROLLING CIRCUIT
606
DATA TABLE
605
VIDEO TAPE
607
REPRODUCING DEVICE
609
FIRST IMAGE MEMORY
IMAGE PROCESSING CIRCUIT
608
610
SECOND IMAGE MEMORY
VIDEO OUTPUT

FIG.24

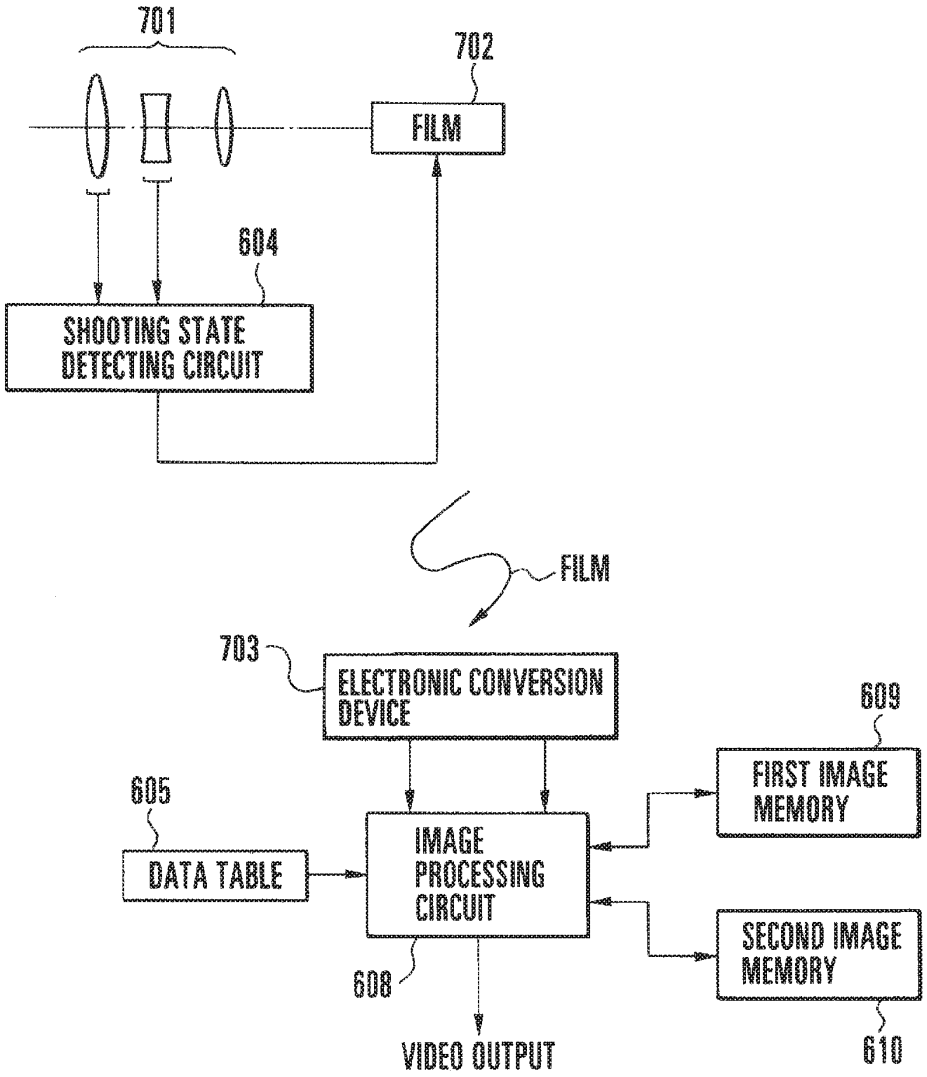

701
702
FILM
604
SHOOTING STATE DETECTING CIRCUIT
FILM
703
ELECTRONIC CONVERSION DEVICE
609
FIRST IMAGE MEMORY
605
DATA TABLE
IMAGE PROCESSING CIRCUIT
SECOND IMAGE MEMORY
608
VIDEO OUTPUT
610

FIG.25(a)
RELATED ART

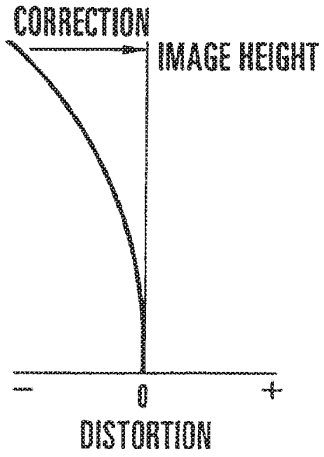


FIG.25(b)
RELATED ART

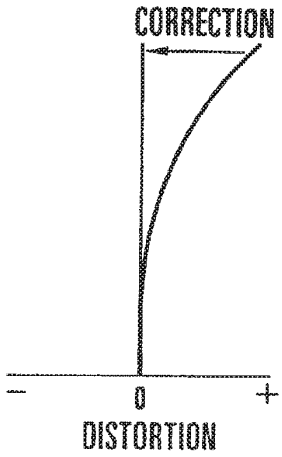


FIG.26(a)
RELATED ART

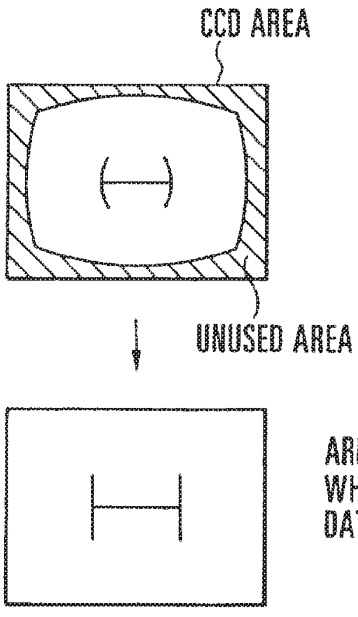


FIG.26(b)
RELATED ART

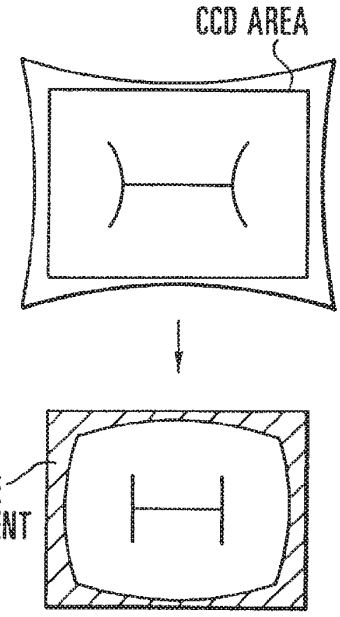


FIG.27(a)-2

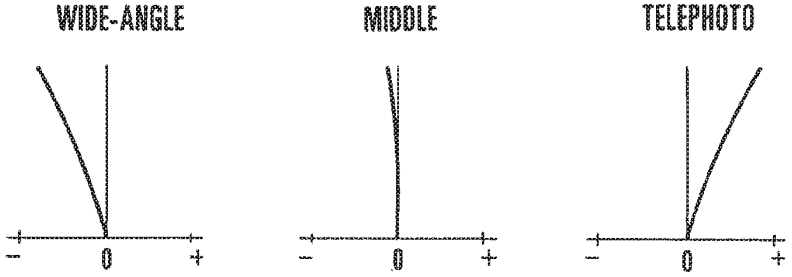


FIG.27(a)-1

FIG.27(a)-3

FIG.27(b)-2

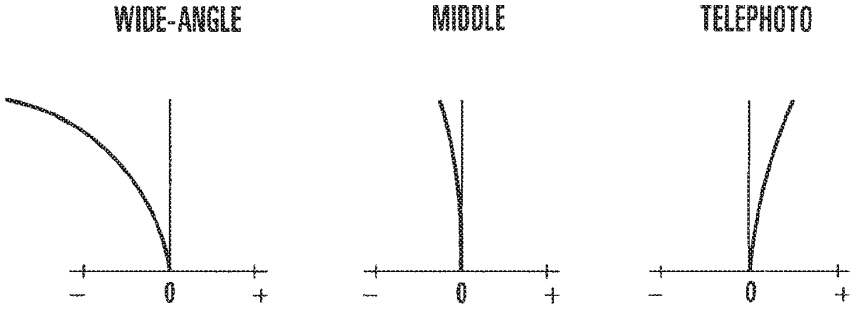
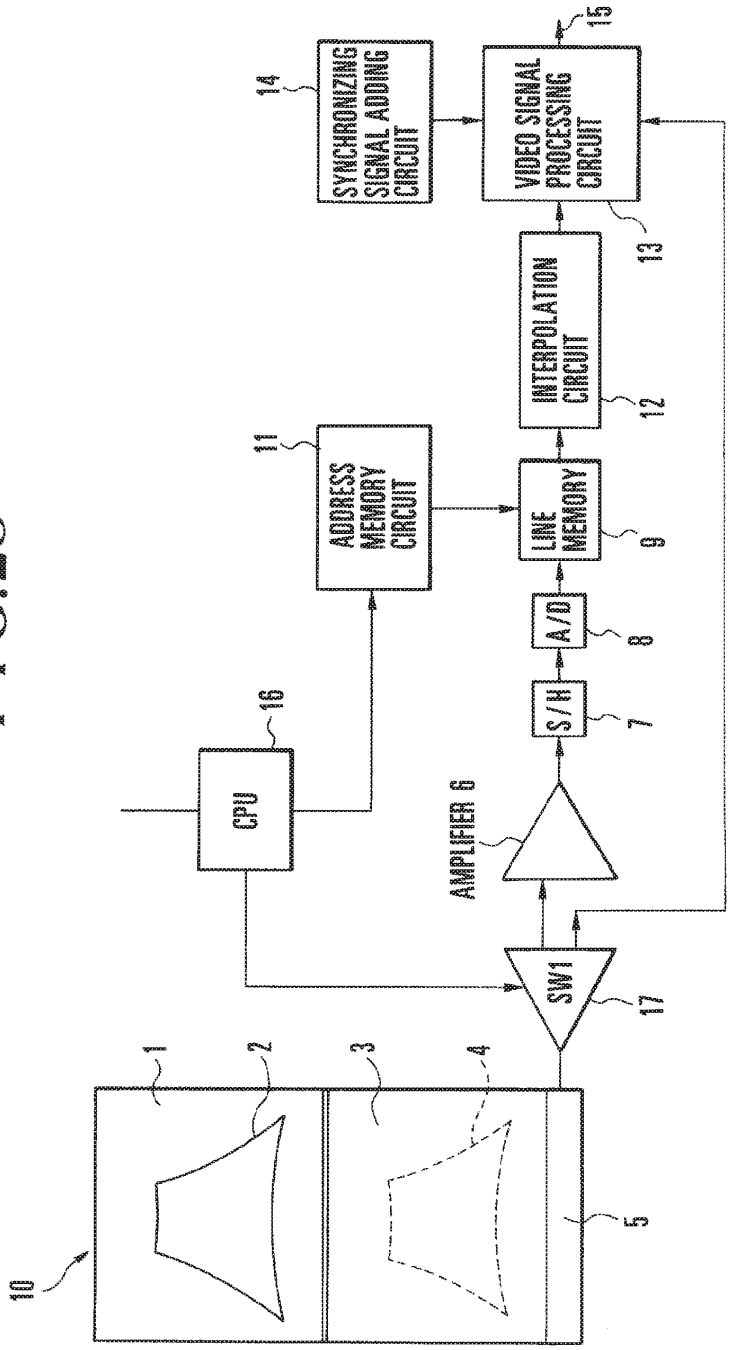


FIG.27(b)-1

FIG.27(b)-3

FIG.28



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FIG.29

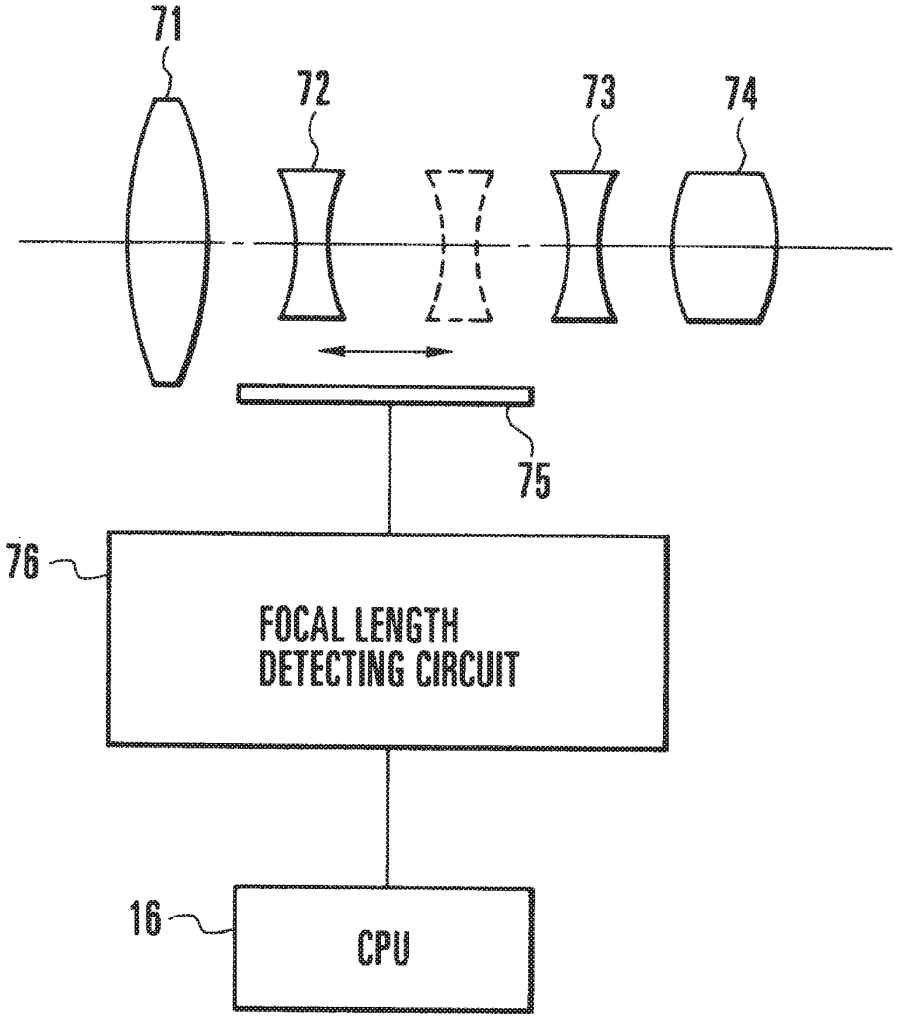


FIG.30

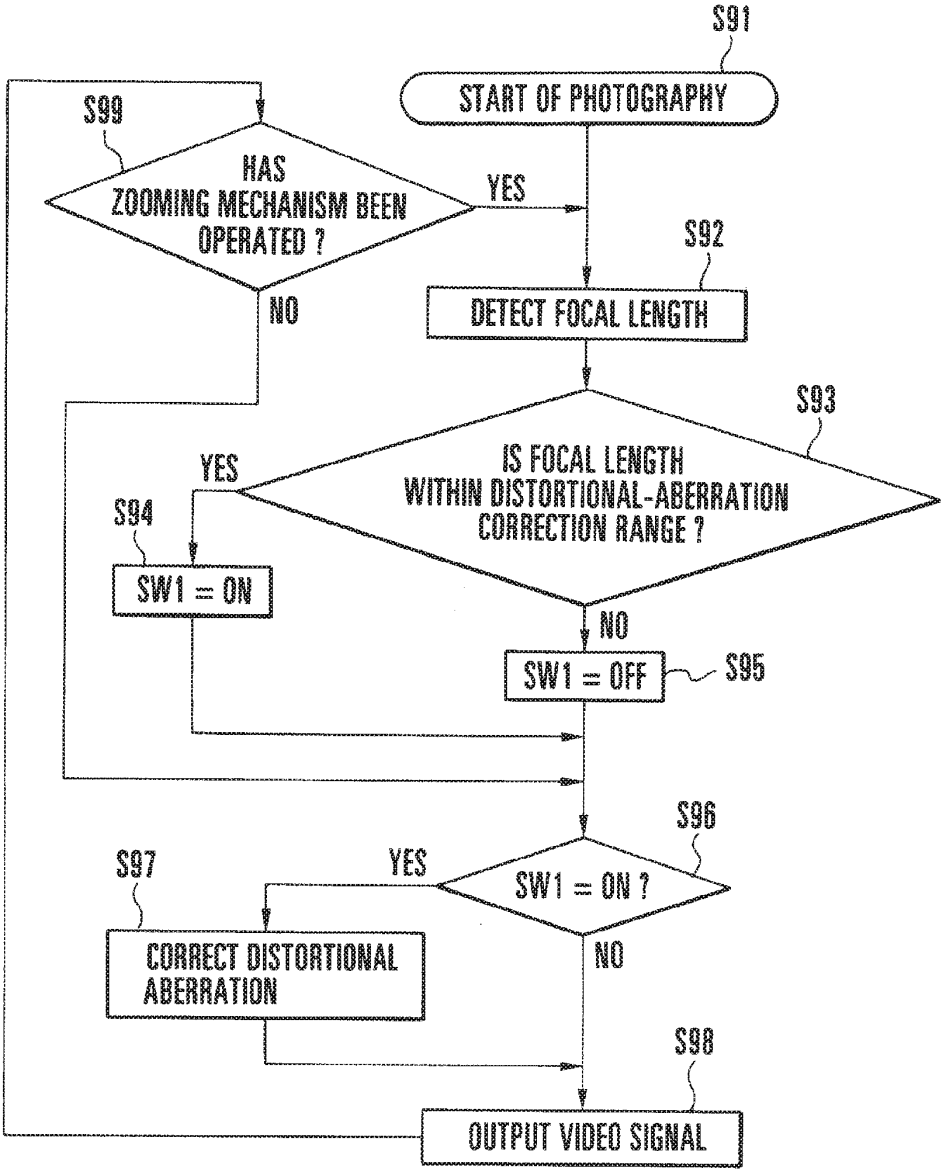

S91
START OF PHOTOGRAPHY
S99
HAS ZOOMING MECHANISM BEEN OPERATED ?
YES
NO
S92
DETECT FOCAL LENGTH
S93
IS FOCAL LENGTH WITHIN DISTORTIONAL-ABERRATION CORRECTION RANGE ?
YES
NO
S94
SW1 = ON
SW1 = OFF
S95
S96
SW1 = ON ?
YES
NO
S97
CORRECT DISTORTIONAL ABERRATION
S98
OUTPUT VIDEO SIGNAL

FIG.31

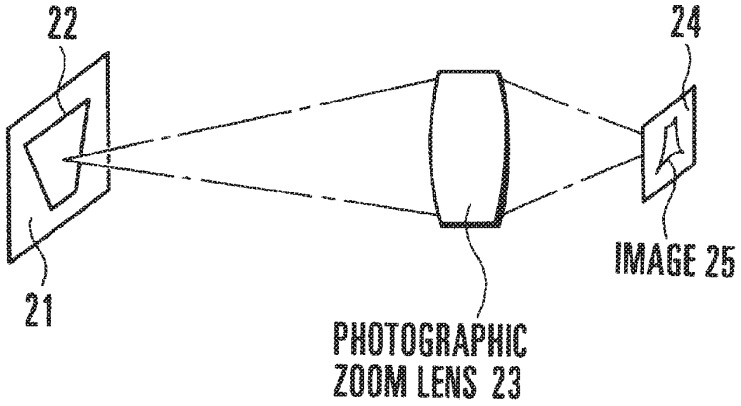

22
24
IMAGE 25
21
PHOTOGRAPHIC
ZOOM LENS 23

FIG.32

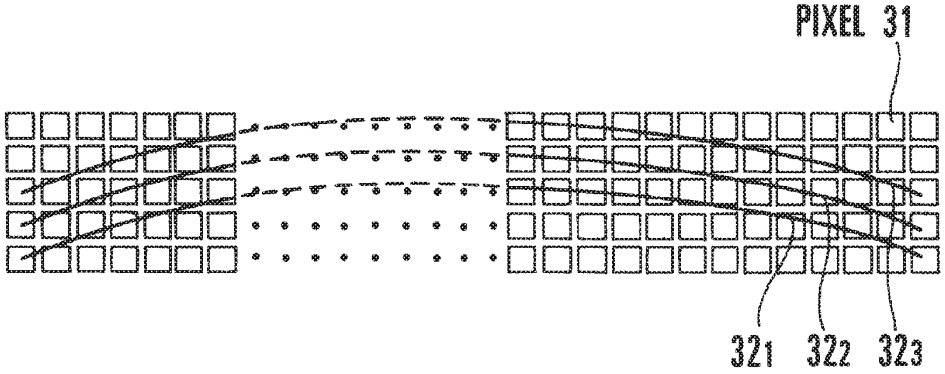

PIXEL 31
321
322
323

FIG.33

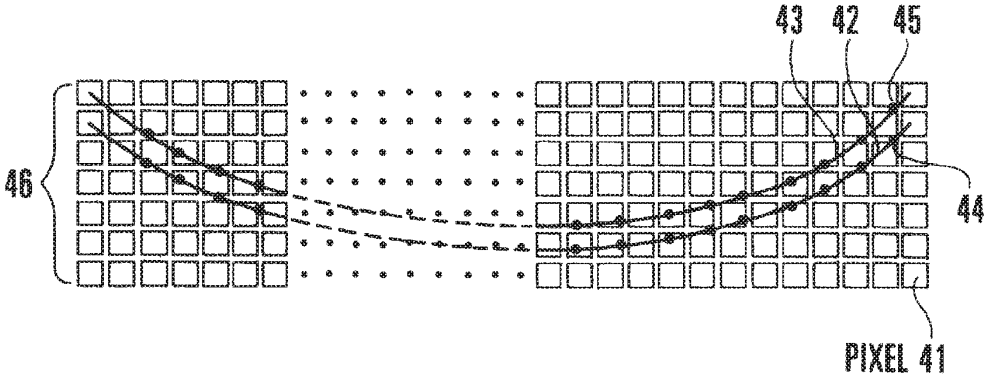


FIG.34

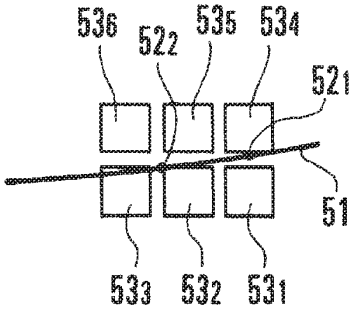
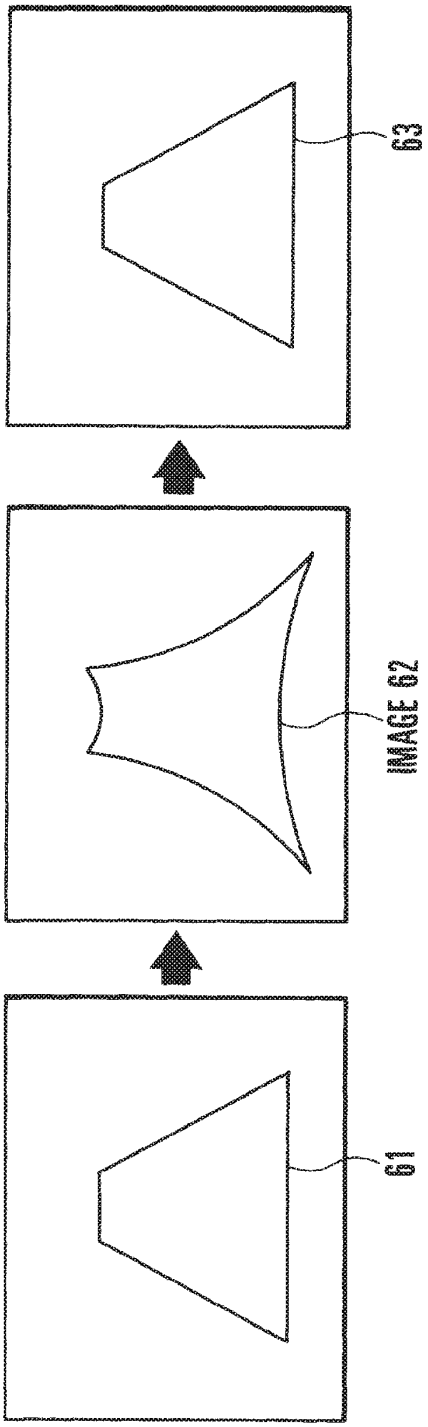


FIG.35



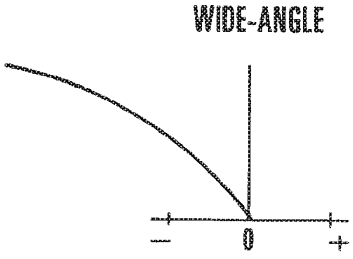


FIG.36(a)

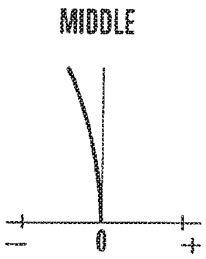


FIG.36(b)

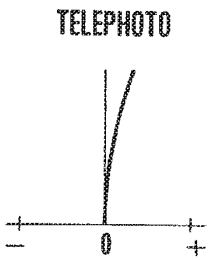


FIG.36(c)

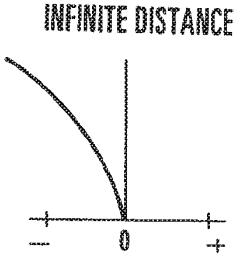


FIG.37(a)

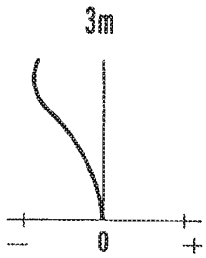


FIG.37(b)

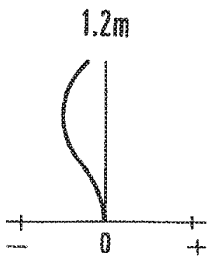
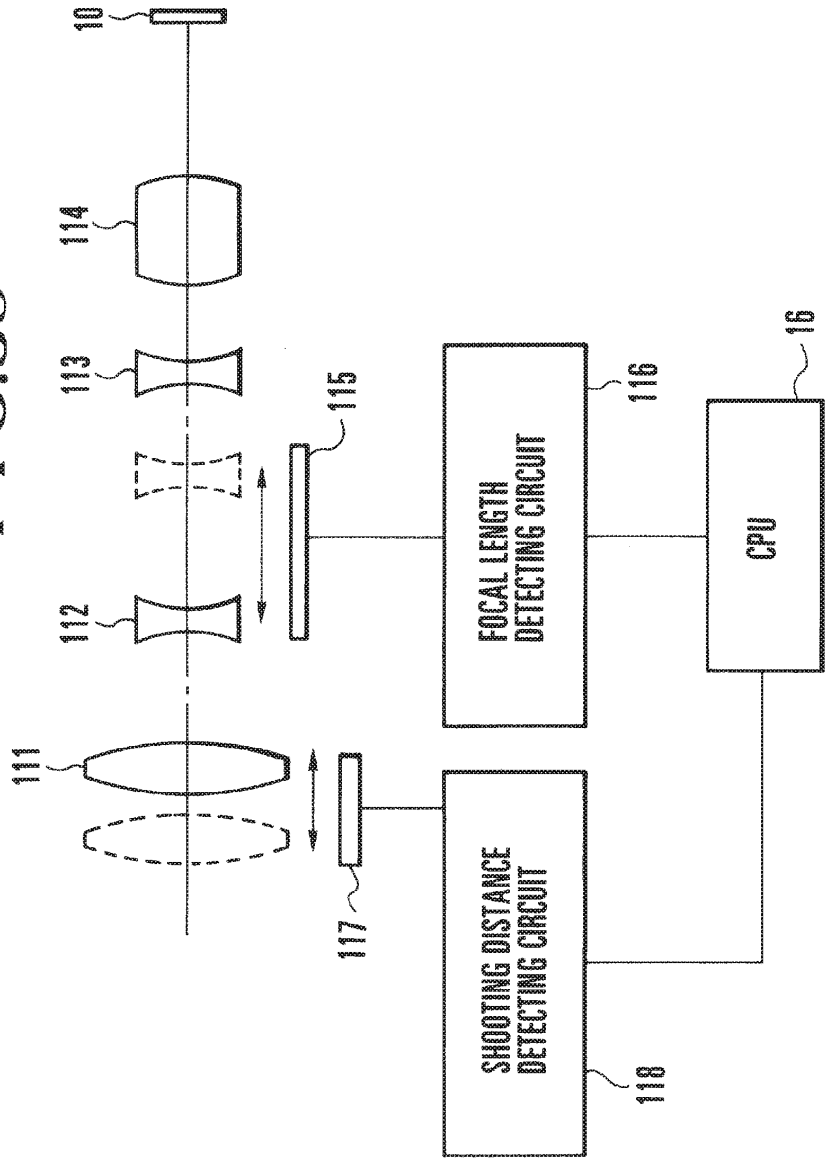


FIG.37(c)

CANON0062573

FIG.38



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FIG. 39

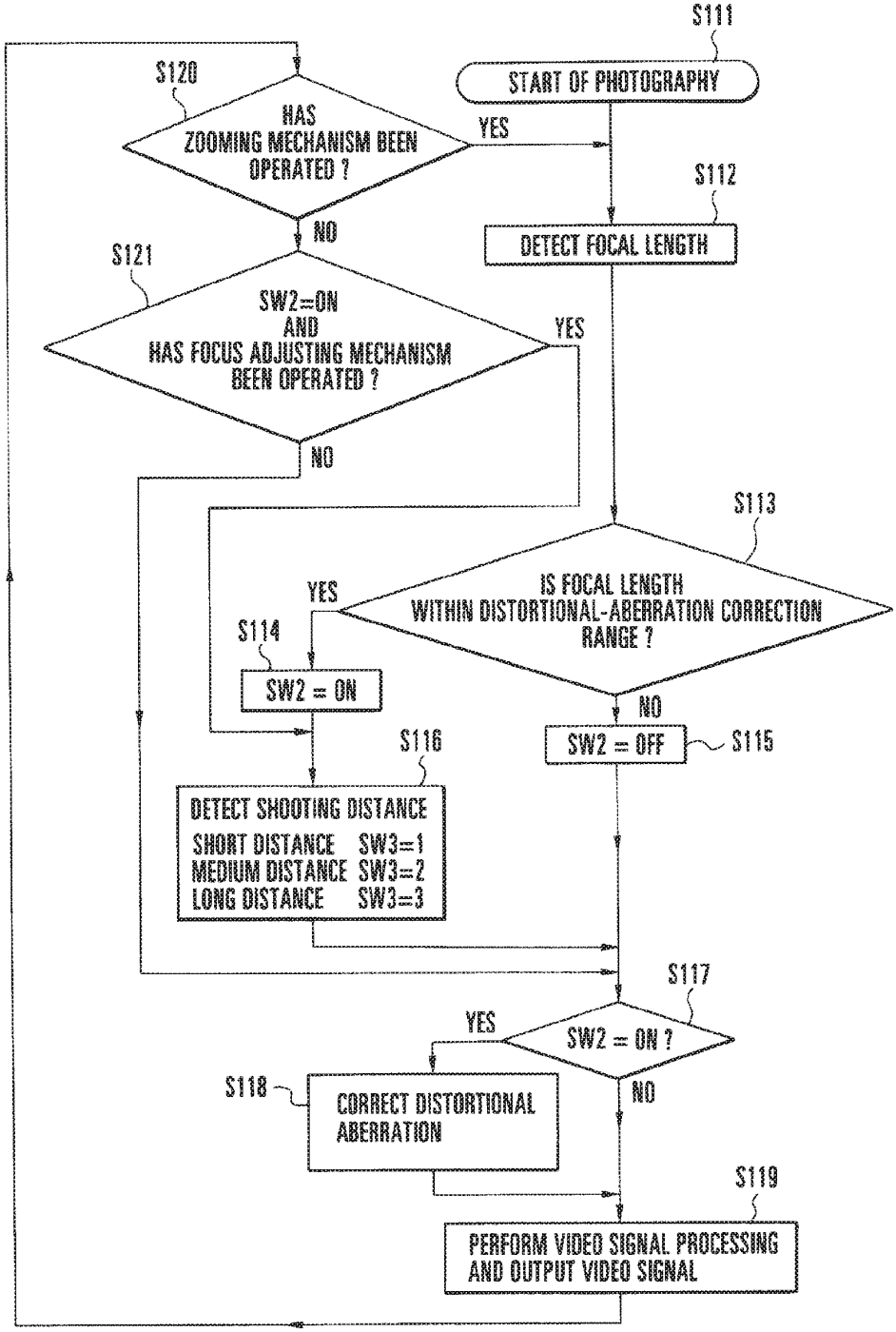
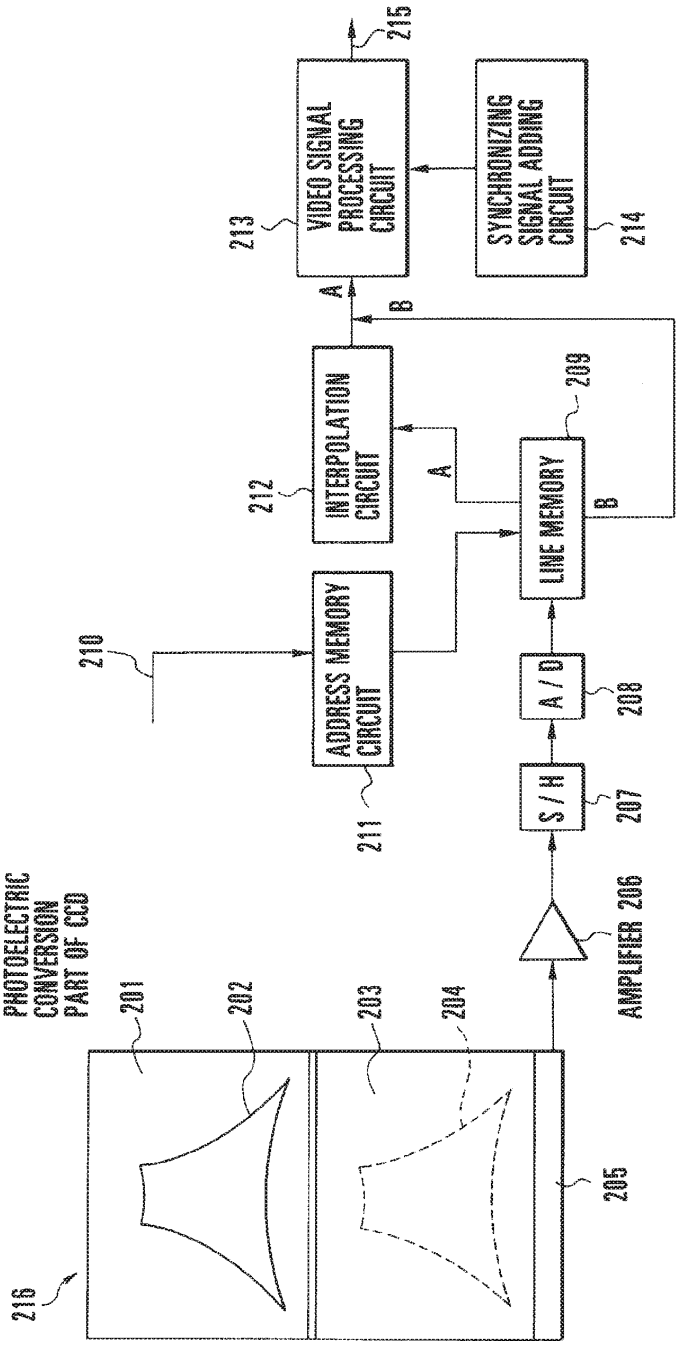

S111
START OF PHOTOGRAPHY
S112
DETECT FOCAL LENGTH
S113
IS FOCAL LENGTH WITHIN DISTORTIONAL-ABERRATION CORRECTION RANGE ?
YES
NO
S114
SW2 = ON
S115
SW2 = OFF
S116
DETECT SHOOTING DISTANCE
SHORT DISTANCE SW3=1
MEDIUM DISTANCE SW3=2
LONG DISTANCE SW3=3
S117
SW2 = ON ?
YES
NO
S118
CORRECT DISTORTIONAL ABERRATION
S119
PERFORM VIDEO SIGNAL PROCESSING AND OUTPUT VIDEO SIGNAL
S120
HAS ZOOMING MECHANISM BEEN OPERATED ?
YES
NO
S121
SW2=ON AND HAS FOCUS ADJUSTING MECHANISM BEEN OPERATED ?
YES
NO

FIG.40



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FIG.41

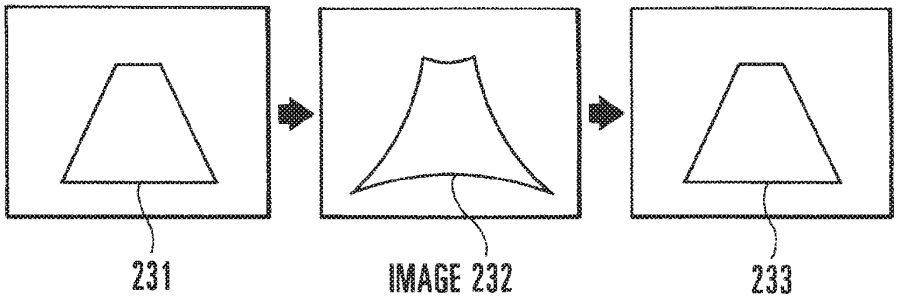

231
IMAGE 232
233

FIG.42

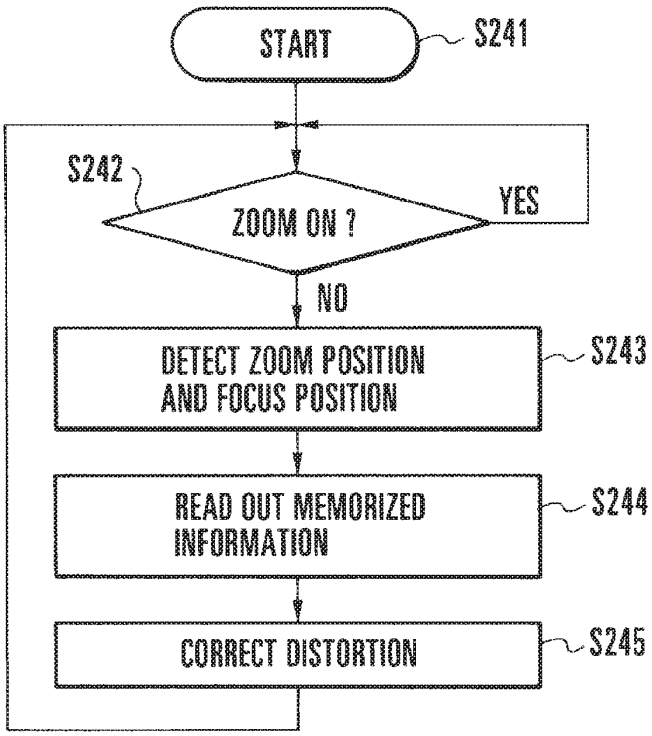

START
S241
S242
ZOOM ON ?
YES
NO
DETECT ZOOM POSITION AND FOCUS POSITION
S243
READ OUT MEMORIZED INFORMATION
S244
CORRECT DISTORTION
S245

FIG.43

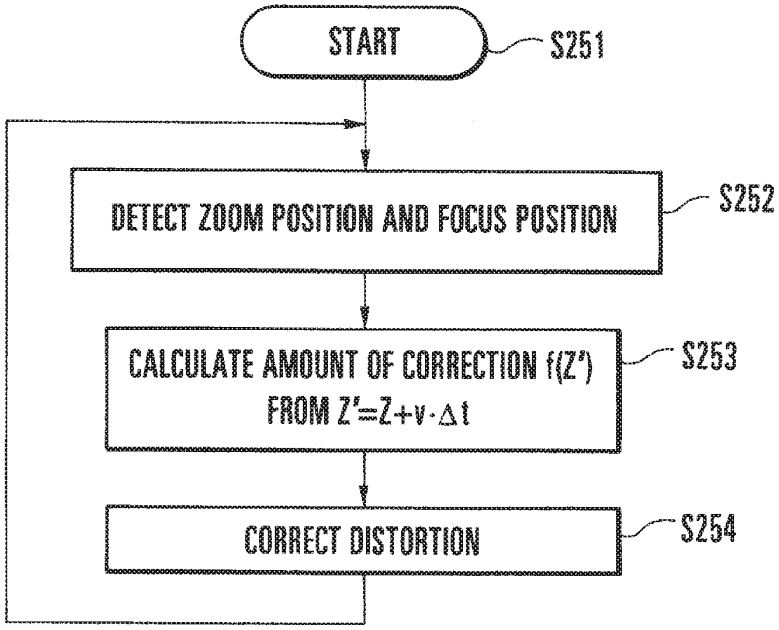

START
S251
DETECT ZOOM POSITION AND FOCUS POSITION
S252
CALCULATE AMOUNT OF CORRECTION f(Z')
FROM Z'=Z+v·Δt
S253
CORRECT DISTORTION
S254

FIG.44

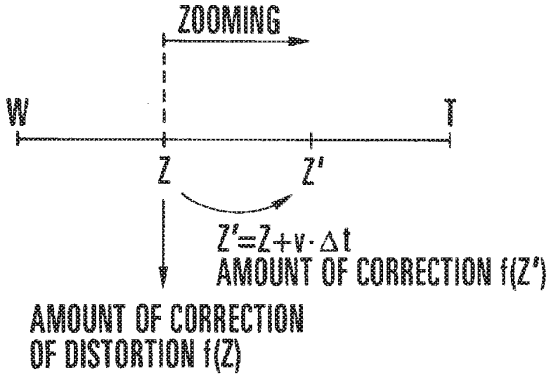
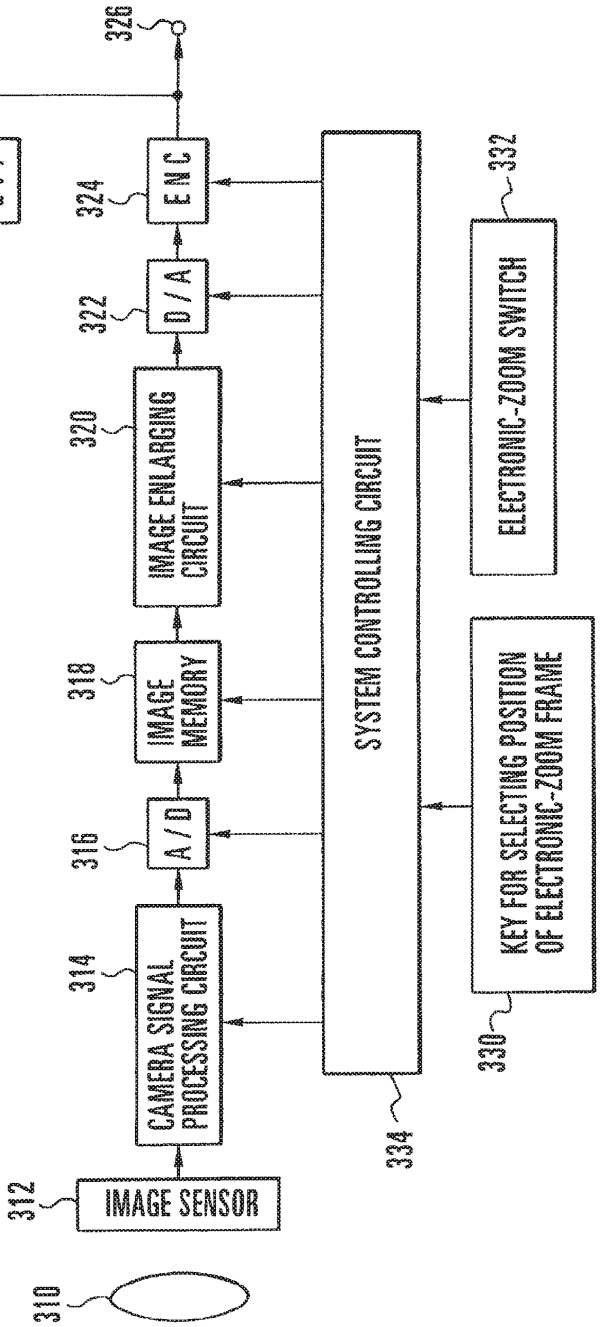

ZOOMING
W
T
Z
Z'
Z'=Z+v·Δt
AMOUNT OF CORRECTION f(Z')
AMOUNT OF CORRECTION
OF DISTORTION f(Z)

FIG.45



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FIG.46

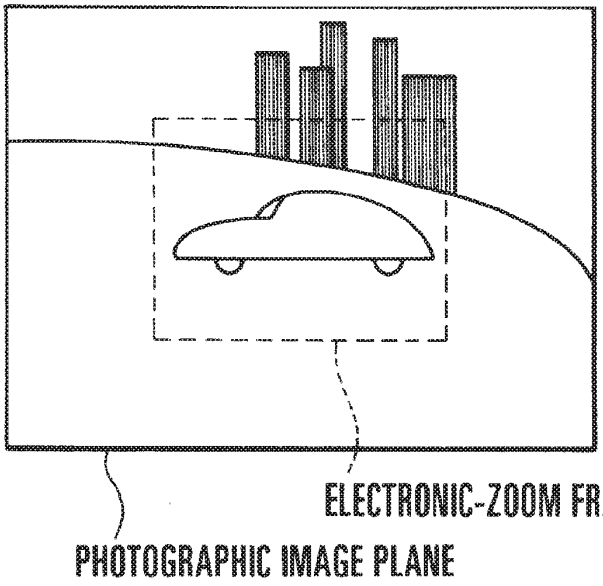


FIG.47

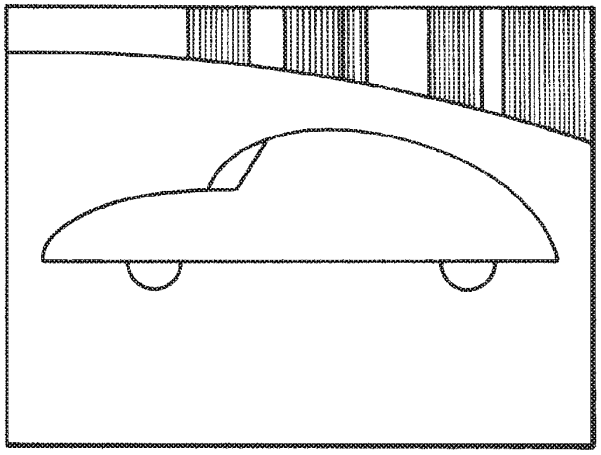


FIG.48

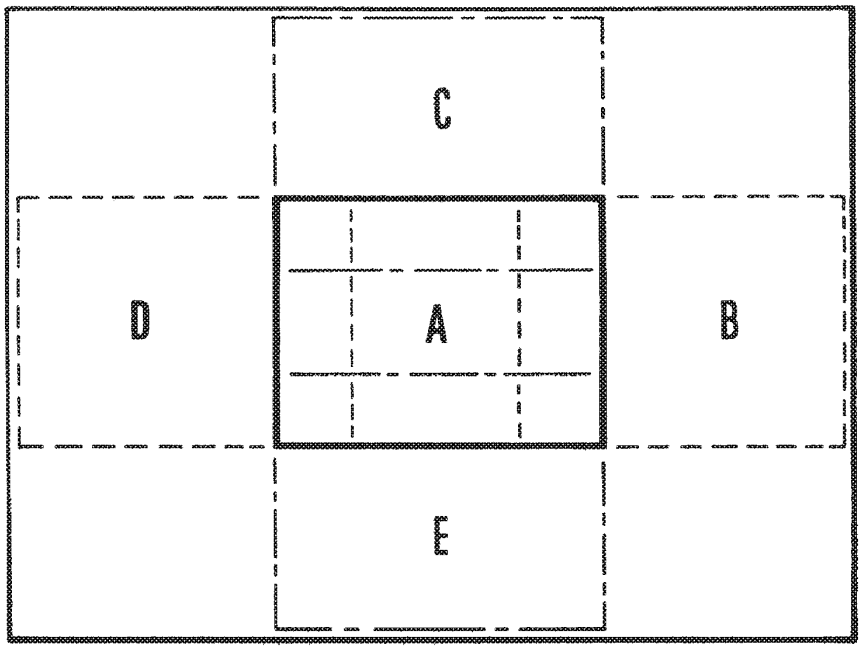
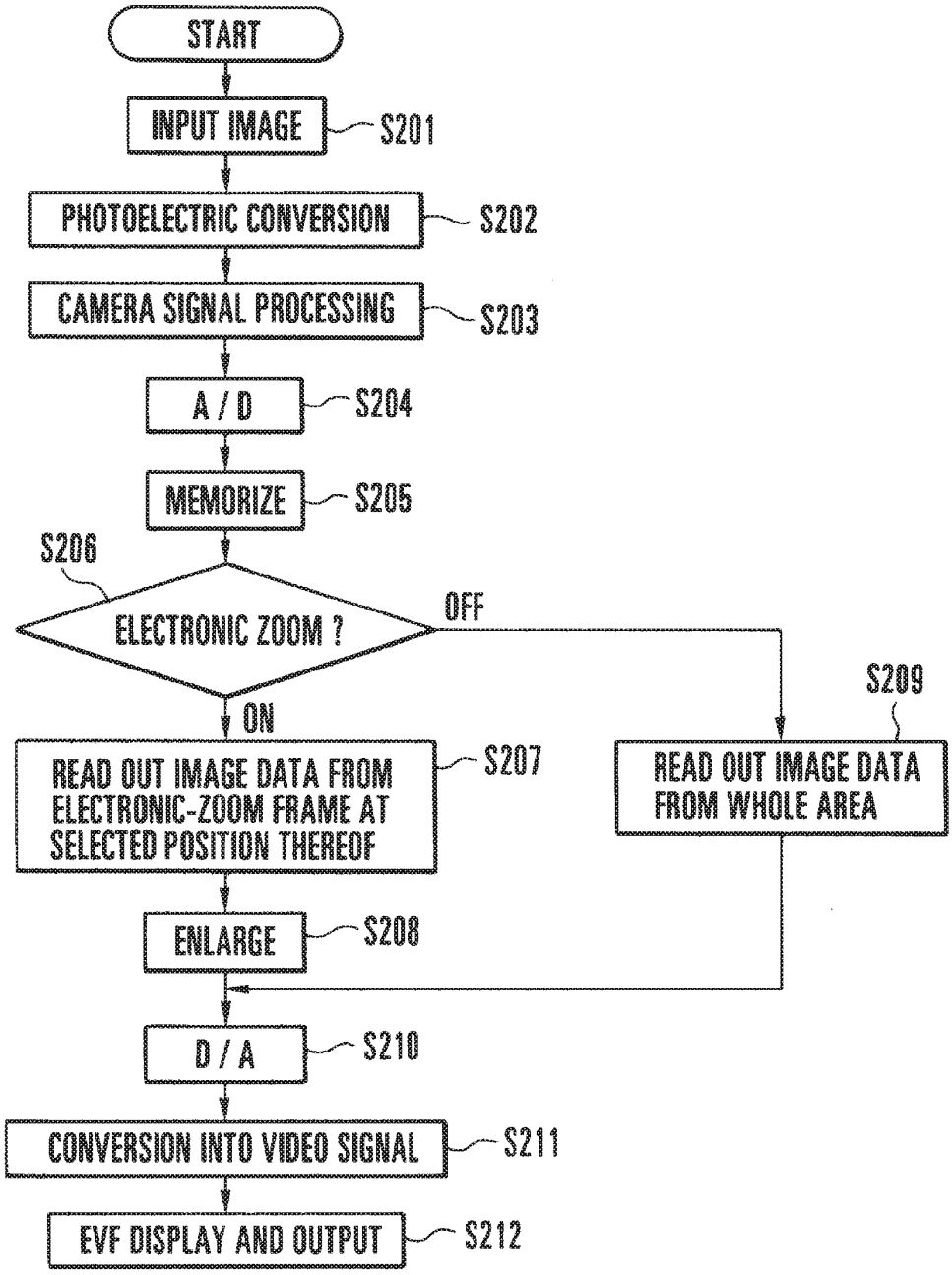


FIG.49



CANON0062582

FIG.50

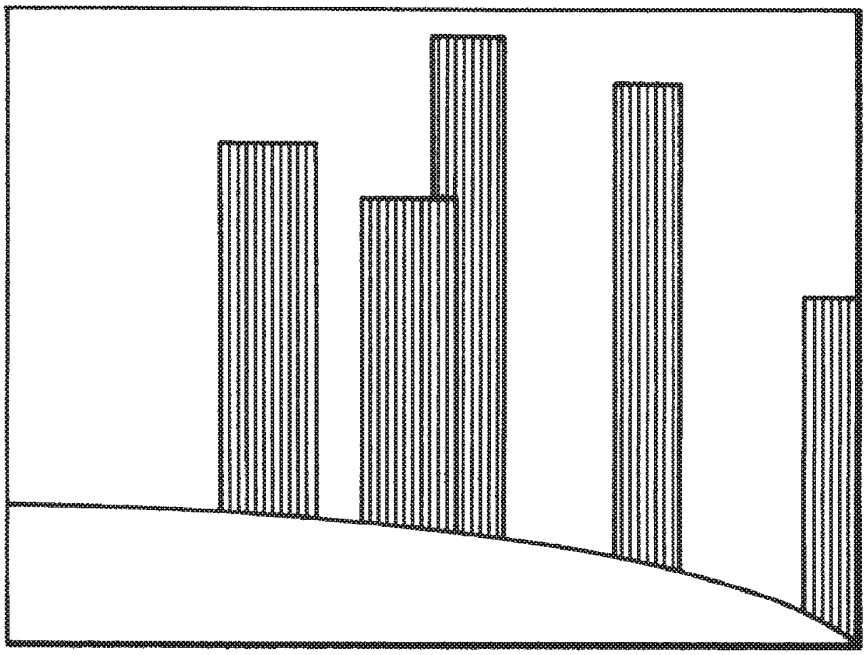
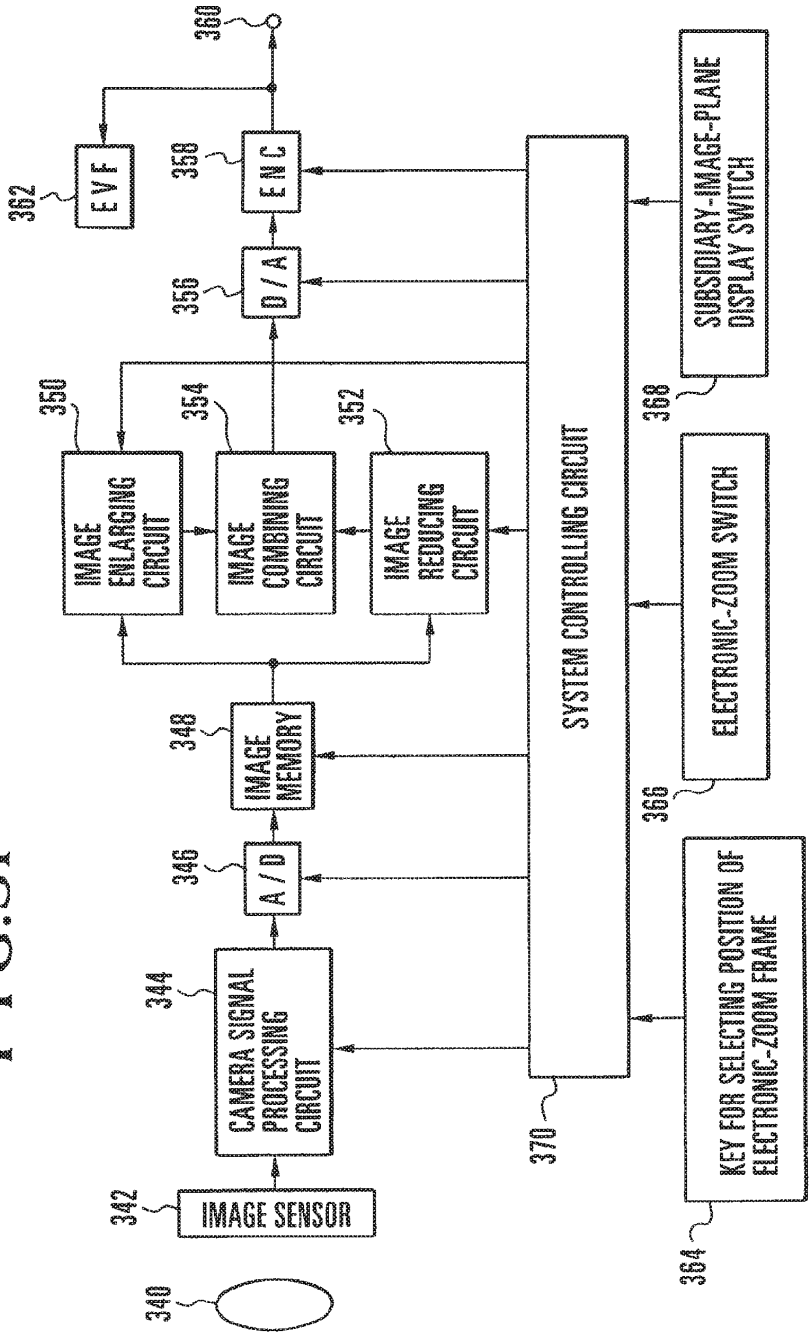


FIG.51



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FIG.52

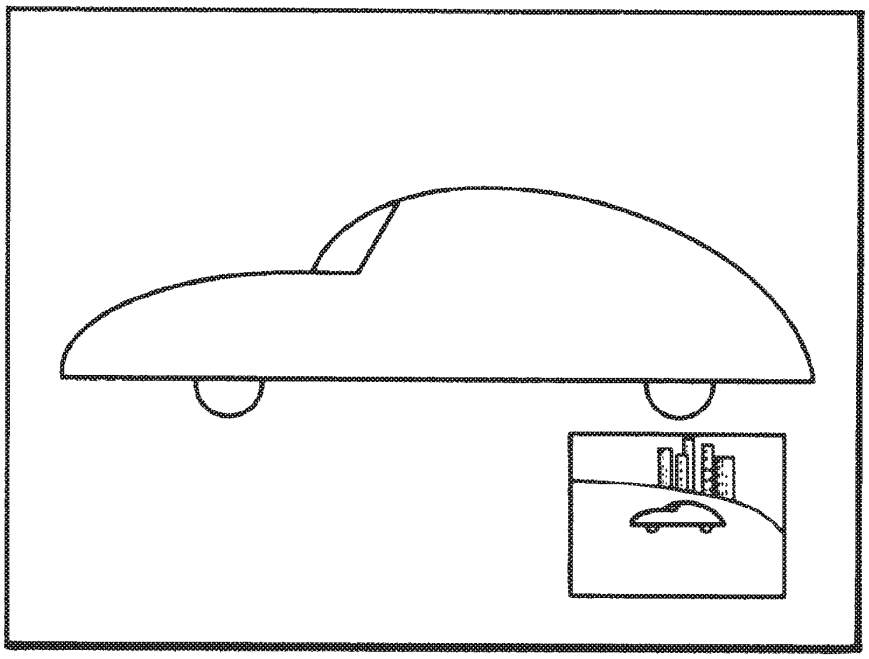
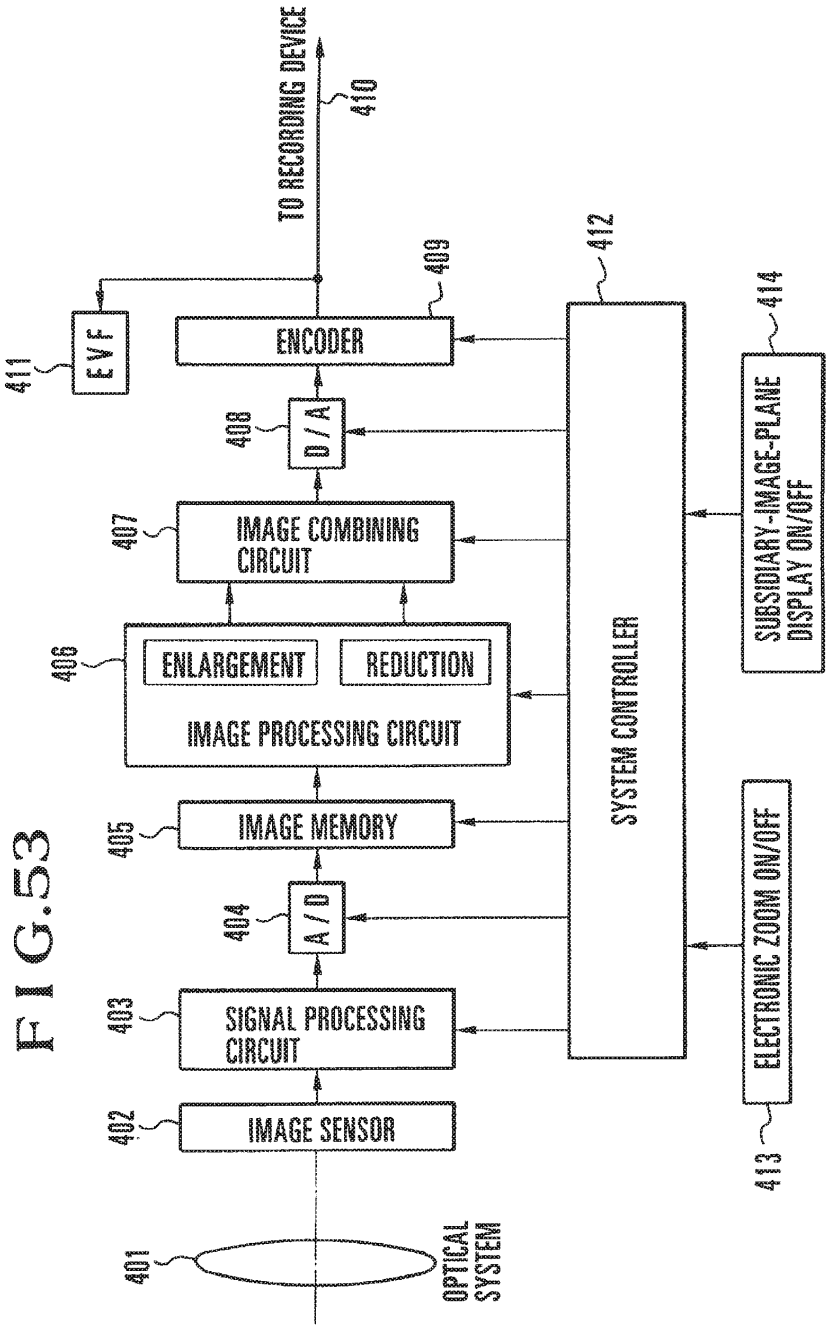


FIG.53



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FIG.54

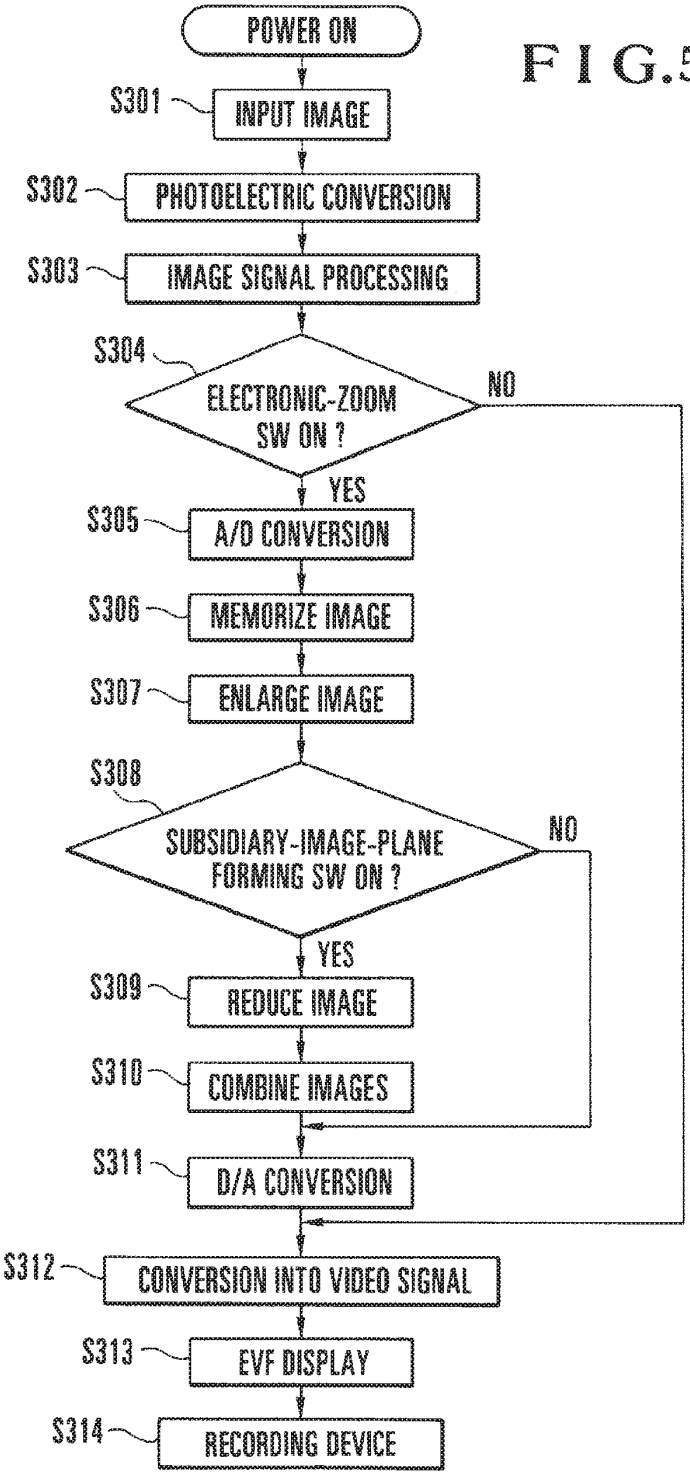

POWER ON
S301
INPUT IMAGE
S302
PHOTOELECTRIC CONVERSION
S303
IMAGE SIGNAL PROCESSING
S304
ELECTRONIC-ZOOM SW ON ?
NO
YES
S305
A/D CONVERSION
S306
MEMORIZE IMAGE
S307
ENLARGE IMAGE
S308
SUBSIDIARY-IMAGE-PLANE FORMING SW ON ?
NO
YES
S309
REDUCE IMAGE
S310
COMBINE IMAGES
S311
D/A CONVERSION
S312
CONVERSION INTO VIDEO SIGNAL
S313
EVF DISPLAY
S314
RECORDING DEVICE

FIG.55

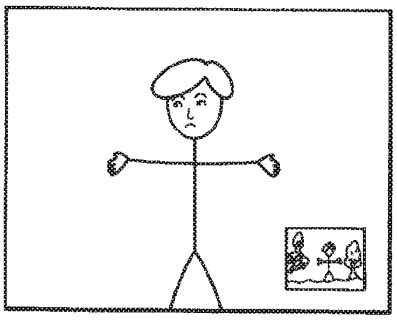


FIG.56

PRIOR ART

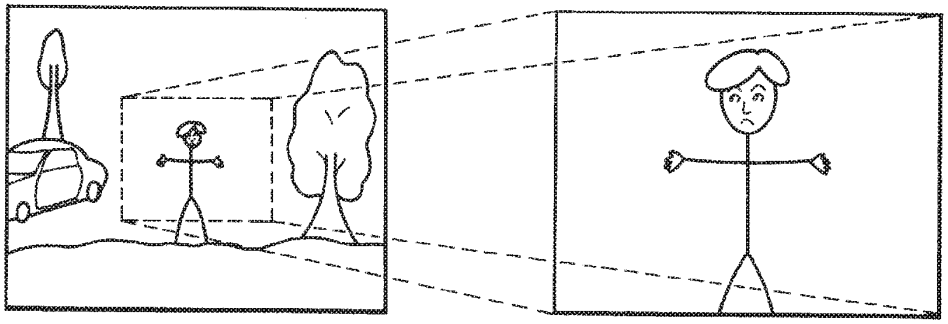
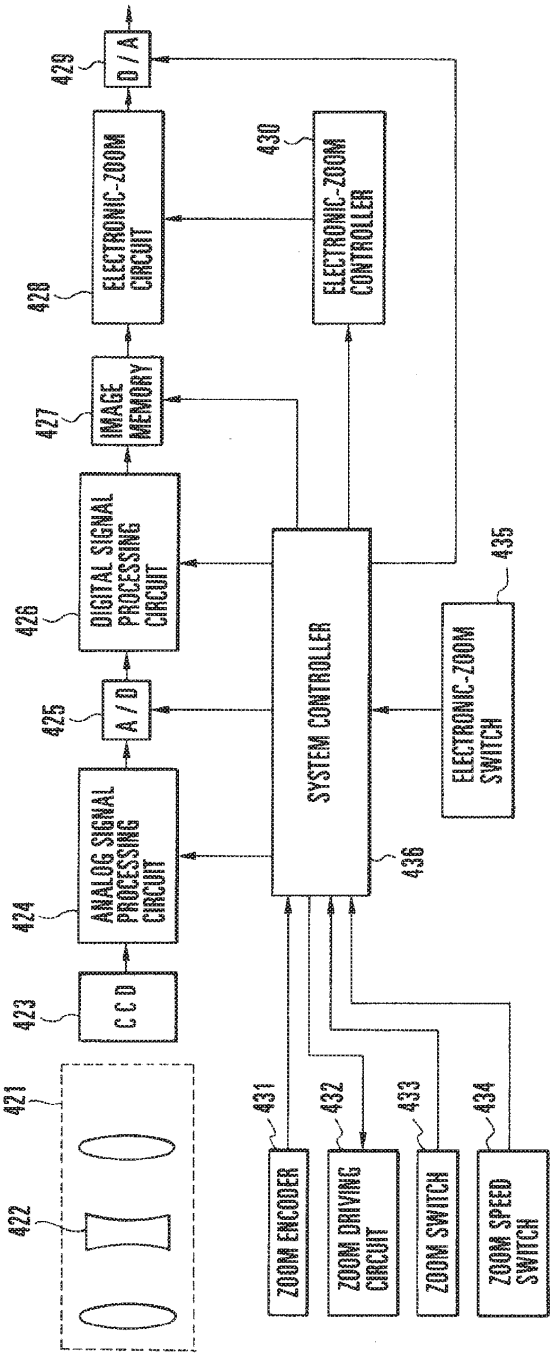


FIG.57



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FIG.58

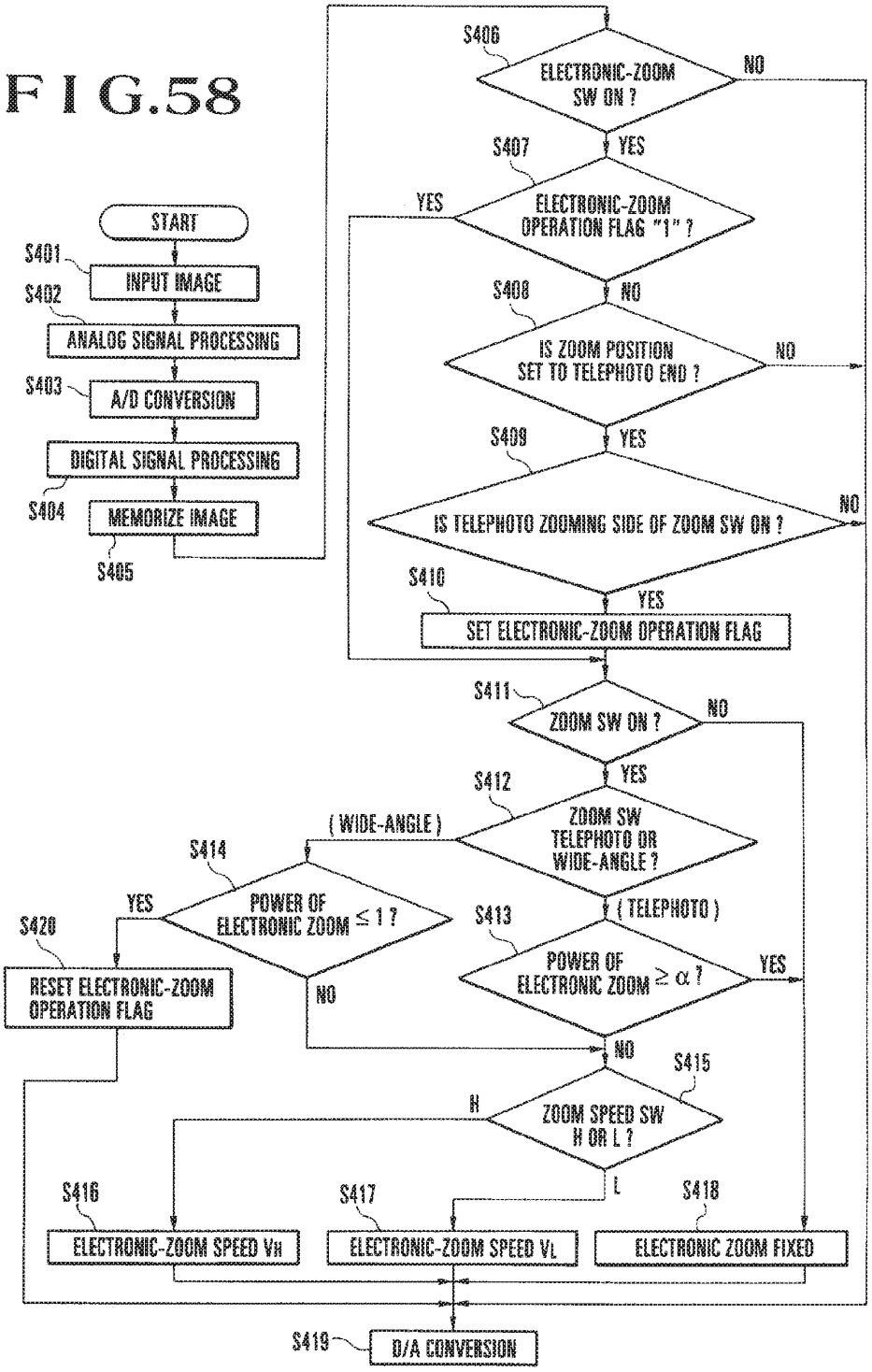

START
S401
INPUT IMAGE
S402
ANALOG SIGNAL PROCESSING
S403
A/D CONVERSION
DIGITAL SIGNAL PROCESSING
S404
MEMORIZE IMAGE
S405
S406
ELECTRONIC-ZOOM SW ON ?
NO
YES
S407
ELECTRONIC-ZOOM OPERATION FLAG "1" ?
YES
S408
NO
IS ZOOM POSITION SET TO TELEPHOTO END ?
NO
S409
YES
IS TELEPHOTO ZOOMING SIDE OF ZOOM SW ON ?
NO
S410
YES
SET ELECTRONIC-ZOOM OPERATION FLAG
S411
ZOOM SW ON ?
NO
YES
S412
ZOOM SW TELEPHOTO OR WIDE-ANGLE ?
(WIDE-ANGLE)
(TELEPHOTO)
S414
POWER OF ELECTRONIC ZOOM ≤ 1 ?
YES
S420
RESET ELECTRONIC-ZOOM OPERATION FLAG
NO
S413
POWER OF ELECTRONIC ZOOM ≥ α ?
YES
NO
S415
ZOOM SPEED SW H OR L ?
H
L
S416
ELECTRONIC-ZOOM SPEED VH
S417
ELECTRONIC-ZOOM SPEED VL
S418
ELECTRONIC ZOOM FIXED
S419
D/A CONVERSION

FIG.59(b)

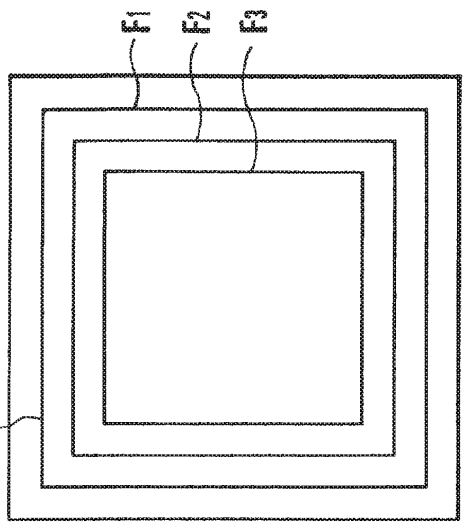
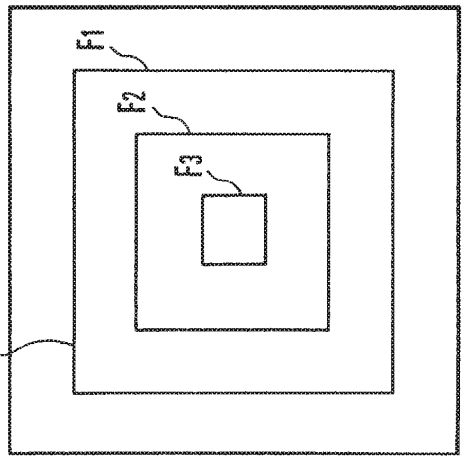


FIG.59(a)



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FIG.60

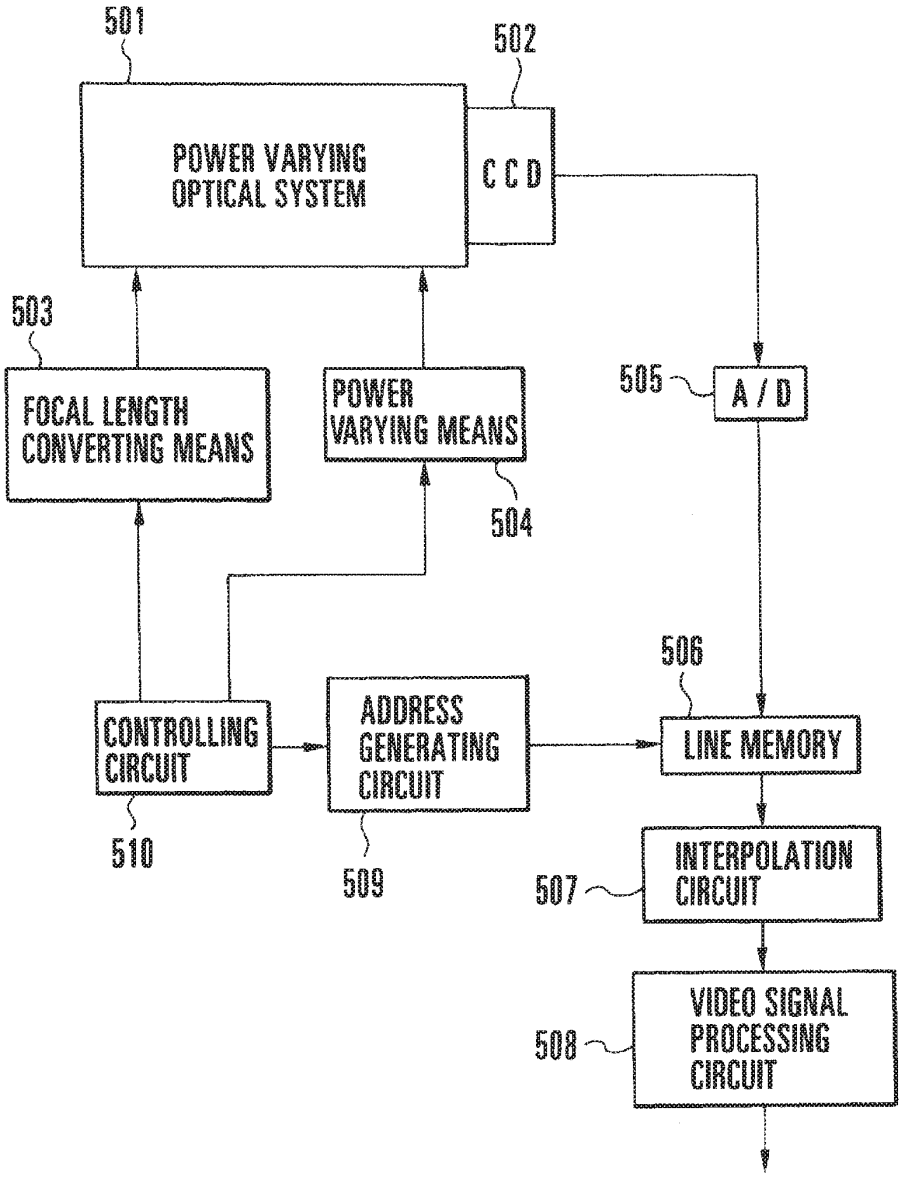

501
502
POWER VARYING OPTICAL SYSTEM
C C D
503
FOCAL LENGTH CONVERTING MEANS
POWER VARYING MEANS
504
505
A / D
506
CONTROLLING CIRCUIT
ADDRESS GENERATING CIRCUIT
LINE MEMORY
510
509
INTERPOLATION CIRCUIT
507
VIDEO SIGNAL PROCESSING CIRCUIT
508

FIG.61

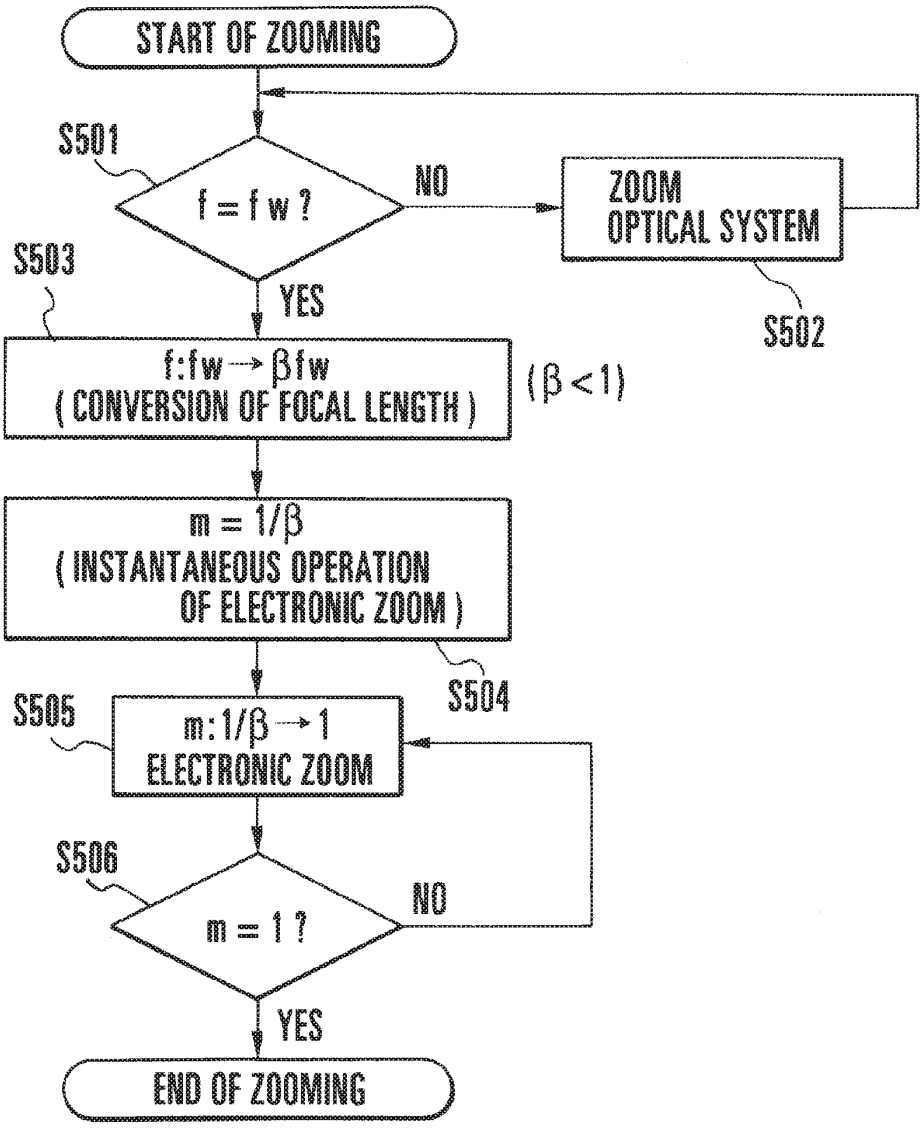

START OF ZOOMING
S501
f = f w ?
NO
ZOOM OPTICAL SYSTEM
S502
YES
S503
f:fw → βfw
(CONVERSION OF FOCAL LENGTH)
(β < 1)
m = 1/β
(INSTANTANEOUS OPERATION OF ELECTRONIC ZOOM)
S504
S505
m: 1/β → 1
ELECTRONIC ZOOM
S506
m = 1 ?
NO
YES
END OF ZOOMING

FIG.62

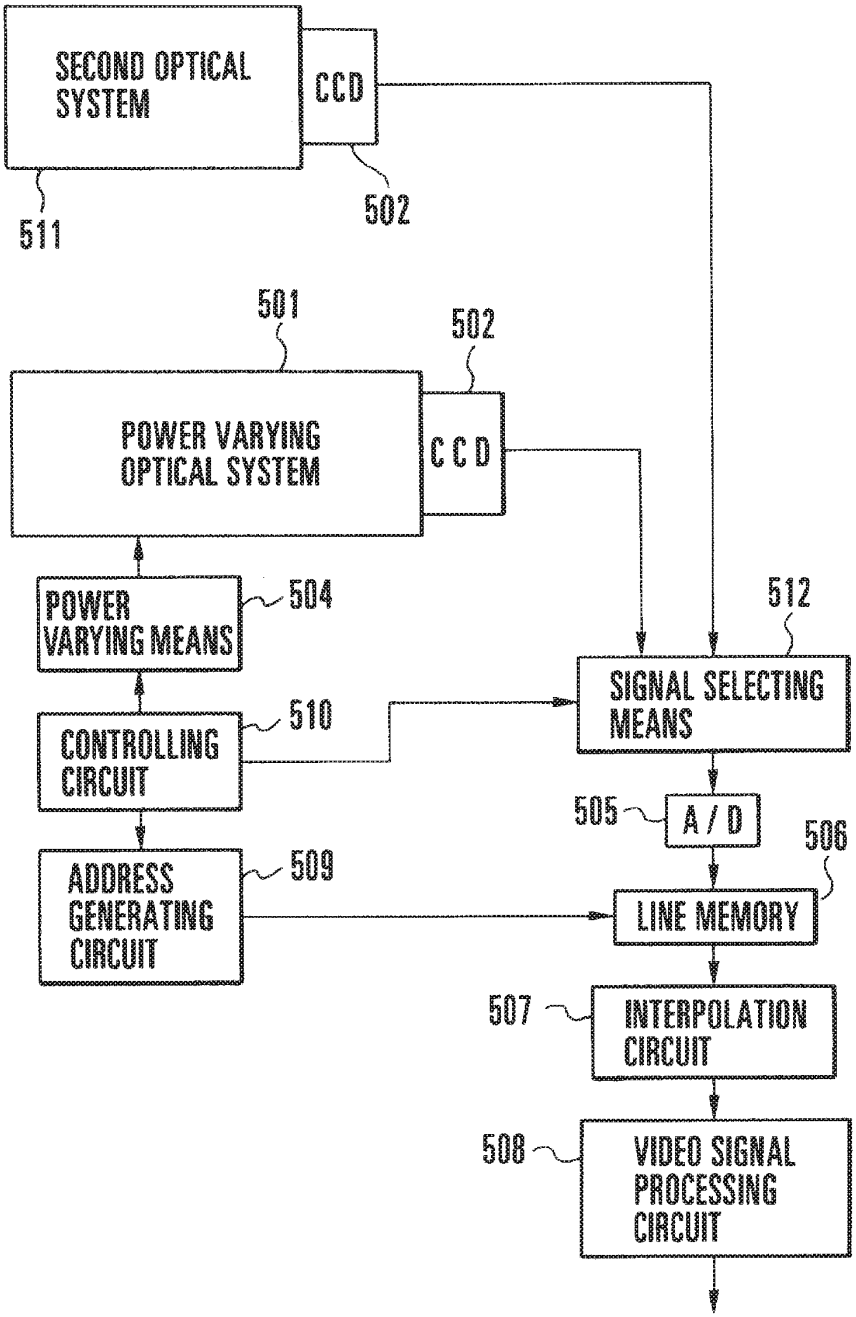

SECOND OPTICAL SYSTEM
CCD
511
502
501
502
POWER VARYING OPTICAL SYSTEM
C C D
POWER VARYING MEANS
504
512
SIGNAL SELECTING MEANS
CONTROLLING CIRCUIT
510
505
A / D
506
ADDRESS GENERATING CIRCUIT
509
LINE MEMORY
507
INTERPOLATION CIRCUIT
508
VIDEO SIGNAL PROCESSING CIRCUIT

IMAGE PICKUP APPARATUS

This application is a continuation of application Ser. No. 08/103,091 filed Aug. 6, 1993, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to improvements in an image pickup apparatus such as a video camera, a still camera or a silver-halide camera, an image reproducing apparatus for reproducing an image recorded by such an image pickup apparatus, and a video system formed by a combination of these apparatus.

2. Description of the Related Art

Conventionally, in an image pickup apparatus, the distortion of a photographic image occurs due to the distortional aberration of each individual photographic lens and a distortion which cannot be completely eliminated in every stage of the design of the photographic lens remains in an image as a residual distortional aberration. As one method for electronically eliminating the residual distortional aberration, it is known that an electron beam is made to scan in distorted form on the basis of the distortional aberration of a photographic lens in an image pickup apparatus using an image pickup tube such as the Plumbicon.

Japanese Laid-Open Patent Application No. Hei 2-252375 discloses another proposal to obtain image data from an image pickup device such as a CCD and correct the image data in the form of a digital signal.

However, the above-described conventional example has a number of problems. For example, since correction of image data is performed with the center (optical axis) of an image plane selected as a datum, on the basis of the focal length of the photographic lens, i.e., as shown in FIGS. **25**(*a*) and **25**(*b*), no image data present in the peripheral portion of the image plane is employed in the case of correction of a negative (barrel form) distortion, as shown in FIG. **26**(*a*). In contrast, in the case of correction of a positive (pincushion form) distortion, image data present in the peripheral portion of the image plane is lost as shown in FIG. **26**(*b*).

Another distortional-aberration correcting method has been proposed with respect to a camera provided with a solid-state image pickup device. According to this method, pixel signals are read out from the solid-state image pickup device in accordance with the geometrical deformation of an image which occurs in a photographic lens, and the read-out pixel signals are subjected to interpolation so that the distortional aberration of the image is corrected. However, in a case where a zoom lens is used as the objective lens, if correction of the distortional aberration of the zoom lens is to be performed at each photographing position thereof by using signal processing, an enormous amount of computing processing and an extremely long computing time as well as a large-scale signal processing circuit are needed for the signal processing. For this reason, although the utilization of this proposal is considered in an extremely limited field, such as a broadcasting station, which needs high-quality images, the aforesaid proposal has not currently been popular.

An art of carrying out electronic zooming by performing signal processing of a signal obtained from an image pickup device, such as a CCD, has also heretofore been known.

According to the known art, since it is necessary to position an image of an object to be electronically zoomed, in an electronic-zoom frame provided in the center of an image plane, the electronic zooming is not very useful in photographing a moving object to which the electronic zooming seems able to be advantageously applied. This is because it is necessary to move the entire image pickup apparatus in accordance with the movement of the object so that an image of the moving object can be positioned in the electronic-zoom frame at all times, with the result that an image shake easily occurs due to the movement of the entire image pickup apparatus.

For example, such an image pickup apparatus having an electronic-zoom function is arranged to perform coordinate transformation so as to enlarge an original image which is not electronically zoomed, as shown in the left-hand portion of FIG. **56**, to a size equivalent to an electronic-zoom frame in which an object selected as a target is to be positioned. By performing the coordinate transformation, the image pickup apparatus can provide an enlarged image such as that shown in the right-hand portion of FIG. **56**.

However, the above-described conventional example has the following problem. Since a photographer cannot obtain image information outside of the electronic-zoom frame while the electronic-zoom function is operating, the photographer encounters the problem that an object, particularly a moving object, occasionally leaves the image plane or that another foreign object suddenly enters the electronic-zoom frame and appears in the image plane. For this reason, it is difficult for the photographer to fully utilize the electronic-zoom function.

As is known in the art, the so-called electronic zoom is intended to achieve an apparent increase in the telephoto effect of an optical system when the optical system is set to its telephoto end, and to attain a large zoom effect without increasing the size of the optical system.

By sequentially executing the electronic zoom and optical zoom (or an optical zooming operation) capable of varying the focal length of the optical system, it is possible to achieve an effect equivalent to the zoom range of a zoom lens having a zoom ratio equal to a multiplication of the zoom ratio of the optical zoom and that of the electronic zoom.

For example, if the optical system has focal lengths of 8–80 mm and the electronic has a zoom ratio of 2 times, it is possible to obtain a lens having focal lengths equivalent to 8–160 mm.

However, in such an electronic zoom, although it is possible to enlarge an image, it is impossible to enlarge an angle of view. Accordingly, although it is possible to achieve "an increase in the telephoto effect", it is impossible to realize "an increase in a wide-angle effect".

Although a lens system may be beforehand designed to have a wide angle of view, there is the problem that the lens system becomes large.

A plurality of means for shifting the focal length of the lens system toward its wide-angle side have recently been proposed in light of the problem.

One well-known method for shifting the focal length of the lens system toward the wide-angle side is disclosed in, for example, Japanese Laid-Open Patent Application No. Sho 59-204817. In this method, an afocal converter made up of lenses having negative and positive refractive powers is disposed forward of the optical system so that the wide-angle effect of the lens system can be increased.

However, since the afocal converter is made up of two or three lenses, there is the problem that if the afocal converter is disposed forward of the optical system, the entire lens system increases in size.

According to another known method, a negative lens is inserted forward of a principal optical system, and the close-up photography capability of the principal optical system is utilized to achieve an increase in the wide-angle effect of the lens system.

However, if the focal length of the lens system is discontinuously converted from its wide-angle end toward a far wider-angle side, there is the problem that no photography can be performed at any angle of view between the wide-angle end and the far wider-angle side.

SUMMARY OF THE INVENTION

It is, therefore, a first object of the present invention to provide an apparatus for performing signal processing of an image signal obtained from an image pickup device and deforming an image into a desired form and enlarging the image up to a desired size.

A second object of the present invention is to provide an apparatus for correcting a distortion of an image necessarily occurring due to a photographic lens, i.e., distortional aberration, by using an electrical method.

A third object of the present invention is to provide an control device for controlling a so-called electronic zoom which is arranged to cause an image pickup device to receive an optical image formed by a photographic lens, perform signal processing of a signal output of the image pickup device, and vary the size of an image.

A fourth object of the present invention is to provide an image pickup apparatus which permits a photographer to confirm image information outside of an electronic-zoom frame during electronic zooming, thereby expanding a photographic opportunity and enabling the photographer to securely use the electronic zoom.

A fifth object of the present invention is to provide an image pickup apparatus capable of smoothly varying an angle of view during switching from optical zoom to electronic zoom or during switching from electronic zoom to optical zoom.

A sixth embodiment of the present invention is to provide a camera provided with a zoom function capable of continuously varying an angle of view from a wide-angle end toward an ultra-wide-angle side so that a photographer can smoothly perform photography even during zooming through the angles of view between the wide-angle end and the ultra-wide-angle side.

The above and other objects, features and advantages of the present invention will become apparent from the following detailed description of preferred embodiments of the present invention, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram schematically showing the arrangement of an image pickup apparatus according to a first embodiment of the present invention;

FIG. **2** is a flowchart showing the operation of the image controlling circuit **102**;

FIG. **3** is a view showing distorted scanning lines;

FIG. **4** is a fragmentary schematic view which serves to explain pixels used for interpolation processing;

FIG. **5** is a flowchart showing a distortion correcting operation according to the first embodiment of the present invention;

FIGS. **6**(*a*), **6**(*b*) and **6**(*c*) are views aiding in explaining the manner of correction of distortional aberration with reference to FIG. **5**;

FIG. **7** is a view aiding in explaining the manner of correction of distortional aberration with reference to FIG. **5**;

FIG. **8** is a view aiding in explaining the manner of correction of distortional aberration with reference to FIG. **5**;

FIG. **9** is a view aiding in explaining the manner of correction of distortional aberration with reference to FIG. **5**;

FIG. **10** is a view aiding in explaining the manner of correction of distortional aberration with reference to FIG. **5**;

FIG. **11** is a view aiding in explaining the manner of correction of distortional aberration with reference to FIG. **5**;

FIG. **12** is a cross sectional view of a lens, suitable for image correction, which produces a large negative distortional aberration on its wide-angle side;

FIGS. **13**(*a*)–**13**(*c*) are views showing aberrations which occur at the wide-angle end of the lens shown in FIG. **12**;

FIGS. **14**(*a*)–**14**(*c*) are views showing aberrations which occur at the telephoto end of the lens shown in FIG. **12**;

FIGS. **15**(*a*) to **15**(*c*) are views showing a numerical example of the lens shown in FIG. **12**;

FIGS. **16**(*a*) to **16**(*e*) are views diagrammatically showing the manner of distortion correction performed according to the first embodiment of the present invention;

FIG. **17** is a view schematically showing the essential portions of an image pickup apparatus to which the first embodiment of the present invention can be applied and which is arranged to separate incident light into three color components and pick up a color image;

FIGS. **18**(*a*) to **18**(*c*) are views diagrammatically showing the manner of distortion correction performed according to the second embodiment of the present invention;

FIG. **19** is a flowchart showing a distortion correcting operation according to the second embodiment of the present invention;

FIG. **20** is a view aiding in explaining the manner of correction of distortional aberration with reference to FIG. **19**;

FIG. **21** is a schematic view showing the manner of distortion correction which is performed by an arrangement in which an electronic-zoom function is added to the apparatus according to the third embodiment of the present invention;

FIG. **22** is a schematic view showing the manner of another distortion correction which is performed by the arrangement in which the electronic-zoom function is added to the apparatus according to the third embodiment of the present invention;

FIG. **23** is a block diagram showing a video system according to a fourth embodiment of the present invention;

FIG. **24** is a video system in which the imaging apparatus of FIG. **23** is replaced with a silver-halide camera;

FIGS. **25**(*a*) and **25**(*b*) are views which serve to explain distortion correction performed in a conventional image pickup apparatus;

FIGS. **26**(*a*) and **26**(*b*) are views which serve to explain problems involved in the distortion correction performed in the conventional image pickup apparatus;

FIGS. **27**(*a*)-**1**, **27**(*a*)-**2**, and **27**(*a*)-**3**, and FIGS. **27**(*b*)-**1**, **27**(*b*)-**2**, and **27**(*b*)-**3**, are views respectively showing the optical performance of a photographic zoom lens according to a fifth embodiment of the present invention and that of a general photographic zoom lens;

FIG. **28** is a block diagram schematically showing the arrangement of a solid-state image pickup camera according to the fifth embodiment of the present invention;

FIG. **29** is a mechanism diagram showing the photographic zoom lens and a focal length detecting part of the solid-state image pickup camera shown in FIG. **28**;

FIG. **30** is a flowchart showing the operation of the solid-state image pickup camera shown in FIG. **28**;

FIG. **31** is a schematic view which serves to explain the operation of the photographic zoom lens shown in FIG. **28**;

FIG. **32** is a schematic diagram showing the relationship between the pixels of a CCD and an image formed thereon;

FIG. **33** is a schematic view showing the relationship between pixels of the line memory shown in FIG. **28** and scanning lines;

FIG. **34** is a schematic view showing interpolation processing performed by the interpolation circuit shown in FIG. **28**;

FIG. **35** is a schematic view which serves to explain distortional-aberration correcting processing according to the fifth embodiment of the present invention;

FIGS. **36**(*a*)–**36**(*c*) are views showing one example of the optical performance of a photographic zoom lens used in a sixth embodiment of the present invention;

FIGS. **37**(*a*)–**37**(*c*) are views showing one example of a variation in distortional aberration depending on shooting distance, in the neighborhood of the wide-angle end of the photographic zoom lens used in the sixth embodiment of the present invention;

FIG. **38** is a block diagram schematically showing the focal length detecting part and the shooting distance detecting part of a solid-state image pickup camera according to the sixth embodiment of the present invention;

FIG. **39** is a flowchart showing the operation of the solid-state image pickup camera shown in FIG. **38**;

FIG. **40** is a block diagram schematically showing the arrangement of a solid-state image pickup camera according to a seventh embodiment of the present invention;

FIG. **41** is a view which serves to explain distortional-aberration correcting processing according to the seventh embodiment of the present invention;

FIG. **42** is a flowchart showing the distortion correcting operation of the solid-state image pickup camera according to the seventh embodiment of the present invention;

FIG. **43** is a flowchart showing the distortion correcting operation of a solid-state image pickup camera according to an eighth embodiment of the present invention;

FIG. **44** is an explanatory view which serves to explain the manner of calculation of the amount of correction performed in Step S**253** of FIG. **43**;

FIG. **45** is a block diagram schematically showing the arrangement of a ninth embodiment of the present invention;

FIG. **46** shows one example of a photographic image;

FIG. **47** shows an image example obtainable by electronically enlarging a central portion of the image shown in FIG. **46**;

FIG. **48** shows an area to which an electronic-zoom frame is to be moved according to the ninth embodiment of the present invention;

FIG. **49** is a flowchart of the operation of the ninth embodiment of the present invention;

FIG. **50** shows an electronically zoomed image obtainable when the electronic-zoom frame is moved to the area C shown in FIG. **48**;

FIG. **51** is a block diagram schematically showing the arrangement of a tenth embodiment of the present invention;

FIG. **52** shows a combined image according to the tenth embodiment of the present invention;

FIG. **53** is a block diagram showing the circuit arrangement of an image pickup apparatus according to an eleventh embodiment of the present invention;

FIG. **54** is a flowchart showing the operation of the image pickup apparatus shown in FIG. **53**;

FIG. **55** is a view showing one example obtained by displaying an original image, which is not electronically zoomed, in the form of an subsidiary image plane within an electronically zoomed image plane in accordance with the eleventh embodiment of the present invention;

FIG. **56** is a view showing an original image which is not electronically zoomed and an image obtainable by enlarging a portion of the original image by electronic zoom;

FIG. **57** is a block diagram showing the circuit arrangement of an image pickup apparatus according to a twelfth embodiment of the present invention;

FIG. **58** is a flowchart showing the operation of the image pickup apparatus shown in FIG. **57**;

FIGS. **59**(*a*) and **59**(*b*) are views showing variations in an image-plane cutting frame for the purpose of varying the speed of the electronic zoom according to the twelfth embodiment of the present invention;

FIG. **60** is a block diagram showing the circuit arrangement and the optical system of a camera having a zoom function according to a thirteenth embodiment of the present invention;

FIG. **61** is a flowchart showing the operation of performing zooming from a telephoto end to a wide-angle side (an ultra-wide-angle end) in the thirteenth embodiment of the present invention; and

FIG. **62** is a block diagram showing the circuit arrangement and the optical system of a camera having a zoom function according to a fourteenth embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described below in detail with reference to the accompanying drawings.

FIG. **1** is a block diagram schematically showing the arrangement of an image pickup apparatus according to a first embodiment of the present invention.

The arrangement shown in FIG. **1** includes a photographic lens **100** which is formed as a lens assembly provided with a focusing lens **100***a* and a variator lens **100***b* and capable of zooming, an image sensor **101** such as a CCD, an image controlling circuit **102** for performing control of various operations, such as correction of image distortion, a first image memory **103** for memorizing image data obtained from the image sensor **101**, a second image memory **104** for memorizing image data the distortion of which is corrected, a data table **105** on which distortional-aberration information about the photographic lens **100** is memorized, and a zoom switch **106** for converting a zoom instruction given by a photographer into an electrical signal.

FIG. **2** is a flowchart showing the operation of the image controlling circuit **102**. The operation will be described below with reference to the flowchart.

[Step S**1**] The image controlling circuit **102** converts image data supplied from the image sensor **101** into a video signal and converts the video signal into a digital image

signal by means of an A/D conversion circuit. The image controlling circuit **102** causes the first image memory **103** to memorize the digital image signal for one frame. The image obtained at this time is an image distorted by the distortional aberration of the photographic lens **100**.

[Step S2] The focal length, i.e., the zoom position, of the photographic lens **100** is detected from the position of the variator lens **100***b* which is one constituent element of the photographic lens **100**, and a zoom position which is aimed at by the photographer is read from the zoom switch **106**.

The process of obtaining zoom information from the position of the variator lens **100***b* and the zoom switch **106** in this manner is intended to perform correction of image distortion with a datum in the correction of the image distortion arbitrarily set as will be described later.

[step S3] An object distance is detected from the focusing lens **100***a* which is one constituent element of the photographic lens **100**.

This step is needed to perform image correction according to the status of the photographic lens **100** since the distortional aberration of the photographic lens **100** varies due to zooming and focusing.

[Step S4] The addresses of distorted pixels at which the addresses of undistorted pixels are located are calculated on the basis of data indicative of the amount of distortion which are memorized on the data table **105**. The data indicative of the amount of distortion may be memorized in the form of raw data relative to each zoom position and each focus position, or may also be memorized in the form of the coefficient of a function which approximates the amount of distortional aberration. It is to be noted that the data indicative of the amount of distortion are prepared as values peculiar to the photographic lens **100**.

The scanning lines of an undistorted image are typically formed as curved lines on a distorted image as shown in FIG. **3**. Since the pixels on the undistorted image do not correspond to individual pixels on the distorted image, for example, a pixel **42***a* located on the top left in FIG. **4** is selected from the pixel **42***a* and pixels **42***b*, **42***c* and **42***d* which surround a corresponding position **42** of undistorted image data, and the address of the pixel **42***a* is calculated.

In FIG. **3**, reference numeral **31** denotes a digital image data array, reference numerals **32** and **33** denote the scanning lines of the undistorted image, and reference numeral **34** denotes the position of image data corresponding to one pixel. In FIG. **4**, reference numeral **41** denotes one scanning line of the undistorted image, and reference numeral **42** denotes the corresponding position of the undistorted image data.

[Step S5] A plurality of data (sample image data) for use in generating undistorted image data are copied to another memory on the basis of the pixel address calculated in Step S4. In the example shown in FIG. **4**, data indicative of the pixels **42***a*, **42***b*, **42***c* and **42***d* are copied.

[Step S6] Data indicative of an undistorted image are generated, as by linear interpolation, from the coordinates of the respective pixels copied in Step S5 and the coordinates of newly generated pixels.

[Step S7] The image data generated in Step S6 are sequentially memorized into the second image memory **104**.

[Step S8] It is determined whether all the operations which are executed in Steps S4 to S7 in the horizontal scanning direction have ended. If they have not yet ended, the process proceeds to Step S4. If it is determined that they have ended, the process proceeds to Step S9.

[step S9] It is determined whether all the operations which are executed in Steps S4 to S7 in the vertical scanning direction have ended. If they have not yet ended, the process proceeds to Step S4. If it is determined that they have ended, the process proceeds to Step S10.

[Step S10] The image data memorized in the second image memory **104** is read out, and the process proceeds to Step S11.

[Step S11] The image data is converted into a video signal conforming to the NTSC system or the like, and the video signal is outputted to an electronic viewfinder (not shown) and to an image recording device (not shown).

In the first embodiment, although an area memory is used as the second image memory **104**, a line memory capable of storing image data for one horizontal scanning line may be substituted for the area memory. If the line memory is used, it is possible to adopt an arrangement in which each time generation of image data for one horizontal scanning line has ended, the image data is converted into a video signal, and which executes control so that this processing operation is repeated for all the vertical scanning lines. Such an arrangement is capable of providing a substantial memory saving.

An algorithm for calculating pixel addresses will be described below with reference to FIG. **5**.

In the following description of the algorithm, it is assumed that the distortional aberration of the photographic lens **100** is "0" at the telephoto end and the distortional aberration becomes more negative toward the wide-angle end, and that image correction is performed with respect to the negative distortional aberration. It is also assumed that Z represents the zoom position of the photographic lens **100** and Zw and Zt (Zw<Zt) represent the zoom positions of the photographic lens **100** at the wide-angle end and the telephoto end, respectively. It is also assumed that Zs represents the zoom position specified by the photographer through the zoom switch **106** and Zmin represents a virtual zoom position at the wide-angle end which is acceptable in terms of the effect of image correction.

The relationship between Zs and Z is Zs=Z until the photographic lens **100** mechanically reaches the wide-angle position.

[Step S51] A comparison is made between the zoom position Zs which is aimed at by the photographer and the zoom position Zw which can be taken by the photographic lens **100** at the wide-angle end. If Zs is not less than Zw, i.e., in the case of the relationship of Zs≧Zw, the process proceeds to Step S52. In the case of the relationship of Zs<Zw, the process proceeds to Step S53.

[Step S52] Since the relationship of Zs≧Zw is established, distortion correction is performed with the center of an image plane selected as a datum. The process proceeds to the next step.

If it is determined in Step S51 that the relationship of Zs<Zw is established, it is determined that the zoom position of the photographic lens **100** has entered the area of the virtual zoom position, and the process proceeds to Step S53 as described previously.

[Step S53] It is determined whether the zoom position Zs which is aimed at by the photographer is less than the virtual zoom position Zmin at the wide-angle end which is acceptable in terms of the effect of image correction. If the zoom position Zs is less than the virtual zoom position Zmin, i.e., in the case of the relationship of Zs<Zmin, the process proceeds to Step S54. In the case of the relationship of Zs≧Zmin, the process proceeds to Step S55.

[Step S54] Since the zoom position Zs which is aimed at by the photographer is less than the virtual zoom position Zmin at the wide-angle end which is acceptable in terms of the effect of image correction, the value of Zmin is substituted into Zs, and the process proceeds to Step S55.

[Step S55] Distortion correction is performed with an arbitrary image height selected as a datum.

A distortional aberration D occurring due to the photographic lens **100** is approximated by a function, i.e., a quadratic function of the image height, and if a coefficient "a" of the quadratic function is a linear function of the zoom position Z of the photographic lens **100**, the following relationships are obtained:

$$D=D(L)=a*L^2$$

$$a=a(Z)=b*Z$$

These relationships are shown in FIGS. **6**(*a*) to **6**(*c*). In FIGS. **6**(*a*) to **6**(*c*), W, M and T respectively represent distortional aberrations occurring at the wide-angle end, a middle angle position, and the telephoto end when photographic lens **100** is set to the zoom position Z.

An optical distortional aberration (D %) is defined as the following value:

$$D\ \% = \{(L-L_0)/L_0)\}\times 100 \quad (1)$$

$$= \{(L/L_0-1)\}\times 100$$

where L_0 represents an ideal image height and L represents an actual image height.

In the distortion correction (Step **S52**) which is performed with the center of the image plane selected as a datum, if $P_0(x_0, y_0)$ represents the ideal image point of an arbitrary point P(x, y) on the image plane as shown in FIG. **7**, the ratio of the distance between the ideal image point $P_0(x_0, y_0)$ and the center of the image plane to the distance between the arbitrary point P(x, y) and the center of the image plane becomes an expansion-to-contraction ratio α:

$$\alpha = L_0/L \quad (2)$$

$$= (1+D/100)^{-1}$$

From the expression (2), the coordinates of the ideal image point P_0 are calculated as follows:

$$x_0=\alpha x$$

$$y_0=\alpha y \quad (3)$$

In practice, an inverse form of function for obtaining the coordinates of an actual image point from the coordinates of an ideal image point is prepared to determine an actual pixel address which corresponds to the scanning of a pixel point.

The distortion correction which is performed with an arbitrary image height selected as a datum (the operation of Step **S55**) will be described below with reference to FIGS. **8** and **9**.

If an image height used as a datum is Ys, the distortion correction performed with an arbitrary image height selected as a datum is defined as distortion correction which is performed so that the amount of distortion correction is made "0" along the circumference of a circle of radius Ys about the center of the image plane. FIG. **8** is an aberration diagram showing this distortion correction. As shown in FIG. **8**, if the amount of distortional aberration at the image height Ys is represented as D_0, the image is corrected so that the amount of distortional aberration occurring at each image height can be made equal at the position of D_0. In other words, correction is performed in such a manner that, as shown in FIG. **9**, the image-point area outside of the circle of radius Ys is expanded, whereas the image-point area inside of the circle of radius Ys is contracted.

If D represents the optical distortional aberration at that time and D' represents the corrected distortional aberration, the following relationship is established from FIG. **8**:

$$D'=D-D_0 \quad (4)$$

If L_1 represents the distance (image height) on the image plane of an arbitrary image point $P_1(x_1, y_1)$ from the center of the image plane and $Ps_1(xs_1, ys_1)$ represents an intersection point of the circle of radius Ys and a straight line which connects the center of the image plane and the image point P_1, the coordinates of $Ps_1(xs_1, ys_1)$ are as follows:

$$xs_1=(Ys/L_1)\cdot x_1$$

$$ys_1=(Ys/L_1)\cdot y_1 \quad (5)$$

Since this intersection point forms a datum point for expansion and contraction, an expansion-to-contraction ratio α' is as follows:

$$\alpha'=(1+D'/100)^{-1} \quad (6)$$

The coordinates $P_{01}(x_{01}, y_{01})$ of an ideal image height are as follows:

$$x_{01}=xs+\alpha'\cdot\Delta x_1$$

$$y_{01}=ys+\alpha'\cdot\Delta y_1 \quad (7)$$

where

$$\Delta x_1=x_1-xs_1$$

$$\Delta y_1=y_1-ys_1 \quad (8)$$

Although an image point P_2 is an image point inside of the circle of radius Ys, an ideal image point P_{02} is obtained in a similar manner.

If distortion correction is to be performed with the center of the image plane selected as a datum, "0" is substituted into D_0 so that the expressions (7) become the same as the expressions (3). Accordingly, whether distortion correction is performed with the center of the image plane selected as a datum or with an arbitrary image height selected as a datum, the amount of correction of distortion aberration can be obtained through processing utilizing the same function which uses D_0 as a parameter.

By selecting an arbitrary image height as a datum for distortion correction, it is possible to reduce the amount of correction of the negative distortional aberration. Accordingly, an image whose distortion is corrected becomes an image which covers a wider area on an image pickup plane than an image whose distortion is corrected with the center of the image plane selected as a datum. This signifies that a photographic angle of view is apparently widened toward the wide-angle side.

The distortion correction performed with an arbitrary image height selected as a datum reaches its maximum limit when an image pickup area is inscribed in a circle selected as the datum, as shown in FIG. **10**. The zoom position in this case is a virtual wide-angle end. If the radius of the circle in

this case is represented as Ymax (maximum datum image height), an ideal image height $Ymax_0$ relative to this image height Ymax becomes as follows:

$$Ymax_0=(1+Dym/100)^{-1}\cdot Ymax \quad (9)$$

where Dym represents the amount of distortional aberration occurring at the image height Ymax (refer to FIG. **11**).

The maximum image height in the Y direction which is based on distortion correction performed with the center (optical axis) of the image plane selected as a datum is Ymax, and an angle of view which can be photographed is expanded by $Ymax_0$/Ymax times by performing the above-described distortion correction.

From the expression (9), "$Ymax_0$/Ymax" is determined by the amount of distortional aberration occurring at the image height Ymax. Accordingly, it will be understood that the amount of expansion of the photographic angle of view is determined by the amount of distortional aberration occurring at the wide-angle end of a photographic lens and the angle of view expands as the negative value of the distortional aberration becomes larger.

A design example of a lens which produces, at its wide-angle end, a large negative distortional aberration suitable for the above-described image correction will be described below.

FIG. **12** is a cross sectional view of the lens, and FIGS. **13**(*a*)–**13**(*c*) and **14**(*a*)–**14**(*c*) are aberration diagrams respectively showing aberrations which occur at the wide-angle end and the telephoto end of the lens.

FIGS. **15**(*a*) to **15**(*c*) show a numerical example.

In the numerical example, "ri" represents the radius of curvature of the i-th lens surface as viewed from an object side, "di" represents the i-th lens thickness or air separation as viewed from the object side, and "ni" and "vi" respectively represent the refractive index and the Abbe number of the glass of the i-th lens element as viewed from the object side.

In the numerical example, r**20** and r**21** represent a glass block such as a face plate. If the z axis is taken in the direction of the optical axis; the H axis is taken in the direction perpendicular to the optical axis; the direction of propagation of light is positive; R represents the radius of the osculating sphere; and B, C, D and E represent aspheric coefficients, respectively, the shape of the aspheric surface is represented as the following expression:

$$X=(1/R)H^2/\left[1+\sqrt{\{1-(H/R)^2\}}\right]+BH^4+CH^6+DH^8+EH^{10}$$

In this numerical example, an optical angle of view ω_0 is a total of approximately 74°. In the case of an image sensor having an image size of 4:3, the above-described maximum datum image height Ymax is represented as:

Ymax=maximum image height×0.6

Since the amount of distortional aberration Dym at this time is −9.3%, the following relationship is obtained:

$$Ymax_0/Ymax=(1+Dym/100)^{-1}$$
$$=1.10$$

Thus, the photographic angle of view becomes 10% wider, and the maximum angle of view is approximately 81° in total.

FIGS. **16**(*a*) to **16**(*e*) diagrammatically show the manner of distortion correction performed according to the first embodiment.

Although the above description of the first embodiment has referred to the image pickup apparatus using a single image sensor, the present invention is also applicable to an image pickup apparatus arranged to separate incident light into R, G and B components and pick up R, G and B images as shown in FIG. **17**.

In such an arrangement, since different image distortions occur in the respective color components, data indicative of the amounts of distortion corresponding to the respective color components are prepared, and image processing for distortion correction is performed for each of the color components. By converting the result of the image processing into a video signal, not only the distortion of the image plane but also lateral chromatic aberration is corrected so that a far higher-quality image can be picked up.

A second embodiment of the present invention will be described below.

Although the arrangement of the second embodiment is substantially identical to that of the first embodiment, the second embodiment adopts a image processing method different from that of the first embodiment.

The first embodiment adopts an algorithm according to which an angle of view is first widened by using a photographic lens and, after the photographic lens has reached its wide-angle end, the angle of view is widened to a further extent by using image processing. In contrast, the second embodiment adopts an algorithm according to which if a negative distortional aberration occurs in the photographic lens, not only distortion correction but also widening of the angle of view is performed. FIGS. **18**(*a*) to **18**(*c*) diagrammatically show the manner of the distortion correction.

For example, if an arbitrary image height which is selected as a datum for distortion correction is fixed to the maximum datum image height Ymax and correction is sequentially performed, to whichever zoom position the photographic lens is set, the image pickup area can be utilized to the maximum extent.

The adoption of this method makes it possible to prevent the amount of distortion correction from varying to extremes. In the case of the above-described image processing, during zooming, as the angle of view of the photographic lens approaches the wide-angle end, the rate at which the angle of view widens increases. In this case, it is desirable that as the angle of view of the photographic lens approaches the wide-angle end, the speed of zooming of the photographic lens be decreased so that it is possible to achieve zooming which is felt smooth by the photographer.

A third embodiment of the present invention will be described below.

The third embodiment relates to an example which is arranged to perform distortion correction of a photographic lens which produces a positive distortional aberration on its telephoto side. The arrangement of the apparatus is substantially identical to that of the first embodiment.

FIG. **19** is a flowchart showing an algorithm for calculating addresses according to the third embodiment. It is assumed that Z_0 represents the zoom position at which the distortional aberration of the photographic lens is "0".

[step **S100**] It is determined whether the zoom position of the photographic lens is closer to the wide-angle end or the telephoto end with respect to Z_0. If the zoom position of the photographic lens is closer to the wide-angle end, i.e., in the case of the relationship of $Zs \leqq Z_0$, the process proceeds to Step **S102**. If the zoom position of the photographic lens is closer to the telephoto end ($Zs > Z_0$), the process proceeds to Step **S101**.

[Step S101] Distortion correction is performed with the four corners of the image plane selected as a datum (as will be described later in more detail).

[Step S102] A comparison is made between the zoom position Zs which is aimed at by the photographer and the zoom position Zw which can be taken by the photographic lens **100** at the wide-angle end. If Zs is not less than Zw, i.e., in the case of the relationship of Zs≧Zw, the process proceeds to Step S103. In the case of the relationship of Zs<Zw, the process proceeds to Step S104.

[Step S103] Since the relationship of Zs≧Zw is established, distortion correction is performed with the center of the image plane selected as a datum, in a manner similar to that executed in Step S52 described previously in connection with the first embodiment. The process proceeds to the next step.

If it is determined in Step S102 that the relationship of Zs<Zw is established, it is determined that the zoom position of the photographic lens **100** has entered the area of the virtual zoom position, and the process proceeds to Step S104 as described previously.

[Step S104] It is determined whether the zoom position Zs which is aimed at by the photographer is less than the virtual zoom position Zmin at the wide-angle end which is acceptable in terms of the effect of image correction. If the zoom position Zs is less than the virtual zoom position Zmin, i.e., in the case of the relationship of Zs<zmin, the process proceeds to Step S105. In the case of the the relationship of Zs≧Zmin, the process proceeds to Step S106.

[step S105] Since the zoom position Zs which is aimed at by the photographer is less than the virtual zoom position Zmin at the wide-angle end which is acceptable in terms of the effect of image correction, the operation of substituting the value of Zmin into Zs is performed.

[Step S106] Distortion correction is performed with an arbitrary image height selected as a datum, in a manner similar to that executed in step S55 described previously in connection with the first embodiment.

The "distortion correction with the four corners of the image plane selected as a datum", which is executed in Step S101, will be described below with reference to FIG. **20**.

If distortion correction with the center of an image plane selected as a datum is performed when a positive distortional aberration occurs, image data in the peripheral portion of the image plane is lost so that an imperfect image occurs, as described previously in the description of the related art. To prevent the occurrence of the imperfect image, the circle referred to in the first embodiment, which is used as a datum for distortion correction, is replaced with a circle which circumscribes a photographic area, and if the coordinates of the ideal image point $P_0(x_0, y_0)$ are represented as follows:

$$x_0=(1+D/100)^{-1}\cdot(x-xs)+xs$$

$$y_0=(1+D/100)^{-1}\cdot(y-ys)+ys \quad (16)$$

the coordinates can be calculated through the expressions used in the first embodiment. In this case, since the sign of the distortional aberration is reversed, the image inside of the circle is expanded in a manner reverse to that described previously in connection with the first embodiment.

Electronic zoom is known as a method for enlarging an image beyond the zoom range of a photographic lens when the zoom position of the photographic lens is set to its telephoto side. The electronic zoom can be effectively combined with a method of correcting telephoto-side distortion according to the present invention. FIG. **21** shows the manner of this combination method. First, the above-described distortion correction with four corners selected as a datum is performed, and the resultant image data is partially trimmed and absent image data is prepared by linear interpolation processing, so that it is possible to obtain an image which is virtually zoomed up.

According to another method, if Zr represents a virtual zoom-up ratio, it is possible to simultaneously perform calculations on distortion correction and electronic zoom-up by replacing (x_0, y_0) in the above-described expressions (10) with $(x_0/Zr, y_0/Zr)$ and determining "x" and "y". FIG. **22** shows the manner of the distortion correction and the electronic zoom-up performed by this method.

A fourth embodiment of the present invention will be described below.

FIG. **23** is a block diagram showing the arrangement of an apparatus according to the fourth embodiment of the present invention, and shows a video system arranged to perform the above-described distortion correction during reproduction of an image.

The arrangement shown in FIG. **23** includes a photographic lens **601** which is formed as a lens assembly capable of zooming, an image sensor **602** such as a CCD, a video signal processing circuit **603** for converting an image pickup signal into a video signal, a shooting state detecting circuit **604** for detecting the shooting state of the photographic lens **601** from the position of a variator lens or the position of a focusing lens, and a data table **605** on which data about distortional aberrations according to the shooting state of the photographic lens **601** are recorded.

A recording controlling circuit **606** is provided for simultaneously recording, on a recording medium such as a video tape, a video signal and an audio signal as well as an information signal for use in performing distortion correction of a recorded video image frame with an arbitrary image height selected as a datum, which information signal is obtained from information about a shooting state supplied from the shooting state detecting circuit **604**, information about a zoom position which is aimed at by the photographer, which information is inputted from a zoom switch **611**, and information about distortional aberration memorized on the data table **605**.

The shown arrangement also includes a reproducing device **607** for reproducing from the recording medium the video signal, the audio signal and the information signal for use in performing distortion correction of a video image frame with an arbitrary image height selected as a datum, an image processing circuit **608** for correcting the distortion of an image, a first image memory **609** for memorizing the image data obtained from the reproducing device **607**, and a second image memory **610** for memorizing image data indicative of the image whose distortion is corrected.

The recording controlling circuit **606** takes out information about distortional aberration from the data table **605** in the form of a coefficient (distortion coefficient) obtained from approximation using a function, on the basis of the information about the shooting state supplied from the shooting state detecting circuit **604**, and makes a comparison between the information about the zoom position supplied from the shooting state detecting circuit **604** and the information about the zoom position which is aimed at by the photographer, supplied from the zoom switch **611**. Thus, the recording controlling circuit **606** obtains an image height which is used as a datum in distortion correction (datum image height), and records a distortion coefficient and a datum image height.

The reproducing device **607** reads out the distortion coefficient and the datum image height, and sends them to

the image processing circuit **608** together with a video signal. In the image processing circuit **608**, an undistorted image is formed according to the sequence of the above-described distortion correction.

The recording medium may also be a magnetic disk or an optical disk. A subject to be recorded is not limited to a moving image, and a still image such as a still video image can also be recorded.

A similar system can also be constructed as shown in FIG. **24**. According to the system shown in FIG. **24**, in a silver-halide camera, data is recorded on a film on which an image is recorded, by optical or magnetic means. The image recorded on the film is converted into a digital signal by a scanner or the like and the recorded data is read out from the film at the same time or by a separate readout device. A video output may be converted into a video signal conforming to the NTSC or HDTV system so that it can be displayed on a display device, or may be outputted as an image copy from a color printer.

Incidentally, in FIG. **24**, reference numeral **701** denotes a photographic lens, reference numeral **702** denotes a film and reference numeral **703** denotes an electronic conversion device. In FIG. **24**, the other reference numerals which are identical to those shown in FIG. **23** denote circuits having functions identical to those of the corresponding circuits shown in FIG. **23**.

According to the arrangement shown in FIG. **24**, the information about the shooting state is recorded on the recording medium, and the information about the distortional aberration is recorded on the data table **605** of the reproducing device. However, similarly to FIG. **23**, the data table on which the information about the distortional aberration is recorded may be provided in a photographic apparatus or in a lens barrel which is separable from the photographic apparatus.

The information about the shooting state of the distortional-aberration information may be recorded not on the recording medium (film) but in another memory device of the photographic apparatus.

According to the first to fourth embodiments, since an image is corrected with an arbitrary image height from the center (optical axis) of an image plane selected as a datum, an image obtained from a photographic lens can be effectively used to photograph an image of quality which exceeds the specifications of a photographic lens.

As is apparent from the above description, according to the first to fourth embodiments, one preferred form of arrangement is provided with distortional-aberration memorizing means for memorizing distortional-aberration information about a photographic lens, state-of-photographic-lens detecting means for detecting a state of the photographic lens, distortional-aberration detecting means for detecting distortional-aberration information about distortional aberration occurring during photography, on the basis of information supplied from the state-of-photographic-lens detecting means, and image correcting means for correcting a distortion of an image due to the photographic lens with an arbitrary image height in a photographed image selected as a datum.

Another preferred form of arrangement includes an image pickup apparatus which is provided with distortional-aberration memorizing means for memorizing distortional-aberration information about a photographic lens; state-of-photographic-lens detecting means for detecting a state of the photographic lens; distortional-aberration detecting means for detecting distortional-aberration information about distortional aberration occurring during photography, on the basis of information supplied from the state-of-photographic-lens detecting means; and distortional-aberration recording means for recording the distortional-aberration information supplied from the distortional-aberration detecting means on a recording medium, and an image reproducing apparatus which is provided with distortional-aberration readout means for reading out the distortional-aberration information recorded on the recording medium and image correcting means for correcting a distortion of an image due to the photographic lens with an arbitrary image height in a photographed image selected as a datum.

Yet another preferred form of arrangement includes an image pickup apparatus which is provided with state-of-photographic-lens detecting means for detecting a state of a photographic lens; and state-of-photographic-lens information recording means for recording state-of-photographic-lens information supplied from the state-of-photographic-lens detecting means on a recording medium, and an image reproducing apparatus which is provided with state-of-photographic-lens readout means for reading out the state-of-photographic-lens information recorded on the recording medium; distortional-aberration memorizing means for memorizing distortional-aberration information about the photographic lens; distortional-aberration detecting means for detecting distortional-aberration information about distortional aberration occurring during photography, on the basis of the state-of-photographic-lens information supplied from the state-of-photographic-lens readout means; and image correcting means for correcting a distortion of an image due to the photographic lens with an arbitrary image height in a photographed image selected as a datum, on the basis of the distortional-aberration information supplied from the distortional-aberration detecting means.

According to any of the aforesaid preferred forms, the amount of distortion of an image is corrected on the basis of the distortional-aberration information about the photographic lens with an arbitrary image height from the center (optical axis) of the image plane of the photographic lens selected as a datum.

Accordingly, the image obtained from the photographic lens can be effectively used to provide an image of quality which exceeds the specifications of the photographic lens.

An embodiment of a control device will be described below which electronically corrects the distortion of an image not over the entire zoom range but in a particular zoom range in which an outstanding distortional aberration occurs, so that zoom speeds can be prevented from being substantially influenced.

FIGS. **27**(*a*)-**1**, **27**(*a*)-**2**, and **27**(*a*)-**3**, and FIGS. **27**(*b*)-**1**, **27**(*b*)-**2**, and **27**(*b*)-**3** are views respectively showing the optical performance of a photographic zoom lens according to a fifth embodiment of the present invention and that of a general photographic zoom lens.

FIGS. **27**(*b*)-**1**, **27**(*b*)-**2**, and **27**(*b*)-**3**, show the distortional aberration of the general zoom lens. As shown, when the zoom lens is set to a wide-angle position, a large distortional aberration occurs on the negative side, whereas when the zoom lens is set to a telephoto position, a distortional aberration occurs on the positive side.

If a zoom lens is to be designed so that requirements such as reduced size, reduced weight and compactness can be satisfied, it is extremely difficult to reduce distortional aberrations at the wide-angle end and the telephoto end of the zoom lens. For this reason, the zoom lens is generally designed in such a way that its distortional aberration is distributed so that the amount of distortional aberration at

the wide-angle end and the amount of distortional aberration at the telephoto end become approximately equal to each other. As a result, the absolute amount of the distortional aberration of the zoom lens is not reduced. However, as can be seen from FIG. **27**(*b*)-**1**, **27**(*b*)-**2** and **27**(*b*)-**3**, although the distortional aberration is large in the neighborhood of the wide-angle end and the telephoto end, the distortional aberration occurring in a middle angle position varies substantially monotonously and is small compared to the distortional aberration occurring at either of the wide-angle end and the telephoto end.

For this reason, according to the fifth embodiment, optical design is adopted which is capable of concentrating the distortional aberration on a particular photographing position as shown in FIG. **27**(*a*)-**1**, **27**(*a*)-**2**, and **27**(*a*)-**3**. More specifically, the design is such that, as described above, the amount of distortional aberration at the wide-angle end and the amount of distortional aberration at the telephoto end are made approximately equal to each other and the distortional aberration at middle focal lengths varies monotonously.

During a photographic operation, the photographing position of a photographic zoom lens which is being operated is detected. If it is determined that the photographing position is close to a photographing position in which a large distortional aberration occurs, which photographing position is memorized in a memory part, a geometrical deformation of an image which has occurred due to the photographic zoom lens is interpolated on the basis of image data read out from a solid-state image sensor in accordance with the geometrical deformation. Thus, the distortional aberration is corrected so that an image free of distortional aberration can be obtained.

In other words, according to the fifth embodiment, a photographing position in which correction is to be performed of distortional aberration is specified in advance, and the optical design of a zoom lens is determined while taking account of the specified photographing position. During a photographic operation, a detection is made as to the photographing position of the zoom lens which is currently being operated, and only if correction of the distortional aberration of the zoom lens is needed (in the fifth embodiment, correction is performed of a distortional aberration occurring only in the neighborhood of the wide-angle end and the telephoto end), pixel data for a plurality of lines are used to calculate the pixel signals of each scanning line affected by the geometrical deformation, thereby correcting the distortional aberration due to the photographic zoom lens. Accordingly, it is possible to achieve high image quality by using a comparatively inexpensive lens.

FIG. **28** is a block diagram schematically showing the arrangement of a solid-state image pickup camera provided with a photographic zoom lens having the above-described optical performance.

The arrangement shown in FIG. **28** includes a CCD **10** which is a solid-state image sensor, and the CCD **10** is made up of a photoelectric conversion part **1**, a storage part **3** and a shift register **5**. Reference numeral **2** denotes an example of an image pattern formed on the photoelectric conversion part **1**, and reference numeral **4** denotes a charge pattern.

The shown arrangement also includes a switch **17** for selectively transmitting a signal supplied from the CCD **10**, in accordance with a command from a CPU **16**, an amplifier **6**, a sample-and-hold (S/H) circuit **7**, an analog/digital (A/D) converter **8**, and a line memory **9** having a memory capacity capable of memorizing an output for several lines from the CCD **10**.

An address memory circuit **11** contains two kinds of address information for use in executing readout from the line memory **9**, and either of the two kinds is memorized for correction of distortional aberration at the wide-angle end, while the other kind is memorized for correction of distortional aberration at the telephoto end. The address memory circuit **11** has the function of causing the line memory **9** to send out data (information indicative of the amount of correction of distortional aberration) (by outputting address information to the line memory **9**). The CPU **16** controls the operation of the present system, and applies to the switch **17** (SW1) ON-OFF information indicating whether a distortional-aberration correcting operation is to be performed, on the basis of focal length information indicative of the current focal length of a photographic zoom lens. If the distortional-aberration correcting operation is to be performed, the CPU **16** selects information indicative of the amount of correction of distortional aberration at the wide-angle or telephoto end via the address memory circuit **11**, and causes the line memory **9** to send out the corresponding data.

The shown arrangement also includes an interpolation circuit **12**, a video signal processing circuit **13** and a synchronizing signal adding circuit **14**. Reference numeral **15** denotes a video signal outputted from the video signal processing circuit **13**.

Although the operation of each of the above-described circuits is controlled by a timing controlling circuit, an illustration of the timing controlling circuit, control signals and the like is omitted for the sake of simplicity.

FIG. **29** is a mechanism diagram showing the photographic zoom lens and a focal length detecting part of the above-described solid-state image pickup camera.

The photographic zoom lens shown in FIG. **29** includes a first lens group (focusing lens) **71** for focus adjustment, a second lens group (variator lens) **72** having a zooming function, a third lens group (compensator lens) **73** for correcting a focus position, and a fourth lens group **74** having an image forming function.

The focal length detecting part shown in FIG. **29** includes a position detector **75** for detecting the position of the variator lens **72** having the zooming function, and a focal length detecting circuit **76** for calculating a focal length from the position information supplied from the position detector **75** (position information about the variator lens **72**) and sending out the resultant focal length information to the CPU **16**.

FIG. **30** is a flowchart showing the operation of the solid-state image pickup camera according to the fifth embodiment of the present invention. The operation of the solid-state image pickup camera will be described below with reference to the flowchart.

[step **S91**] A photographic operation is started.

[Step **S92**] Focal length information is detected via the focal length detecting circuit **76**, and the current focal length information is obtained.

[Step **S93**] It is determined whether the focal length information corresponds to a focal length which lies within a predetermined distortional-aberration correction range in the neighborhood of the wide-angle end or the telephoto end. If the focal length information corresponds to the focal length which lies within the predetermined distortional-aberration correction range, the process proceeds to Step **S94**. Otherwise, the process proceeds to Step **S95**.

[Step **S94**] Since the current focal length information about the photographic zoom lens (to be exact, the variator lens **72**) corresponds to the focal length which lies within the predetermined distortional-aberration correction range, a variable SW1 is turned on. Thus, the switch Sw1 is turned on and a signal from the CCD **10** is coupled to the amplifier **6**.

[Step S95] Since the current focal length information about the photographic zoom lens corresponds to a focal length which lies outside the predetermined distortional-aberration correction range, the variable SW1 is turned off. Thus, the switch SW1 is turned off and a signal from the CCD **10** is directly coupled to the video signal processing circuit **13**.

[step S96] It is determined whether the variable SW1 is on or off. If it is on, the process proceeds to Step S97, whereas if it is off, the process proceeds to Step S98.

[Step S97] A distortional-aberration correcting circuit which is made up of the amplifier **6**, the circuit **7**, the A/D converter **8**, the line memory **9** and the interpolation circuit **12** is activated to perform distortional-aberration correction on the basis of the signal from the CCD **10** and address information from the address memory circuit **11**. (The operation of each of these circuits will be described later in detail.) Then, the process proceeds to Step S98.

[Step S98] The video signal processing circuit **13** is operated to generate a video signal on the basis of the signal from the aforementioned distortional-aberration correcting circuit or the CCD **10**, and outputs the video signal.

[Step S99] It is determined whether an operation of a zooming mechanism has been performed. If the operation of the zooming mechanism has been performed, there is a possibility that the zooming mechanism may have been operated during the above-described computations and the focal length may have been varied from that obtained in Step S92. Accordingly, the process returns to Step S92 in which focal length information is newly detected, and the operations subsequent to Step S92 are performed. On the other hand, if the operation of the zooming mechanism has not been performed, it is determined that the focal length has not varied, and the process returns to Step S96 and the operations subsequent to Step S96 is performed.

FIG. **31** is a schematic diagram which serves to explain the operation of the photographic zoom lens.

In FIG. **31**, reference numeral **21** denotes an object plane, and reference numeral **22** denotes an object. Reference numeral **23** denotes the photographic zoom lens made up of the aforementioned lens groups shown in FIG. **29**. Reference numeral **24** denotes an image surface, and reference numeral **25** denotes an image.

An image of the object **22** in the object plane **21** is formed as the image **25** on the image surface **24** by the photographic zoom lens **23**. The CCD **10** which is the solid-state image sensor is disposed on the image surface **24** for performing photoelectric conversion of the image **25**. The photographic zoom lens **23** has a distortional aberration which is set to a value larger than a normal allowable value. Accordingly, the image **25** is distorted compared to the object **22** as shown in FIG. **31**.

However, in lens design, it is well known that if the allowable value of a particular aberration is made greater than those of the other aberrations, it is possible to facilitate correction of the other aberrations. Accordingly, it is possible to achieve various advantages such as a reduction in the size of the photographic zoom lens **23**, a reduction in the number of lens elements to be incorporated therein, and utilization of an inexpensive glass material.

Referring again to FIG. **28**, the image pattern **2** corresponding to the image **25** formed by the photographic zoom lens **23** is produced on the photoelectric conversion part **1** of the CCD **10**. The CCD **10** used in the fifth embodiment is of a frame transfer type. More specifically, the image pattern **2** obtained by photoelectric conversion in the photoelectric conversion part **1** is transferred to the storage part **3** as the charge pattern **4**, and the charge pattern **4** is read out by the shift register **5** on line-by-line basis.

FIG. **32** is a schematic diagram showing the relationship between the image and the CCD.

In FIG. **32**, reference numeral **31** denotes each pixel of the CCD **10**, and reference numerals 32_1, 32_2 and 32_3 denote first, second and third scanning lines, respectively.

The first to third scanning lines 32_1, 32_2 and 32_3 represent the first three scanning lines. Although they should originally constitute straight lines, they are formed as curved lines by the influence of distortional aberration. In other words, the shape of each of these curved lines corresponds to the shape of a curved line which occurs due to distortional aberration when an image of a horizontal straight line which extends in the object plane **21** of the photographic zoom lens **23** is formed on the image surface **24**.

The charge pattern **4** is sequentially read out on line-by-line basis and on pixel-by-pixel basis for each line. Regarding the manner of reading out the pixels **31**, the rightmost pixel on the lowermost line (as viewed in FIG. **32**) is first read out, and the left-hand adjacent pixel is then read out. Thus, the pixels for one line are sequentially read out. Then, the pixel signals on the second lowermost line are sequentially read out from the rightmost pixel. A similar readout operation is performed on the third lowermost line et seqq.

Referring to FIG. **28**, the pixel signals read out from the shift register **5** of the CCD **10** are, as described above, directly sent to the video signal processing circuit **13** if the switch SW1 is off.

If the switch SW1 is on, the switch SW1 outputs the pixel signals to the distortional-aberration correcting circuit. That is to say, the pixel signals are amplified by the amplifier **6**, and the amplified pixel signals are held in the S/H circuit **7**. The output from the S/H circuit **7** is digitized by the A/D converter **8**, and the digital output from the A/D converter **8** is supplied to and memorized in the line memory **9**. The pixel signals for a plurality of lines of the CCD **10** are stored in the line memory **9** before a readout operation is started. This storing operation is carried out to read out pixel signals along a curved scanning line because the curved scanning line extends across a plurality of pixel lines.

The CCD **10** sends the kind of data required for distortional-aberration correction to the address memory circuit **11** on the basis of focal length information about the photographic zoom lens **23**, and the address memory circuit **11** reads out shape data about a scanning line and generates address information for use in reading out the pixel signals memorized in the line memory **9**. The shape data about the scanning line may be obtained by directly sampling the scanning line, or may be obtained as a coefficient by performing appropriate approximation using a function. The shape data about the scanning line which corresponds to the state of the photographic zoom lens **23** is obtained during the process of designing the photographic zoom lens **23** or by optical measurement performed after a trial production.

Since the positions of pixels at the CCD **10** generally do not coincide with those of pixels on such curved scanning lines, the positions of the pixels on the curved scanning line need to be subjected to interpolation processing. Accordingly, data for a plurality of pixels are read out from the line memory **9** and supplied to the interpolation circuit **12**, in which the value of one pixel on the scanning line is calculated.

The memory capacity of the line memory **9** is determined in the following manner.

FIG. **33** is a view showing the relationship between the pixels of the line memory **9** and the scanning line.

In FIG. **33**, each pixel is denoted by reference numeral **41**. The pixels **41** correspond to the pixels of the CCD **10** in one-to-one relation. Reference numeral **42** denotes the most curved scanning line, i.e., a scanning line which extends across a greater number of pixel lines of the line memory **9** than any other scanning line. Reference numeral **43** denotes a scanning line next to the most curved scanning line **42**. Reference numeral **44** denotes each pixel of the most curved scanning line **42**, and reference numeral **45** denotes each pixel of the scanning line **43** next to the scanning line **42**. In the shown example, it is necessary to calculate the values of pixel data at the position of each pixel **44** represented as a black dot on the most curved scanning line **42** and at the position of each pixel **45** represented as a black dot on the next scanning line **45**.

The size of the line memory **9** is indicated at **46**. The size **46** of the line memory **9** is selected as a memory capacity capable of memorizing data indicative of the pixels **31** of the CCD **10** which can be used to calculate the values of all the pixels **44** of the most curved scanning line **42**. In other words, the size **46** of the line memory **9** corresponds to the number of lines obtained by adding, if necessary, the number of adjacent lines required for interpolation processing to the number of the pixels **31** of the CCD **10** across which the most curved scanning line **42** extends. Of course, the size **46** of the line memory **9** may be greater than the aforesaid number of lines.

If the line memory **9** has a memory capacity for the size **46**, the values of all the pixels **44** on the most curved scanning line **42** can be calculated from the pixels **41** of the line memory **9**.

When the values of the pixels **45** on the next scanning lines **43** are to be calculated, the pixel data on the lowermost line in the line memory **9** are discarded and the next line which has not yet memorized in the line memory **9**, for example, pixel data on the uppermost line in FIG. **32**, are read from the CCD **10**. Since the size **46** of the line memory **9** is selected so that the line memory **9** can memorize a sufficient amount of pixel data **41** to calculate the values of all the pixels on any scanning line, the values of all the pixels **45** on the next scanning line **43** are also calculated. Similarly, the values of all the pixels on the other scanning lines are calculated.

If the shape of a scanning line differs from the above-described one, it may not be necessary to read out new pixel data before calculating the values of the pixels, or it may be necessary to read out pixel data for two or more lines. A timing controlling circuit (not shown) adjusts the manner of reading out pixel data in response to a signal from the address memory circuit **11**. If the final output signal of the solid-state image pickup camera is a video signal, it is necessary to output pixel data for each line on line-by-line basis at intervals of a predetermined time period. Accordingly, as the case may be, it is also preferable to adopt an arrangement in which the line memory **9** is provided with a buffer memory for timing adjustment.

The interpolation processing performed by the interpolation circuit **12** will be described below with reference to FIG. **34**.

In FIG. **34**, reference numeral 52_1 denotes a scanning line, and reference numerals 52_2 and 53_5 denote pixels of the scanning line 52_1. Reference numerals 53_1 53_2, . . . , 53_5 denote pixels of the line memory **9**.

To calculate the values of the pixels of the scanning line **51**, since the positions of the pixels 52_1 and 52_2 differ from those of the pixels 53_1 to 53_5 of the line memory **9**, it is necessary to calculate the values of the pixels 52_1 and 52_2 as interpolated values. The simplest method is to select pixels closest to the respective pixels 52_1 and 52_2 from the pixels 53_1 to 53_5 of the line memory **9** and obtain the values of the closest pixels as the values of the pixels 52_1 and 52_2. Specifically, the values of the pixels 52_1 and 52_2 of the scanning line **51** are respectively obtained as the values of the pixels 53_4 and 53_2 of the line memory **9**. It is also preferable to adopt an arrangement in which, in the above-described processing, the address memory circuit **11** is made to determine appropriate addresses so that the interpolation processing is performed during a readout from the line memory **9**. With such an arrangement, the special interpolation circuit **12** can be omitted.

Another approximation method is to calculate interpolated values from adjacent four pixels in the line memory **9** by linear approximation. Specifically, the values of the pixels 52_1 and 52_2 of the scanning line **51** are respectively calculated by sending the four pixels 53_1, 53_2, 53_4, 53_5 and the four pixels 53_2, 53_3, 53_5, 53_4 to the interpolation circuit **12** and performing linear approximation using the corresponding four pixels.

Still another approximation method is a "cubic convolution method". The cubic convolution method is a method of performing interpolation on the basis of the value of neighboring pixels by using a cubic spline curve. In this method, sixteen neighboring pixels are needed for calculation of one pixel.

Referring again to FIG. **28**, the output signal from the interpolation circuit **12** is sent to the video signal processing circuit **13**, in which the signal is converted into a signal of predetermined format, such as an NTSC television signal or a high-definition television signal. A synchronizing signal is supplied from the synchronizing signal adding circuit **14** to the video signal processing circuit **13**, whereby a final video signal is formed. The video signal **15** outputted from the video signal processing circuit **13** is displayed on a monitor, supplied to the succeeding processing circuit, and so on, according to the entire system arrangement.

Distortional-aberration correcting processing will be described below with reference to FIG. **35**.

In FIG. **35**, an object is indicated by reference numeral **61**, and an image of the object **61** is indicated by reference numeral **62**. The image **62** is obtained through the photographic zoom lens **23**, and a charge pattern on the CCD **10** also has the same shape as the image **62**. Reference numeral **63** denotes an image formed by an output video signal.

In FIG. **35**, the three patterns **61**, **62** and **63** are exaggeratedly depicted in such a manner that the relationship in size between the three patterns **61**, **62** and **63** differs from the relationship between the actual scales of them.

The image **62** is distorted with respect to the object **61** by the distortional aberration of the photographic zoom lens **23**. However, since distortional-aberration correction is electrically performed as described previously, the image **63** formed by the output video signal **15** is obtained as an image similar to the object **61** as shown in FIG. **35**.

FIGS. **36**(*a*)–**36**(*c*) are views showing one example of the optical performance of a photographic zoom lens used in a sixth embodiment of the present invention.

As shown in FIGS. **36**(*a*)–**36**(*c*), the photographic zoom lens used in the sixth embodiment has a distortional aberration the amount of which is extremely large at its wide-angle end and approximately equivalent at the telephoto end and the middle angle position. The distortional aberration monotonously varies over the focal lengths between the middle angle position and the telephoto end. For this reason, in the sixth embodiment, correction is performed of a

distortional aberration occurring in the neighborhood of the wide-angle end.

FIGS. **37**(*a*)–**37**(*c*) are views showing one example of a variation in distortional aberration depending on shooting distance in the neighborhood of the wide-angle end. FIGS. **37**(*a*)–**37**(*c*) show from the left-hand side distortional aberrations occurring in photography at infinity, at an object distance of 3 m, and at the shortest shooting distance (1.2 m).

It is understood from FIGS. **37**(*a*)–**37**(*c*) that even if the same focal length is selected, the distortional aberration greatly varies depending on the shooting distance. For this reason, in the sixth embodiment, as will be described below, not only focal length information but also shooting distance information is used as discrimination information for distortional-aberration correction.

FIG. **38** is a block diagram schematically showing the focal length detecting part and the shooting distance detecting part of a solid-state image pickup camera according to the sixth embodiment of the present invention. Since the arrangement of the other constituent elements is similar to that shown in FIG. **28**, an illustration thereof is omitted.

The photographic zoom lens shown in FIG. **38** includes a first lens group (focusing lens) **111** having a focus-position adjusting function, a second lens group (variator lens) **112** having a zooming function, a third lens group (compensator lens) **113** having a focus-position correcting function, and a fourth lens group **114** having an image forming function.

The arrangement shown in FIG. **29** also includes a detector **115** for detecting the position of the variator lens **112**, and a focal length detecting circuit **116** for calculating a focal length from the position of the variator lens **112** and sending out the resultant focal length information to the CPU **16**, a detector **117** for detecting the position of the focusing lens **111**, and a shooting distance detecting circuit **118** for calculating a shooting distance from the position of the focusing lens **111** and sending out the resultant shooting distance information to the CPU **16**.

FIG. **39** is a flowchart showing the operation of the above-described solid-state image pickup camera. The operation thereof will be described below with reference to the flowchart.

[Step S111] A photographic operation is started.

[Step S112] Detection of a focal length is performed by the focal length detecting circuit **116**, and the current focal length information is obtained.

[Step S113] It is determined whether the focal length information corresponds to a focal length which lies within a predetermined distortional-aberration correction range in the neighborhood of the wide-angle end. If the focal length information corresponds to the focal length which lies within the predetermined distortional-aberration correction range, the process proceeds to Step S114. Otherwise, the process proceeds to Step S115.

[Step S114] Since the current focal length information about the photographic zoom lens (to be exact, the variator lens **112**) corresponds to the focal length which lies within the predetermined distortional-aberration correction range, a variable SW2 is turned on. Thus, the switch SW2 is turned on and a signal from the CCD **10** is coupled to the amplifier **6**. Then, the process proceeds to Step S116.

[Step S115] Since the current focal length information about the photographic zoom lens corresponds to a focal length which lies outside the predetermined distortional-aberration correction range, the variable SW2 is turned off. Thus, the switch SW2 is turned off and a signal from the CCD **10** is directly coupled to the video signal processing circuit **13**. Then, the process proceeds to Step S117.

[Step S116] The current shooting distance information is detected by the shooting distance detecting circuit **118**, and it is determined to which of a predetermined shooting distance zone the shooting distance corresponds. The result of this decision is memorized as a variable SW3. Then, the process proceeds to Step S117.

In Step S116, a decision result indicative of short distance is memorized as the variable SW3=1, a decision result indicative of medium distance is memorized as the variable Sw3=2, and a decision result indicative of long distance is memorized as the variable SW3=3.

[Step S117] It is determined whether the variable SW2 is on or off. If it is on, the process proceeds to Step S118, whereas if it is off, the process proceeds to Step S119.

[Step S118] The distortional-aberration correcting circuit which is made up of the amplifier **6**, the circuit **7**, the A/D converter **8**, the line memory **9** and the interpolation circuit **12** is activated to perform distortional-aberration correction on the basis of the signal from the CCD **10** and address information selected on the basis of the shooting distance data (the kind of signal of the variable SW3). Then, the process proceeds to Step S119.

[Step S119] The video signal processing circuit **13** is operated to generate a video signal on the basis of the signal from the aforementioned distortional-aberration correcting circuit or the CCD **10**, and outputs the video signal. Then, the process proceeds to Step S120.

[Step S120] It is determined whether an operation of a zooming mechanism has been performed. If the operation of the zooming mechanism has been performed, there is a possibility that after the video signal has been outputted, the zooming mechanism may have been operated to vary the focal length. Accordingly, the process returns to Step S112 in which focal length information is newly detected, and the operations subsequent to Step S112 are performed. On the other hand, if the operation of the zooming mechanism has not been performed, the process proceeds to Step S121.

[Step S121] It is determined whether the variable SW2 is on (i.e., whether the focal length is within the distortional-aberration correction range) and whether a focus adjusting mechanism is in operation. If both conditions are satisfied, the process proceeds to Step S116. If both conditions are not satisfied, the process proceeds to Step S117 and the operations subsequent to Step S117 are performed.

The above-described operations are repeatedly performed.

According to the above-described fifth and sixth embodiments, during optical design, the photographic zoom lens is designed so that photographic conditions under which to perform distortional-aberration correction during photography are restricted to extremely limited photographic patterns selected from all possible photographic patterns. During photography, the photographing position of the photographic zoom lens which is being operated is detected, and only when distortional-aberration correction is needed, i.e., only when the focal length is within the distortional-aberration correction range, correction is performed of a distortional aberration due to the photographic zoom lens. Accordingly, it is possible to reduce the scale of a signal processing circuit which is used for performing the distortional-aberration correction during photography, and it is possible to materially improve the signal processing capability to perform various signal processings during photography. Further, it is possible to design a light-weight, compact photographic zoom lens which uses a reduced number of lens elements, whereby it is possible to provide a far more inexpensive solid-state image pickup camera of further reduced size.

FIG. **31** is a schematic diagram showing a photographic zoom lens according to a seventh embodiment of the present invention.

In FIG. **31**, reference numeral **21** denotes an object plane, and reference numeral **22** denotes an object. Reference numeral **23** denotes the photographic zoom lens made up of the aforementioned lens groups shown in FIG. **29**. Reference numeral **24** denotes an image surface, and reference numeral **25** denotes an image.

An image of the object **22** in the object plane **21** is formed as the image **25** on the image surface **24** by the photographic zoom lens **23**. A CCD **216** which is a solid-state image sensor to be described later is disposed on the image surface **24** for performing photoelectric conversion of the image **25**. The photographic zoom lens **23** has a distortional aberration which is set to a value larger than a normal allowable value. Accordingly, the image **25** is distorted compared to the object **22** as shown in FIG. **31**.

However, in lens design, it is well known that if the allowable value of a particular aberration is made greater than those of the other aberrations, it is possible to facilitate correction of the other aberrations. Accordingly, it is possible to achieve various advantages such as a reduction in the size of the photographic zoom lens **23**, a reduction in the number of lens elements to be incorporated therein, and utilization of an inexpensive glass material.

FIG. **40** is a block diagram schematically showing the arrangement of a solid-state image pickup camera provided with the above-described photographic zoom lens.

The arrangement shown in FIG. **40** includes the CCD **216** which is a solid-state image sensor, and the CCD **216** is made up of a photoelectric conversion part **201**, a storage part **203** and a shift register **205**. Reference numeral **202** denotes an example of an image pattern formed on the photoelectric conversion part **201**, and reference numeral **204** denotes a charge pattern.

The shown arrangement also includes an amplifier **206**, a sample-and-hold (S/H) circuit **207**, an analog/digital (A/D) converter **208**, and a line memory **209** having a memory capacity capable of memorizing an output for several lines from the CCD **216**. A lens state signal **210** indicates the current state of the photographic zoom lens **23** (i.e., the lens state), and contains information about the state of zooming, the state of focus, a zooming speed and the like. The shown arrangement also includes an address memory circuit **211** for outputting address information for use in executing readout from the line memory **209**, an interpolation circuit **212**, a video signal processing circuit **213** and a synchronizing signal adding circuit **214**. An output video signal is denoted by reference numeral **215**.

Although the operation of each of the above-described circuit elements is controlled by a timing controlling circuit, an illustration of the timing controlling circuit, control signals and the like is omitted for the sake of simplicity.

The operation of the above-described solid-state image pickup camera will be described below.

Referring to FIG. **40**, signals indicative of pixels of the CCD **216**, which are read out from the shift register **205**, are amplified by the amplifier **206**. The amplified signals are supplied to and held by the S/H circuit **207**. The output from the S/H circuit **207** is digitized by the A/D converter **208**, and the digital output from the A/D converter **208** is supplied to and memorized in the line memory **209**. The signals for a plurality of lines of the CCD **216** are stored in the line memory **209** before a readout operation is started. This storing operation is carried out to read out pixel signals along a curved scanning line because the curved scanning line extends across a plurality of pixel lines. If the lens state signal **210** is inputted to the address memory circuit **211**, the address memory circuit **211** can detect the current lens state.

The address memory circuit **211** includes a built-in ROM (read-only memory) in which shape data about scanning lines corresponding to various lens states are memorized. The shape data about scanning lines corresponding to various lens states may be obtained by directly sampling the scanning lines, or may be obtained as a coefficient by performing appropriate approximation using a function. The shape data about the scanning lines which correspond to the states of the photographic zoom lens **23** are obtained during the process of designing the photographic zoom lens **23** or by optical measurement performed after a trial production.

If zooming is inoperative, the address memory circuit **211** reads out data from the aforesaid ROM in accordance with the state of the photographic zoom lens **23**, and generates from the read-out data an address for reading out a pixel signal from the line memory **209**. The read-out pixel signal is outputted to the video signal processing circuit **213** as a corrected version of the signal obtained at the CCD **216**.

Since the positions of pixels obtained at the CCD **216** generally do not coincide with those of pixels on a curved scanning line, the positions of the pixels on the curved scanning line need to be subjected to interpolation processing. Accordingly, data for a plurality of pixels are read out from the line memory **209** and supplied to the interpolation circuit **212**, in which the value of one pixel on the scanning line is calculated.

FIG. **41** is an explanatory view of distortional-aberration correcting processing.

In FIG. **41**, an object is indicated by reference numeral **231**, and an image of the object **231** is indicated by reference numeral **232**. The image **232** is obtained through the photographic zoom lens **23**, and a charge pattern on the CCD **216** also has the same shape as the image **232**. Reference numeral **233** denotes an image formed by the output video signal **215**.

In FIG. **41**, the three patterns **231**, **232** and **233** are exaggeratedly depicted in such a manner that the relationship in size between the three patterns **231**, **232** and **233** differs from the relationship between the actual scales of them.

The image **232** is distorted with respect to the object **231** by the distortional aberration of the photographic zoom lens **23**. However, since distortional-aberration correction is electrically performed as described previously, the image **233** formed by the output video signal **15** is obtained as an image similar to the object **231** as shown in FIG. **41**.

During a zooming operation, the above-described image-distortion correcting data which is part of the ROM data is not used and, hence, no interpolation is performed, so that a distorted image obtained at the CCD **216** is outputted along a path B.

The above-described distortion correcting operation will be described below with reference to the flowchart of FIG. **42**.

[step S**241**] A photographic operation is started.

[Step S**242**] It is determined whether the zoom is on or off. If the zoom is on, since no distortion correction is performed, the process stays in Step S**242**. If the zoom is off, the process proceeds to Step S**243** to perform distortion correction.

[Step S**243**] A zoom position and a focus position are detected, and the process proceeds to Step S**244**.

[Step S**244**] Shape data about a scanning line which corresponds to the aforesaid lens state is taken out, and the process proceeds to Step S**245**.

[Step S245] Interpolation processing is performed on the basis of the shape data about the scanning line, thereby performing the distortion correction.

It is to be noted that although the distortional aberration has been referred to herein as a geometrical distortion by way of example, the seventh embodiment can, of course, be applied to another kind of geometrical aberration.

It is also preferable to adopt an arrangement in which when the zoom is on, an image formed at the CCD **216** is directly outputted to the video signal processing circuit **213** by an analog circuit.

According to the above-described seventh embodiment, since no distortion correction is performed during a zooming operation, it is possible to achieve simplified computing processing and rapid zooming.

FIG. **43** is a flowchart showing the distortion correcting operation of a solid-state image pickup camera according to an eighth embodiment of the present invention. FIG. **44** is a view which serves to explain the manner of calculation of the amount of correction in Step S253 of FIG. **43**.

When the zoom is off, if a focal length f is f=Z, distortion correction is performed from scanning-line shape data based on the lens state at that time by means of the interpolation circuit.

However, if the zoom is on, the amount of correction, f(Z'), for a focal length Z' to which the current focal length Z will have varied with the elapse of Δt owing to zooming is beforehand obtained by:

$$Z'=Z+v\cdot\Delta t$$

where v represents a zooming speed and Δt represents the time required for distortion correction computation processing. When the focal length Z' is reached during the zooming, distortion correction is performed at the same time.

Steps S251 to S254 of FIG. **43** show the above-described operation performed when the zoom is on.

By performing the above-described control, it is possible to solve, without decreasing the zooming speed, the degradation of image quality due to the problem that distortion correction occasionally becomes unable to follow the zooming speed during zooming.

According to the above-described eighth embodiment, since distortion correction is performed on the basis of the zooming speed during zooming, it is possible to provide an undistorted image at real time.

As described above, in accordance with the fifth to eighth embodiments of the present invention, there is provided an arrangement which includes a photographic zoom lens which is formed in such a manner that its distortional aberration is concentrated on a specific photographing position, detecting means for detecting a photographing position of the photographic zoom lens, and correcting means for correcting, if the detecting means detects that the photographing position of the photographic zoom lens during photography is located within a position where a large distortional aberration occurs, a geometrical deformation of an image occurring due to the photographic zoom lens by reading out image data from the solid-state image sensor on the basis of the geometrical deformation. During optical design, the photographic zoom lens is formed in such a manner that the distortional aberration is concentrated on the specific shooting position. During photography using the photographic zoom lens, if the photographing position of the photographic zoom lens enters the position where the large distortional aberration occurs, the image data is read out from the solid-state image pickup device on the basis of the geometrical deformation of the image occurring due to the photographic zoom lens, and distortional-aberration correction is performed of the geometrical deformation.

Accordingly, it is possible to improve image quality and to provide not only an inexpensive photographic zoom lens but also a low-cost image pickup circuit.

Also, control means is provided for switching the manner of correction of the geometrical deformation according to whether a zooming operation is being performed, so that, during the zooming operation, the operation of correcting the geometrical deformation is not performed or the operation of correcting the deformation is performed by using zooming speed information.

Accordingly, it is possible to improve the zooming speed and to provide an undistorted output image.

An embodiment which will be described later discloses a control device which is arranged to display, during electronic zooming, a video image corresponding to the entire area of the image sensor on a portion of a display so that a user can visually confirm which portion of the entire image plane corresponds to an object image picked up by electronic zooming.

FIG. **45** is a block diagram schematically showing the arrangement of a ninth embodiment of the present invention. The shown arrangement includes a photographic lens **310**, an image sensor **312** for converting an optical image formed by the photographic lens **310** into an electrical signal, a camera signal processing circuit **314** for subjecting the output of the image sensor **312** to camera signal processing such as gamma correction or color adjustment and outputting luminance and color-difference signals (or RGB signals), and an A/D converter **316** for converting the analog output of the camera signal processing circuit **314** into a digital signal.

The shown arrangement also includes an image memory **318** having a memory capacity for at least one image plane for temporarily memorizing image data outputted from the A/D converter **316**, and an image enlarging circuit **320** for electrically enlarging a specified area of an image memorized in the image memory **318** to a predetermined size by means of coordinate transformation. Incidentally, if the specified area corresponds to the entire size of the image plane, the image enlarging circuit **320** provides an output of equal magnification.

The shown arrangement also includes a D/A converter **322** for converting the output data of the image enlarging circuit **320** into an analog signal, and a video encoder **324** for converting the image signal outputted from the D/A converter **322** into a predetermined video format, for example, a video signal conforming to the NTSC system. The output of the video encoder **324** is applied to an output terminal **326** and to an electronic viewfinder (EVF) **328**. A video image recording device, such as a video tape recorder or a video cassette recorder, is connected to the output terminal **326**.

An electronic-zoom frame position selecting key **330** is provided for selecting a position of an electronic-zoom frame within a photographic image plane displayed in the electronic viewfinder **328**, and is formed by, for example, a key switch for inputting an instruction indicative of any of upward, downward, rightward and leftward movements. An electronic-zoom switch **332** is provided for turning on or off an electronic zoom. A system controlling system **334** controls the entire arrangement and, specifically, controls the electronic realized by the image memory **318** and the image enlarging circuit **320**, in accordance with the electronic-zoom frame position selecting key **330** and the electronic-zoom switch **332**.

According to the ninth embodiment, as shown in FIG. **48**, five areas A, B, C, D and E are set in the photographic image

plane, and the electronic-zoom frame can be moved to any of the five areas A, B, C, D and E. The areas A, B, C, D and E may have the same size or different sizes. The reason why the electronic-zoom frame is made to move to any of the aforesaid fixed positions is to simplify a control system. Of course, it is possible to adopt an arrangement capable of continuously moving the electronic zoom within the photographic image plane. In this arrangement, the key switch **330** may be replaced with an operating member such as a cross-shaped lever which is easier to operate.

As a matter of course, it is also possible to adopt an arrangement capable of recognizing or memorizing the feature of an object and causing the electronic-zoom frame to move automatically so as to track a specific object.

The operation of the ninth embodiment will be described below with reference to FIG. **49**. When a power supply is turned on, the image sensor **312** converts an optical image formed by the photographic lens **310** into an electrical signal (Steps S**201** and S**202**), and the camera signal processing circuit **314** subjects the output of the image sensor **312** to camera signal processing (Step S**203**). The output of the camera signal processing circuit **314** is converted into a digital signal by the A/D converter **316** (Step S**204**), and the digital signal is temporarily memorized in the image memory **318** in units of one image plane (Step S**205**).

If it is determined in Step S**206** that the electronic-zoom switch **332** is on, the system controlling circuit **334** determines which of the areas A, B, C, D and E is to be electronically zoomed, on the basis of the state of the electronic-zoom frame position selecting key **330**. The image enlarging circuit **320** reads out, from the image memory **318**, image data indicative of the image contained in the electronic-zoom frame located in a specified position, and displays the image data as an image enlarged up to a predetermined image size, for example, as shown in FIG. **47** (steps S**207** and S**208**). On the other hand, if it is determined in Step S**206** that the electronic-zoom switch **332** is off, the image enlarging circuit **320** reads out image data corresponding to the entire image plane from the image memory **318** and outputs the image data without modification (Step S**209**).

The D/A converter **322** converts the digital output of the image enlarging circuit **320** into an analog signal (step S**210**), and the video encoder **324** converts the output of the D/A converter **322** into a video signal of predetermined format (Step S**211**). The output of the video encoder **324** is applied to the electronic viewfinder **328** and is also outputted through the output terminal **326** to an external circuit (Step S**212**). The output video signal of the video encoder **324** becomes, when the electronic zoom is on, a signal representative of an enlarged video image of the image contained in the electronic-zoom frame located in the specified position.

For example, if the electronic-zoom frame is moved to the area C, the enlarged image shown in FIG. **50** is obtained from the photographic image shown in FIG. **46**.

In the ninth embodiment, it is also possible to adopt an arrangement in which when the electronic-zoom switch **332** is off, the output of the camera signal processing circuit **314** is directly supplied to the video encoder **324**, while if the electronic-zoom switch **332** is on, the output of the camera signal processing circuit **314** is made to pass through the circuits **316** to **322**.

According to the ninth embodiment, if the electronic zoom is in operation, it is impossible to obtain image information outside of the electronic-zoom frame from the photographic image plane displayed in the electronic viewfinder **328** or the signal outputted from the output terminal **326**. The image information outside of the electronic-zoom frame is occasionally needed as a material for determining whether the electronic zoom is to be turned off.

A tenth embodiment which satisfies such a demand will be described below. FIG. **51** is a block diagram showing the arrangement of the tenth embodiment. The shown arrangement includes a photographic lens **340**, an image sensor **342**, a camera signal processing circuit **344**, an A/D converter **346** for converting the analog output of the camera signal processing circuit **344** into a digital signal, and an image memory **348**. These elements **340** to **348** are substantially identical to the elements **310** to **318** shown in FIG. **45**.

The shown arrangement also includes an image enlarging circuit **350** for electronically enlarging a specified area of an image memorized in the image memory **348** to a predetermined size through coordinate transformation, and an image reducing circuit **352** for reducing the image memorized in the image memory **348** to a predetermined size. The image enlarging circuit **350** provides an output of equal magnification if the specified area corresponds to the entire size of the image plane. The shown arrangement also includes an image combining circuit **354** for combining (or selecting either one of) the output of the image enlarging circuit **350** and the output of the image reducing circuit **352**.

The shown arrangement also includes a D/A converter **356** for converting the output data of the image combining circuit **354** into an analog signal, and a video encoder **358** for converting the image signal outputted from the D/A converter **356** into a predetermined video format, for example, a video signal conforming to the NTSC system. The output of the video encoder **358** is applied to an output terminal **360** and to an electronic viewfinder (EVF) **362**. A video image recording device, such as a video tape recorder or a video cassette recorder, is connected to the output terminal **326**.

The shown arrangement also includes an electronic-zoom frame position selecting key **364** similar to the electronic-zoom frame position selecting key **330**, an electronic-zoom switch **366** similar to the electronic-zoom switch **332**, a subsidiary-image-plane display switch **368** for specifying whether to display a photographic image in the form of a subsidiary image plane, and a system controlling circuit **370** for controlling the entire arrangement. Specifically, the system controlling circuit **370** controls the electronic zoom in accordance with the electronic-zoom frame position selecting key **364** and the electronic-zoom switch **366**, and also controls the subsidiary-image-plane display of the photographic image in accordance with the subsidiary-image-plane display switch **368**.

Referring to the feature of the tenth embodiment, when the electronic-zoom switch **366** is turned on, the image enlarging circuit **350** electronically enlarges the image contained in the area specified by the electronic-zoom frame position selecting key **364**, in a manner similar to that explained in connection with the embodiment shown in FIG. **45**. The image enlarging circuit **350** reduces the entire photographic image memorized in the image memory **348** to a predetermined size.

When the subsidiary-image-plane display switch **368** is turned on, the image combining circuit **354** combines a reduced image outputted from the image reducing circuit **352** with a predetermined portion of an enlarged image outputted from the image enlarging circuit **350**, and outputs the combined image. When the subsidiary-image-plane display switch **368** is turned off, the image combining circuit **354** outputs the output image of the image enlarging circuit **350** without modification.

When both the electronic-zoom switch **366** and the subsidiary-image-plane display switch **368** are turned on, the image enlarging circuit **350**, the image reducing circuit **352** and the image combining circuit **354** cooperate to cause the image combining circuit **354** to output an image such as that shown in FIG. **52**. A user can obtain image information outside of the electronic-zoom area through the subsidiary image plane.

If a video signal indicative of only an electronically zoomed video image is to be outputted from the output terminal **360** to an external circuit, it is preferable to adopt an arrangement in which the output of the image enlarging circuit **350** is converted into a video signal conforming to the NTSC system or the like by another video encoder so that the output of this video encoder and the output of the video encoder **358** can be selectively supplied to the output terminal **360**.

If a frame line corresponding to the electronic-zoom frame which is set is displayed in the subsidiary image plane, the usability of the electronic zoom is improved. To display such a frame line in the subsidiary image plane, it is preferable to write frame-line data into a portion in the image memory **348** which corresponds to an electronic-zoom frame position selected by the electronic-zoom frame position selecting key **364**.

The ninth and tenth embodiments described above are arranged in such a manner that the position of the electronic-zoom frame can be altered. However, it is also possible to adopt an arrangement which is provided with means for setting the size of the electronic-zoom frame so that the size of the electronic-zoom frame can be altered.

As will be readily understood from the above description, according to the ninth and tenth embodiments, since the electronic-zoom frame can be moved, it is possible to track the movement of an object by moving not the entire image pickup apparatus but the electronic-zoom frame, whereby it is possible to suppress an image shake due to the image pickup apparatus. Accordingly, it is possible to utilize the electronic zoom more effectively.

FIG. **53** is a block diagram showing the circuit arrangement of an image pickup apparatus according to an eleventh embodiment of the present invention.

The arrangement shown in FIG. **53** includes an optical system **401** for forming an object image on the surface of an image sensor which will be described later, an image sensor **402** for performing photoelectric conversion of the object image provided by the optical system **401**, a signal processing circuit **403** for processing a time-series signal relative to the object image, which is obtained from the image sensor **402**, an A/D converter **404** for converting an electrical signal (analog signal) processed by the signal processing circuit **403** into a digital signal, and an image memory **405** for memorizing image data supplied from the A/D converter **404**.

The shown arrangement also includes an image processing circuit **406** for enlarging and reducing an image, an image combining circuit **407** for combining an enlarged image and a reduced image, a D/A converter **408** for restoring a digital signal subjected to the above-described image processing to an analog signal, an encoder **409** for converting the analog signal obtained by the D/A conversion into a standard video signal **410** conforming to the NTSC system, and an electronic viewfinder (EVF) **411** for confirmation of a photographic image plane displayed therein.

A system controller **412** is provided for checking the operational state of each selecting member which will be described later and controlling each constituent element in accordance with the checked operational state, and can be easily realized by using a general-purpose microprocessor. An electronic-zoom function selecting member **413** is provided for specifying whether to make an electronic-zoom function operative (on) or inoperative (off), and a subsidiary-image-plane display selecting member **414** for specifying whether to display (on) an original image which is not enlarged, in the form of a subsidiary image plane or to inhibit display of the subsidiary image plane (off).

FIG. **54** is a flowchart showing the operation of the image pickup apparatus having the above-described arrangement.

When a power switch (not shown) of the apparatus is turned on, an object image is inputted to the image sensor **402** through the optical system **401** (Step S**301**). The object image formed on the image sensor **402** is converted into an electrical signal by the image sensor **402** (Step S**302**). The signal processing circuit **403** which has received the electrical signal converts the signal into a time-series signal relative to the object image (Step S**303**).

Then, the system controller **412** checks the state of the electronic-zoom function selecting member **413** and determines whether the electronic-zoom function is on (Step S**304**). If it is determined that the electronic-zoom function is off, the process proceeds to Step S**312**. If it is determined that the electronic-zoom function is on, the process proceeds to Step S**305**, in which the time-series analog signal relative to the object image is converted into a digital signal by the A/D converter **404**. Then, information for one image plane is temporarily memorized in the image memory **405** (Step S**306**), and the image processing circuit **406** performs the image processing of selecting a digital image signal indicative of the image contained in the electronic-zoom frame from the memorized digital signal and enlarging the image up to the full size of the image plane (Step S**307**).

The variation of the image at that time will be described below with reference to FIG. **56**. The image contained in the electronic-zoom frame is selected from an image for one image plane, such as that shown in the left-hand part of FIG. **56**, and is enlarged up to the full size of the image plane so that the image shown in the right-hand part of FIG. **56** is formed. This image processing can be easily realized by performing coordinate transformation radially from the center of the electronic-zoom frame toward the outside thereof. Accordingly, detailed description of the image processing is omitted herein.

Then, the system controller **412** checks the state of the subsidiary-image-plane display selecting member **414** for displaying an original image plane, which is not enlarged up to an electronically zoomed image plane, as a subsidiary image plane, and checks whether a subsidiary-image-plane display function for displaying the original image plane which is not enlarged is on (Step S**308**). If it is determined that the subsidiary-image-plane display function is off, the process proceeds to Step S**311**. If it is determined that the subsidiary-image-plane display function is on, the process proceeds to Step S**309**. In Step S**309**, the image processing circuit **406** performs the image processing of reducing the image signal memorized in the image memory **405** at a predetermined ratio. Then, the image combining circuit **407** combines the image obtained in Step S**309** and the image obtained in Step S**307** so that the subsidiary-image-plane display signal indicative of the original image which is not electronically zoomed is made to overlap the electronically zoomed image (Step S**310**).

The state of the image at that time is shown in FIG. **55**. The aforesaid image processing can be realized by performing coordinate transformation radially toward the center of the electronic-zoom frame.

Then, the combined digital image signal is converted into an analog signal by the D/A converter **408** (Step S311), and the analog signal is restored to the standard video signal **410** by the encoder **409** (Step S312). The thus-obtained image is displayed in the EVF **411** (Step S313), and a photographer confirms this image. Also, the image is recorded by the recording device (not shown) (Step S314).

If it is determined in Step S304 that the electronic-zoom function is off, the process proceeds to Step S312 as described previously and the time-series analog signal relative to the object image is immediately restored to the standard video signal **410** by the encoder **409**. The thus-obtained normal image is supplied to the EVF **411** and to the recording device (Steps S313 and S314).

If it is determined in Step S308 that the subsidiary-image-plane display selecting member **414** is off, the process proceeds to Step S311, in which the enlarged-image digital signal is converted into an analog signal by the D/A converter **408**. The analog signal is converted into the standard video signal **410** by the encoder **409** (Step S312). The thus-obtained image is supplied to the EVF **411** and to the recording device (Steps S313 and S314).

There is a great possibility that a temporally varying foreign object which is contained in image information outside of the electronic-zoom frame may enter the electronic-zoom frame. Also, if such a temporally varying foreign object enters the electronic-zoom frame, it will affect the movement of a target object within the electronic-zoom frame. Accordingly, during the image reducing processing of Step S309, it is also preferable to detect the temporally varying foreign object, as by selecting temporally immediately previous information and making a comparison. In this case, after the photographer has been informed of the detected portion, as by blinking or a variation in color, the process may proceed to Step S310.

According to the eleventh embodiment, the image pickup apparatus is provided with means for enlarging an image, means for reducing an image and means for combining image signals processed by the respective means, and is arranged so that a photographer can perform photography while confirming, in the EVF **411**, image information outside of the electronic-zoom frame during the operation of the electronic-zoom function. Accordingly, it is possible to realize electronic-zoom photography capable of expanding an photographic opportunity, and the photographer can securely use the electronic zoom.

FIG. **57** is a block diagram showing the circuit arrangement of an image pickup apparatus according to a twelfth embodiment of the present invention.

The arrangement shown in FIG. **17** includes a photographic lens **421** which is formed as a lens assembly provided with a variator lens **422**, a CCD **423** which is an image sensor for performing photoelectric conversion of an object image passing through the photographic lens **421**, an analog signal processing circuit **424** for processing an analog signal supplied from the CCD **423**, an A/D converter **425** for converting an analog signal supplied from the analog signal processing circuit **424** into a digital signal, a digital signal processing circuit **426** for processing an input digital signal, and an image memory **427** for temporarily storing, as image data, a signal supplied from the digital signal processing circuit **426**.

An electronic-zoom circuit **428** is controlled by an electronic-zoom controller **430**, and has the function of cutting out a predetermined area (image frame) from the image data memorized in the image memory **427** and enlarging the image data contained in the predetermined area up to the full size of an image plane. The electronic-zoom circuit **428** also has the function of outputting the memorized image data from the image memory **427** without performing an enlarging operation.

A D/A converter **429** converts the digital signal from the electronic-zoom circuit **428** into an analog signal, and outputs the analog signal to an electronic viewfinder (EVF) (not shown) and to a recording device (not shown).

A system controller **436** controls the analog signal processing circuit **424**, the A/D converter **425**, the digital signal processing circuit **426** and the image memory **427**. Further, the system controller **436** detects the state of a zoom switch **433** and the state of a zoom speed switch **434** and controls a zoom driving circuit **432** to cause the variator lens **422** to move in the direction of the optical axis thereof, thereby executing optical zooming. Also, the system controller **436** detects the state of an electronic-zoom switch **435**. If the electronic-zoom switch **435** is off, the system controller **436** does not execute electronic zooming, whereas if the electronic-zoom switch **435** is on, the system controller **436** controls the electronic-zoom controller **430** in accordance with the respective states of a zoom encoder **431**, the zoom switch **433** and the zoom speed switch **434**, thereby executing electronic zooming according to each individual condition.

FIG. **58** is a flowchart showing the operation of the image pickup apparatus having the above-described arrangement.

First, an image is inputted to the CCD **423** through the photographic lens **421** (Step S401), and the electrical signal formed by photoelectric conversion in the CCD **423** is processed by the analog signal processing circuit **424** (Step S402). The signal outputted from the analog signal processing circuit **424** is converted into a digital signal by the A/D converter **425** (Step S403). The digital signal is processed by the digital signal processing circuit **426** (step S404), and the resultant digital signal is memorized in the image memory **427** (Step S405).

In Step S406, it is checked whether the electronic-zoom switch **435** is on or off. If the electronic-zoom switch **435** is off, the process proceeds to Step S419, in which no electronic zooming is performed and the image data memorized in the image memory **427** in Step S405 is immediately converted into an analog signal by the D/A converter **429**. The image data is outputted to the electronic viewfinder (EVF) (not shown) and to the recording device (not shown).

On the other hand, if it is determined in Step S406 that the electronic-zoom switch **435** is on, the process proceeds to Step S407. In Step S407, it is checked whether the electronic zoom is in its operative state, by making reference to the state of an electronic-zoom operation flag. If the electronic zoom is in the operative state, the process proceeds to Step S411. If the electronic zoom is not in the operative state, the process proceeds to Step S408, in which it is determined whether the zoom position (the position of the variator lens **422**) is a telephoto end, through the zoom encoder **431**. If the current zoom position is not the telephoto end, the process proceeds to Step S419, in which the image data memorized in the image memory **427** in Step S405 is converted into an analog signal by the D/A converter **429**. The image data is outputted to the electronic viewfinder (EVF) (not shown) and to the recording device (not shown). On the other hand, if it is determined in Step S408 that the current zoom position is the telephoto end, the process proceeds to Step S409, in which it is checked whether the zoom switch **433** is operated so that further driving toward the telephoto side can be executed. If the zoom switch **433** is not operated so that further driving toward the telephoto side can be

executed, the process proceeds to Step **S419**, in which, as described above, the image data memorized in the image memory **427** in Step **S405** is converted into an analog signal by the D/A converter **429**. The image data is outputted to the electronic viewfinder (EVF) (not shown) and to the recording device (not shown). If the zoom switch **433** is operated so that further driving toward the telephoto side can be executed, the process proceeds to Step **S410**, in which the electronic-zoom operation flag is set.

Then, in Step **S411**, it is determined whether the zoom switch **433** has been pressed. If the zoom switch **433** has not been pressed, the process proceeds to Step **S418**, in which electronic zooming is executed at the same enlargement ratio as the previous one. If the zoom switch **433** has been pressed, the process proceeds to Step **S412**, in which it is checked whether the zoom switch **433** is operated so that driving toward the telephoto side can be executed or so that driving toward the wide-angle side can be executed. If the zoom switch **433** has been pressed so that driving toward the telephoto side can be executed, the process proceeds to Step **S413**, in which it is determined whether the power of electronic zooming at that time is not less than a predetermined power α. If the power of electronic zooming at that time is not less than the predetermined power α, the process proceeds to Step **S418**, in which the enlargement ratio is set to an enlargement ratio corresponding to the electronic-zooming power α.

If the zoom switch **433** has been pressed so that driving toward the wide-angle side can be executed, the process proceeds to Step **S414**, in which it is determined whether the power of electronic zooming at that time is not greater than "1". If the power of electronic zooming at that time is not greater than "1", the process proceeds to Step **S420**, in which the electronic-zoom operation flag is reset. Then, the process proceeds to Step **S419**.

If it is determined in Step **S413** that the electronic-zoom power is less than α, or if it is determined in Step **S414** that the electronic-zoom power exceeds "1", the process proceeds to Step **S415**. In Step **S415**, the state of the zoom speed switch **434** is checked to determine which of a high speed V_H and a lower speed V_L has been selected as the zoom speed. If the high speed V_H has been selected as the zoom speed, the process proceeds to Step **S416**, in which the speed of electronic zooming (power varying) is increased. If the zoom speed switch **434** is set for the low speed V_L, the process proceeds to Step **S417**, in which the speed of electronic zooming (power varying) is decreased.

Then, the process proceeds to Step **S419** from any of Steps **S416**, **S417**, **S418** and **S420** to Step **S419**, in which the electronically zoomed image is converted into an analog signal by the D/A converter **429**. The analog signal is outputted to the electronic viewfinder (EVF) (not shown) and to the recording device (not shown).

The (power-varying) speed of the electronic zoom can be varied by changing the rate of variation of an image cutting frame, as shown in FIGS. **59**(*a*) and **59**(*b*). That is, it is possible to increase the power-varying speed of the electronic zoom by increasing the rate of variation of the image cutting frame (refer to FIG. **59**(*a*)), while it is possible to decrease the power-varying speed of the electronic zoom by increasing the rate of variation of the image cutting frame (refer to FIG. **59**(*b*)), it is possible to increase the power-varying speed of the electronic zoom.

In the twelfth embodiment, although two different optical-zoom speeds are used, n optical-zoom speeds may be employed. If n optical-zoom speeds are employed, n electronic-zoom speeds may be prepared or the number of electronic-zoom speeds may be set to n/2, n/3 and so on.

According to the above-described twelfth embodiment, the image pickup apparatus is provided with a function which causes the zoom speed of the electronic zoom to vary according to the driving speed of the optical zoom which is variable in two or more steps in zoom speed. Accordingly, it is possible to smoothly vary the angle of view during a switching from the optical zoom to the electronic zoom or during a switching from the electronic zoom to the optical zoom.

As described above, according to the above-described eleventh embodiment, the image pickup apparatus is provided with image reducing means for electronically reducing to a predetermined size an image for one image plane formed by an image signal supplied from signal processing means, and image combining means for combining the image reduced by the image reducing means with a portion of an image enlarged by electronic-zoom means and outputting a combined image to display means, so that an original image plane which is not electronically zoomed is displayed at real time in the form of a subsidiary image plane on a portion of an image enlarged by electronic zooming.

Accordingly, the eleventh embodiment makes it possible for a photographer to confirm image information outside of the electronic-zoom frame during electronic zooming. Accordingly, it is possible to realize electronic-zoom photography capable of expanding an photographic opportunity, and the photographer can securely use the electronic zoom.

According to the twelfth embodiment, the image pickup apparatus is provided with electronic-zoom speed setting means for varying, if the optical zoom is switched to the electronic zoom, the zoom speed of the electronic-zoom means in accordance with a zoom speed detected by state-of-optical-zoom detecting means, so that the electronic-zoom speed can be varied according to the driving speed of the optical zoom which can be varied in zoom speed.

Accordingly, it is possible to smoothly vary the angle of view during a switching from the optical zoom to the electronic zoom or during a switching from the electronic zoom to the optical zoom.

FIG. **60** is a block diagram showing the circuit arrangement and the optical system of a camera having a zoom function according to a thirteenth embodiment of the present invention.

The arrangement shown in FIG. **60** includes a power varying optical system **501** whose focal length is variable, an image sensor **502** such as a CCD, focal-length converting means **503**, such as a wide-angle attachment, for discontinuously converting the focal length, power varying means **504** having the function of continuously varying the focal length of the power varying optical system **501**, an A/D conversion circuit **505** for converting an analog signal into a digital signal, a line memory **506**, an interpolation circuit **507**, a video signal processing circuit **508**, an address generating circuit **509** for generating a readout address, and a control circuit **510** for controlling the focal-length converting means **503**, the power varying means **504**, the address generating circuit **509** and other associated elements.

In the above-described arrangement, a signal from the image sensor **502** is converted into a digital signal by the A/D conversion circuit **505**, and the digital signal is stored in the line memory **506**.

If a portion of an image plane is to be cut out and used in an enlarged state, i.e., if so-called electronic zooming is to be performed, the address generating circuit **509** generates an address information signal for reading out a required area in accordance with a signal outputted from the control circuit **510**.

On the basis of the address information, the information memorized in a required portion of the line memory **506** is outputted to the interpolation circuit **507**, in which the information is subjected to appropriate interpolation. The output of the interpolation circuit **507** is converted into a video signal by the video signal processing circuit **508**, and the video signal is suppled to a recording system (not shown).

FIG. **61** is a flowchart showing the operation of the camera during zooming from its telephoto end to its wide-angle side (its ultra-wide-angle end). Such an operation will be described below with reference to the flowchart of FIG. **61**.

Ordinary zooming is performed by the power varying means **504** until the power varying optical system **501** reaches the wide-angle end (Steps S**501**→S**502**→S**501**). When the power varying optical system **501** reaches the wide-angle end, the focal length is discontinuously and instantaneously varied from the wide-angle end toward a far wider-angle side (the ultra-wide-angle side) by the focal-length converting means **503** (Step S**503**). As means for instantaneously varying the focal length, a wide-angle attachment may be inserted before the front face of the power varying optical system **501** or an arrangement for moving a part different from an ordinary power varying part may also be adopted.

In Step S**503**, if nothing but the above-described processing is done, the angle of view will vary discontinuously.

For this reason, at the same time, the electronic zoom is instantaneously operated so that the angle of view of the electronic zoom is made equal to the angle of view at the wide-angle end (steps S**504**→S**505**→S**506**). Accordingly, it is possible to prevent discontinuity from occurring in the variation of the angle of view during zooming.

In practice, however, since a slight time is required to vary the focal length from the wide-angle end to the ultra-wide-angle end, there is the problem that an image is disturbed during this time. To solve the problem, it is desirable that, during the predetermined time required to vary the focal length, an image obtained before the variation of the focal length be held in a memory and the output of the memory be used as an image representative of the variation of the angle of view.

By performing zooming from the wide-angle end toward the ultra-wide-angle end by means of the electronic zoom, it is possible to vary continuously the angle of view from the wide-angle end to the ultra-wide-angle end.

On the other hand, if zooming from the ultra-wide-angle side to the wide-angle side is to be performed, zooming from the ultra-wide-angle end to the angle of view equivalent to the wide-angle end is performed by using the electronic zoom. When the wide-angle end is reached, the electronic zoom is switched to optical zooming based on the power varying optical system **501** and the electronic zoom is cancelled. Subsequently, the optical zooming toward the telephoto end is performed by the power varying means **504**.

As is apparent from the above description, by effectively combining focal length converting means capable of discontinuously varying a focal length with an electronic-zoom function, it is possible to achieve a field-of-view varying effect equivalent to the effect of the variable angle of view of a zoom lens which can optically zoom up to an ultra-wide-angle range. Accordingly, a user can smoothly perform photography even during zooming between the wide-angle end and the ultra-wide-angle side.

FIG. **62** is a block diagram showing the circuit arrangement and the optical system of a camera having a zoom function according to a fourteenth embodiment of the present invention. In FIG. **62**, the same reference numerals are used to denote parts which are identical to those shown in FIG. **60**.

The arrangement shown in FIG. **62** includes a second optical system **511** having a focal length shorter than the focal length of the power varying optical system **501** which is set to the wide-angle end, and signal selecting means **512** for selecting either one of the output signals of the two optical systems **501** and **511** as a signal to be processed.

If a user selects zooming from the wide-angle end toward a far wider-angle side during the use of the power varying optical system **501**, the output of the second optical system **511** is selected by the signal selecting means **512**.

However, this output is not a signal output indicative of the whole of the scene photographed by the second optical system **511**, but is a signal output which has been electronically zoomed up to a size which is equivalent to the size of a video image which is provided by the power varying optical system **501** at the wide-angle end thereof.

If zooming toward a far wider-angle side is be performed, the power of the electronic zoom may be progressively decreased.

On the other hand, if zooming from the ultra-wide-angle side toward the telephoto side is to be performed, the electronic zoom is used to perform zooming from the ultra-wide-angle side up to an angle of view equivalent to that of the second optical system **511** at the wide-angle end. When the angle of view equivalent to that of the second optical system **511** at the wide-angle end is reached, the electronic zoom is switched to the power varying optical system **501** so that optical zooming up to the telephoto end can be continuously performed by the power varying means **504**.

As is apparent from the above description, by effectively combining two optical systems having discontinuously different focal lengths with an electronic-zoom function, it is possible to continuously vary the angle of view between the ultra-wide-angle side and the telephoto side. Accordingly, the user can smoothly perform photography even during zooming between the wide-angle end and the ultra-wide-angle side.

Of course, it is also possible to adopt an arrangement capable of performing zooming from the telephoto end toward an ultra-telephoto side by means of the electronic zoom.

It is to be noted that, in the above-described fourteenth embodiments, it is necessary to satisfy the following expression:

$$1/\beta \leqq z \tag{11}$$

where $\beta(<1)$ represents the ratio of the focal length of the power varying optical system **501** at the wide-angle end thereof to the focal length of the second optical system **511** at the wide-angle end thereof or the magnification required for conversion between the focal lengths of the two optical systems **501** and **511**, and $Z(>1)$ represents the power of the electronic zoom.

If the power of the electronic zoom is smaller than the lower limit of the expression (11), it is impossible to continuously vary the angle of view even with the electronic zoom.

As is apparent from the above description, according to the thirteenth embodiment, there is provided an arrangement which is provided with control means for causing, if zooming from the wide-angle end of a power varying optical system toward a far wider-angle side is specified, focal

length varying means to function to set a focal length to an ultra-wide-angle side and, at the same time, causing electronic-zoom means to operate to vary the power of an electronic zoom continuously up to the ultra-wide-angle side in the state of keeping the size of an output image equal to that of an image obtainable from the power varying optical system. The electronic-zoom means is combined with means for varying discontinuously and instantaneously the focal length from the wide-angle end toward a far wider-angle side (ultra-wide-angle side), so that zooming between a telephoto end and the ultra-wide-angle side can be continuously performed.

According to the fourteenth embodiment, there is provided an arrangement which is provided with control means for selecting, if zooming toward a far wider-angle side from the wide-angle end of a first optical system having a power varying function is specified, an image obtained from a second optical system having a focal length shorter than the focal length of the first optical system at the wide-angle end thereof and, at the same time, causing electronic-zoom means to operate to vary the power of an electronic zoom continuously up to the ultra-wide-angle side in the state of keeping the size of an output image equal to that of an image obtainable from the first optical system. The electronic-zoom means is combined with a second optical system having a focal length shorter than the focal length of the first optical system at the wide-angle end thereof, so that zooming between a telephoto end and the ultra-wide-angle side can be continuously performed.

Accordingly, it is possible to continuously vary the angle of view between the wide-angle end and the ultra-wide-angle side, so that the user can smoothly perform photography even during zooming between the wide-angle end and the ultra-wide-angle side.

What is claimed is:

1. An image pickup apparatus comprising:

an image pickup device for generating an electrical signal from an optical image formed by a zoom lens;

aberration information memorizing means for memorizing distortional aberration information about the zoom lens;

focal length detection means for detecting a focal length of the zoom lens; and

signal processing means for processing the electrical signal based on the distortional aberration information and the focal length so as to correct distortional aberration based on a center of an image plane when the zoom lens is in a predetermined focal length zone, and to correct the distortional aberration based on an arbitrary image height when the zoom lens is not in the predetermined focal length zone.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,905,530

DATED : May 18, 1999

INVENTOR(S) : Hideo YOKOTA, et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

COLUMN 6:

Line 10, "an" (first occurrence) should read --a--.

COLUMN 12:

Line 21, "a" should read --an--.

COLUMN 13:

Line 27, "zmin" should read --Zmin--.
Line 28, "the the" should read --the--.

COLUMN 19:

Line 35, "is" should read --are--.

COLUMN 26:

Line 57, "[step S241]" should read --[Step S241]--.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,905,530

DATED : May 18, 1999

INVENTOR(S) : Hideo YOKOTA, et al. Page 2 of 2

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

COLUMN 33:

Line 45, "an" should read --a--.

Signed and Sealed this

Sixth Day of February, 2001

Attest:

Q. TODD DICKINSON

Attesting Officer

Director of Patents and Trademarks

US007590305B2

(12) **United States Patent**
Steinberg et al.

(10) **Patent No.: US 7,590,305 B2**
(45) **Date of Patent: *Sep. 15, 2009**

(54) **DIGITAL CAMERA WITH BUILT-IN LENS CALIBRATION TABLE**

(75) Inventors: **Eran Steinberg**, San Francisco, CA (US); **Yury Prilutsky**, San Mateo, CA (US); **Peter Corcoran**, Clargalway (IE); **Adrian Zamfir**, Bucuresti (RO); **Petronel Bigioi**, Galway (IE)

(73) Assignee: **FotoNation Vision Limited**, Galway (IE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 806 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **10/842,244**

(22) Filed: **May 10, 2004**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation-in-part of application No. 10/676,820, filed on Sep. 30, 2003.

(51) **Int. Cl.**
H04N 5/225 (2006.01)

(52) **U.S. Cl.** **382/275**; 348/335

(58) **Field of Classification Search** 348/335; 382/275

See application file for complete search history.

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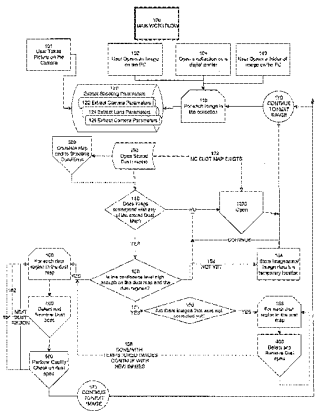
(Continued)

Primary Examiner—Charles Kim
Assistant Examiner—John W Lee
(74) *Attorney, Agent, or Firm*—Andrew V. Smith

(57) **ABSTRACT**

A digital camera that automatically corrects dust artifact regions within acquired images by compiling a dust map includes an optical system for acquiring an image with a corresponding dust calibration table for such optical system, including a lens assembly and an aperture stop, in which the corresponding dust calibration map can reside. A transformation between the dust map and the specific lens calibration table, enables the use for a single dust map in multiple instances of lenses and focal length, without the need to recalibrate the digital camera for each instance.

22 Claims, 9 Drawing Sheets



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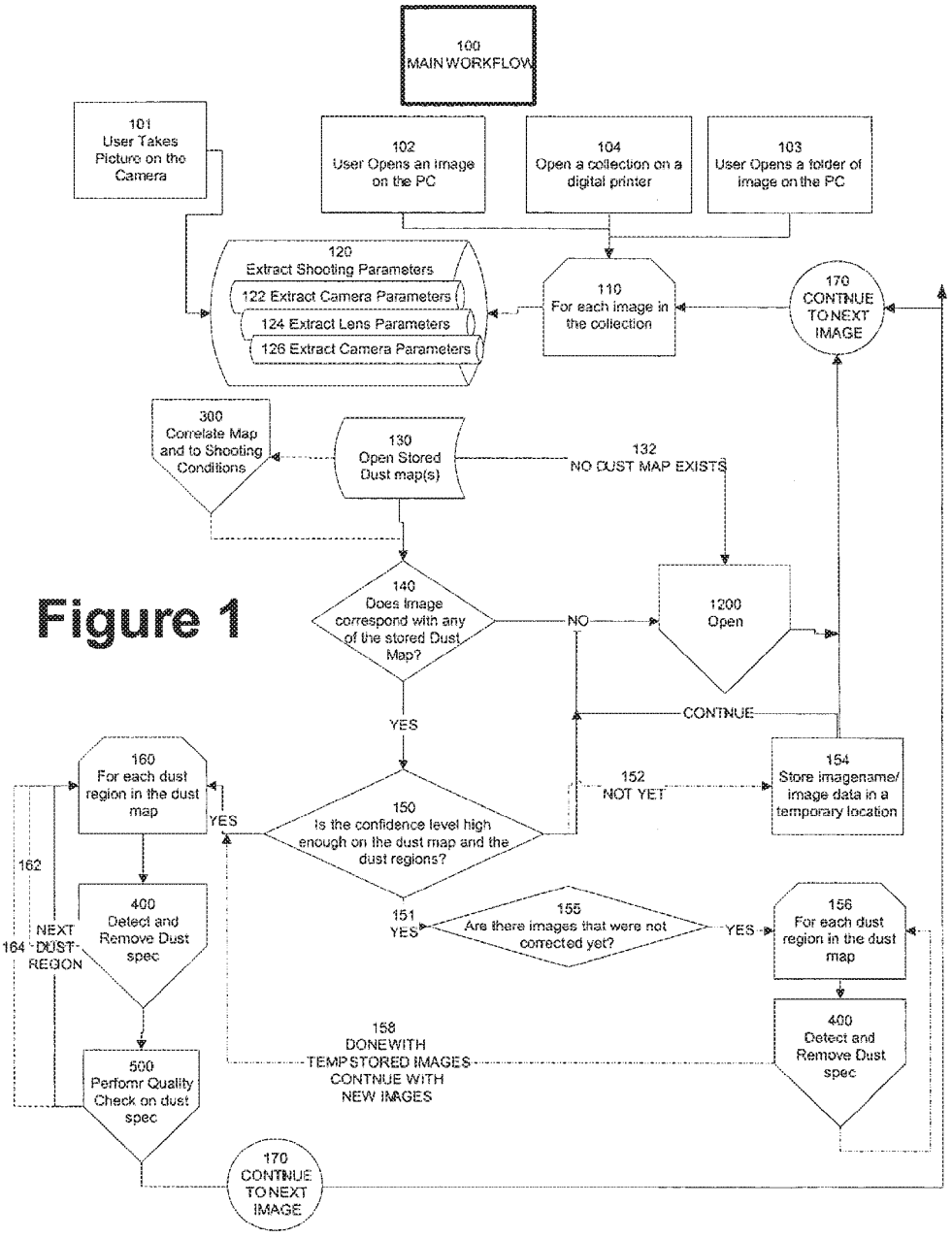

100
MAIN WORKFLOW
101
User Takes Picture on the Camera
102
User Opens an image on the PC
104
Open a collection on a digital printer
103
User Opens a folder of image on the PC
120
Extract Shooting Parameters
122 Extract Camera Parameters
124 Extract Lens Parameters
126 Extract Camera Parameters
110
For each image in the collection
170
CONTINUE TO NEXT IMAGE
300
Correlate Map and to Shooting Conditions
130
Open Stored Dust map(s)
132
NO DUST MAP EXISTS
140
Does Image correspond with any of the stored Dust Map?
NO
1200
Open
CONTINUE
YES
160
For each dust region in the dust map
YES
150
Is the confidence level high enough on the dust map and the dust regions?
152
NOT YET
154
Store imagename/ image data in a temporary location
162
NEXT DUST REGION
164
400
Detect and Remove Dust spec
151
YES
155
Are there images that were not corrected yet?
YES
156
For each dust region in the dust map
400
Detect and Remove Dust spec
158
DONE WITH TEMP STORED IMAGES
CONTNUE WITH NEW IMAGES
500
Perfomr Quality Check on dust spec
170
CONTINUE TO NEXT IMAGE

Figure 1

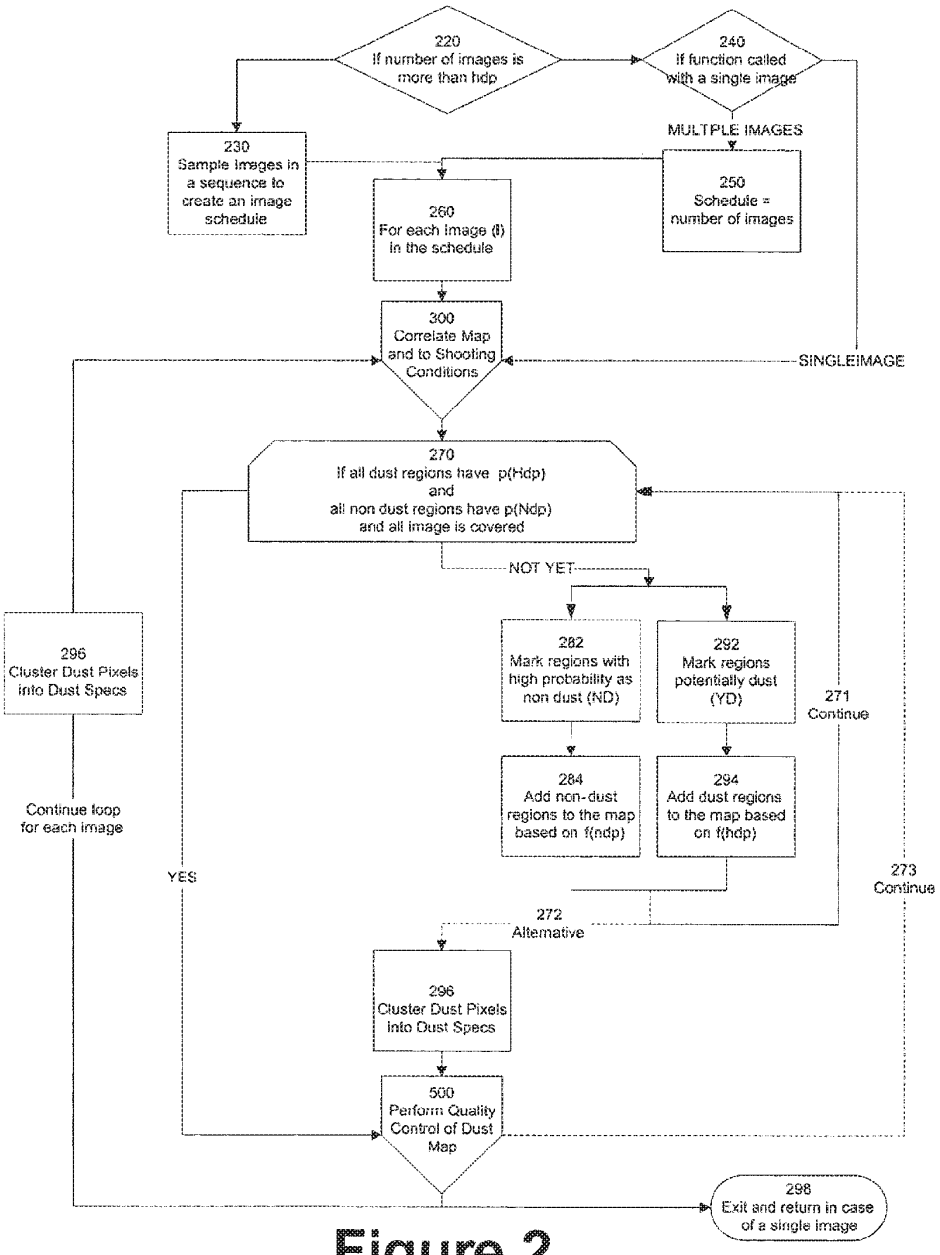

220
If number of images is more than hdp
240
If function called with a single image
MULTPLE IMAGES
230
Sample images in a sequence to create an image schedule
250
Schedule = number of images
260
For each image (i) in the schedule
300
Correlate Map and to Shooting Conditions
SINGLEIMAGE
270
If all dust regions have p(Hdp) and all non dust regions have p(Ndp) and all image is covered
NOT YET
282
Mark regions with high probability as non dust (ND)
292
Mark regions potentially dust (YD)
271
Continue
296
Cluster Dust Pixels into Dust Specs
284
Add non-dust regions to the map based on f(ndp)
294
Add dust regions to the map based on f(hdp)
Continue loop for each image
YES
273
Continue
272
Alternative
296
Cluster Dust Pixels into Dust Specs
500
Perform Quality Control of Dust Map
298
Exit and return in case of a single image

Figure 2

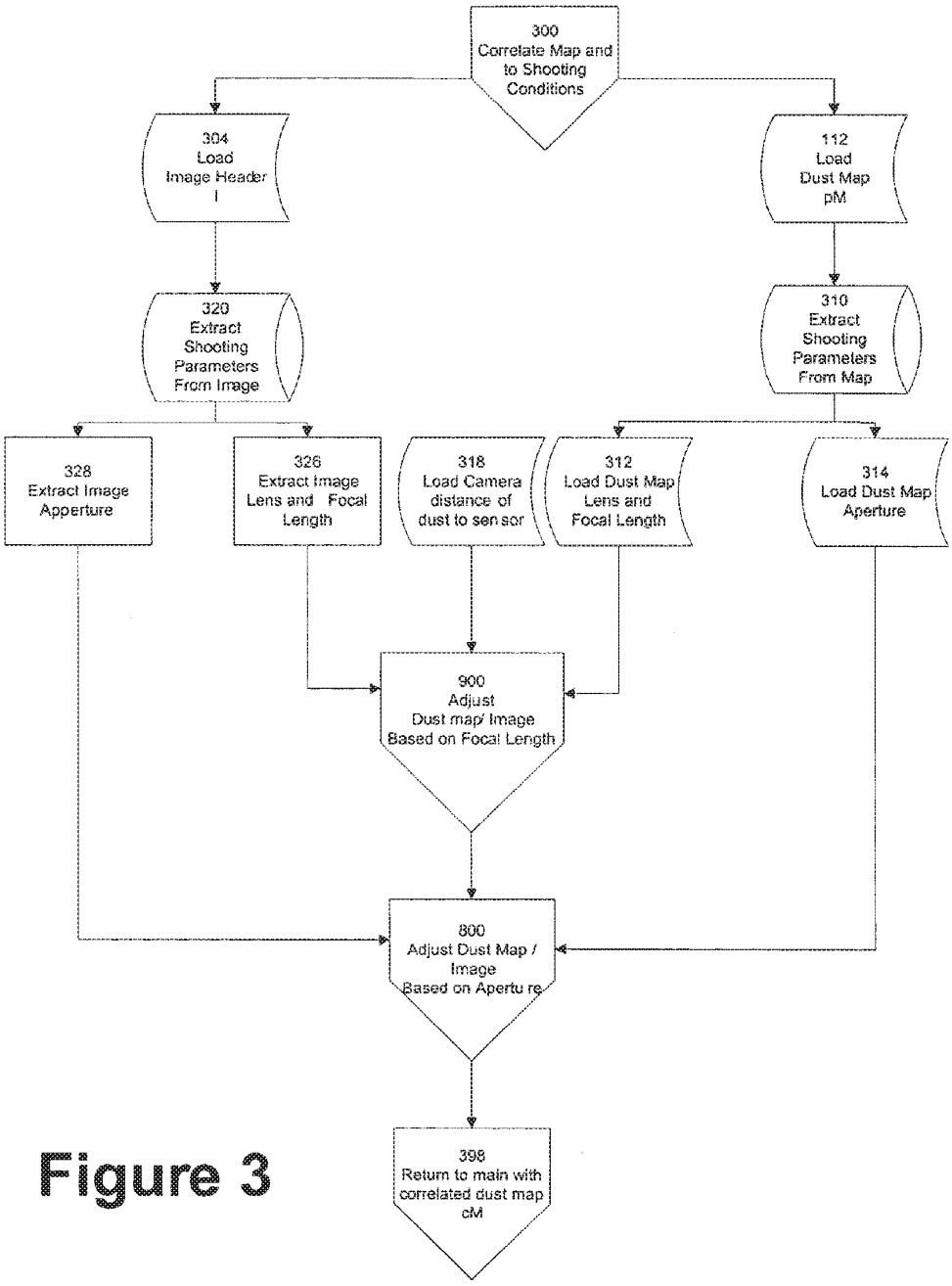

300
Correlate Map and to Shooting Conditions
304
Load Image Header I
112
Load Dust Map pM
320
Extract Shooting Parameters From Image
310
Extract Shooting Parameters From Map
328
Extract Image Apperture
326
Extract Image Lens and Focal Length
318
Load Camera distance of dust to sen sor
312
Load Dust Map Lens and Focal Length
314
Load Dust Map Aperture
900
Adjust Dust map/ Image Based on Focal Length
800
Adjust Dust Map / Image Based on Apertu re
398
Return to main with correlated dust map cM

Figure 3

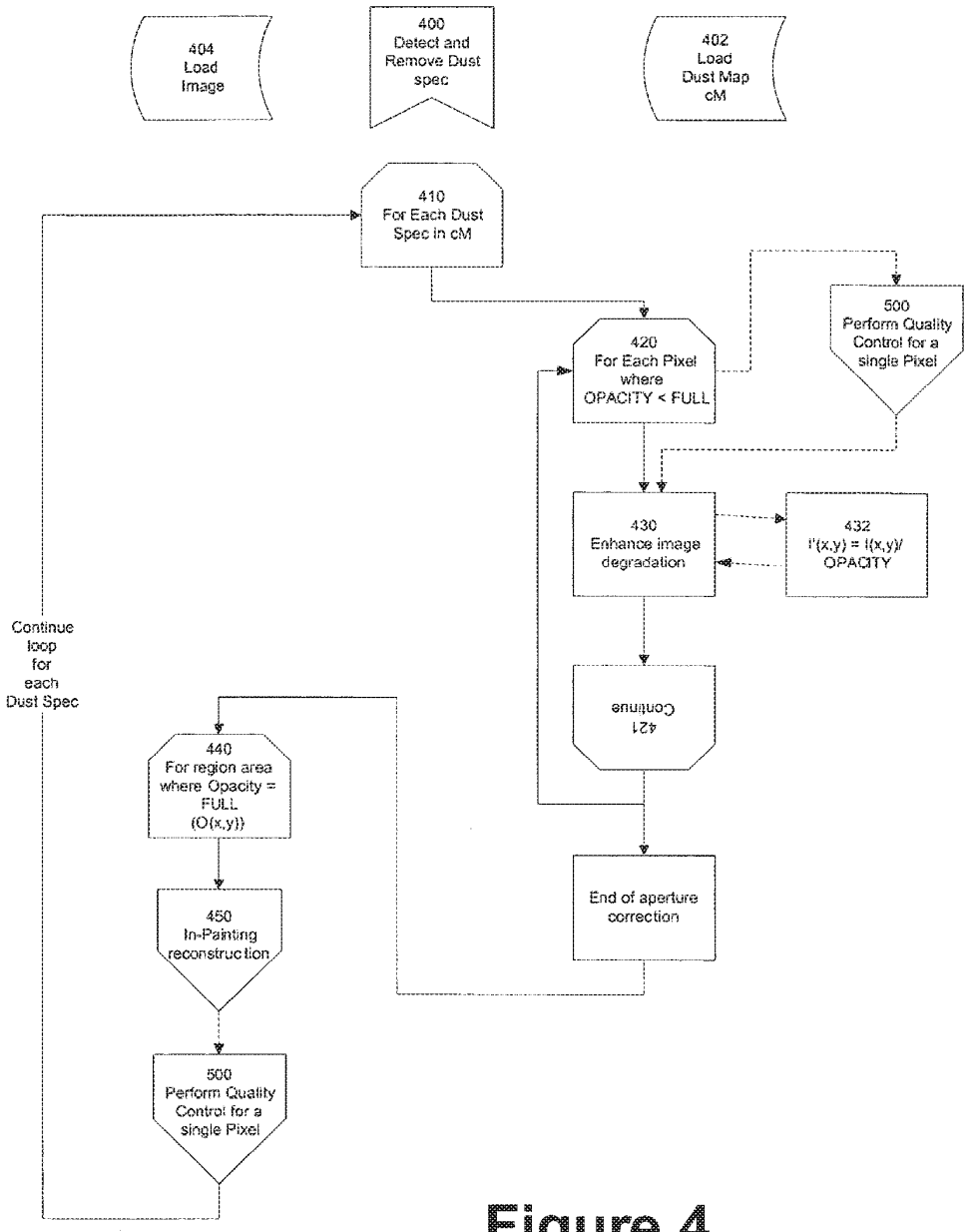

404
Load
Image
400
Detect and
Remove Dust
spec
402
Load
Dust Map
cM
410
For Each Dust
Spec in cM
500
Perform Quality
Control for a
single Pixel
420
For Each Pixel
where
OPACITY < FULL
430
Enhance image
degradation
432
I'(x,y) = I(x,y)/
OPACITY
421
Continue
Continue
loop
for
each
Dust Spec
440
For region area
where Opacity =
FULL
(O(x,y))
450
In-Painting
reconstruction
500
Perform Quality
Control for a
single Pixel
End of aperture
correction

Figure 4

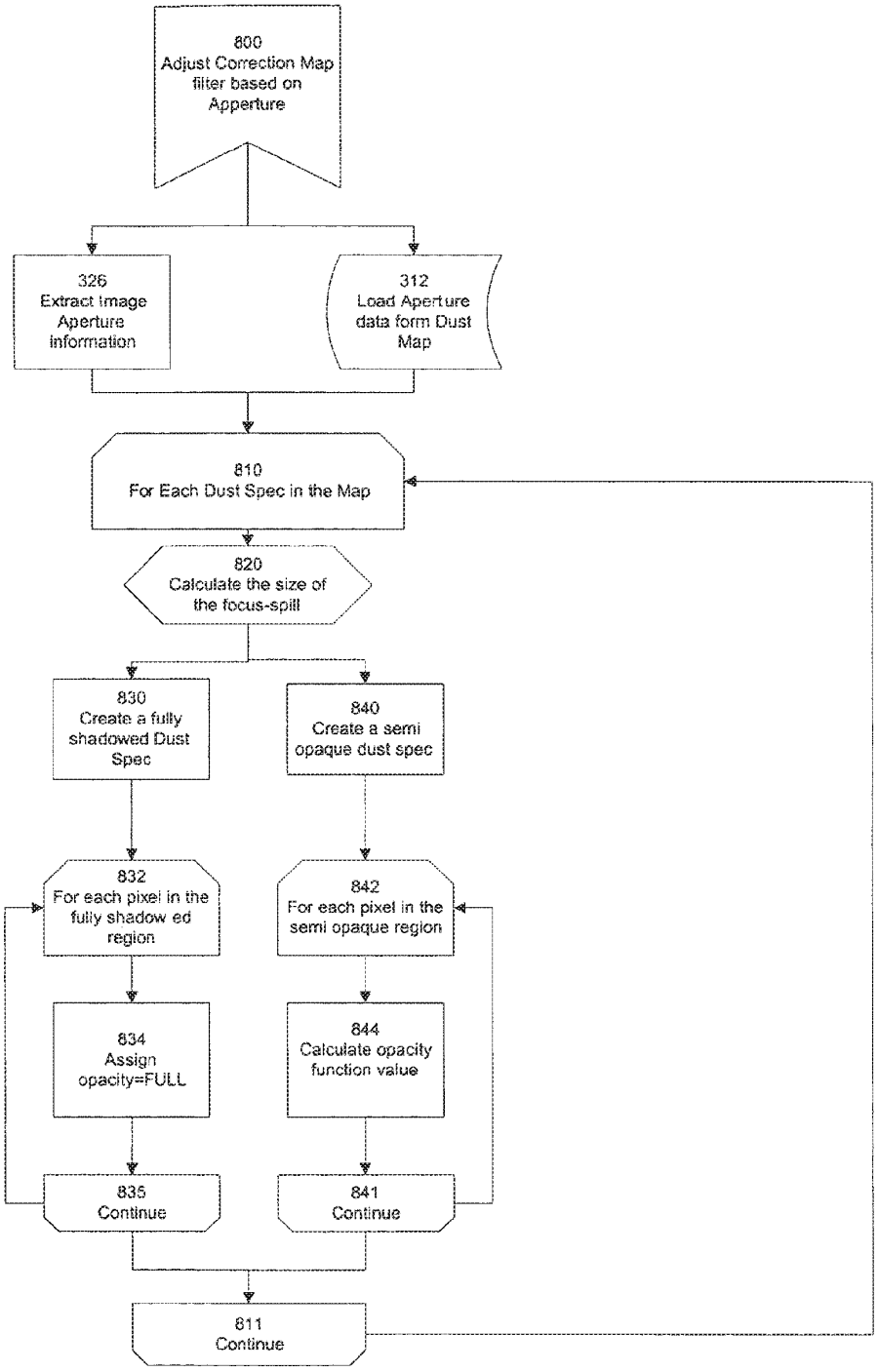

800
Adjust Correction Map filter based on Apperture
326
Extract Image Aperture Information
312
Load Aperture data form Dust Map
810
For Each Dust Spec in the Map
820
Calculate the size of the focus-spill
830
Create a fully shadowed Dust Spec
840
Create a semi opaque dust spec
832
For each pixel in the fully shadow ed region
842
For each pixel in the semi opaque region
834
Assign opacity=FULL
844
Calculate opacity function value
835
Continue
841
Continue
811
Continue

Figure 5

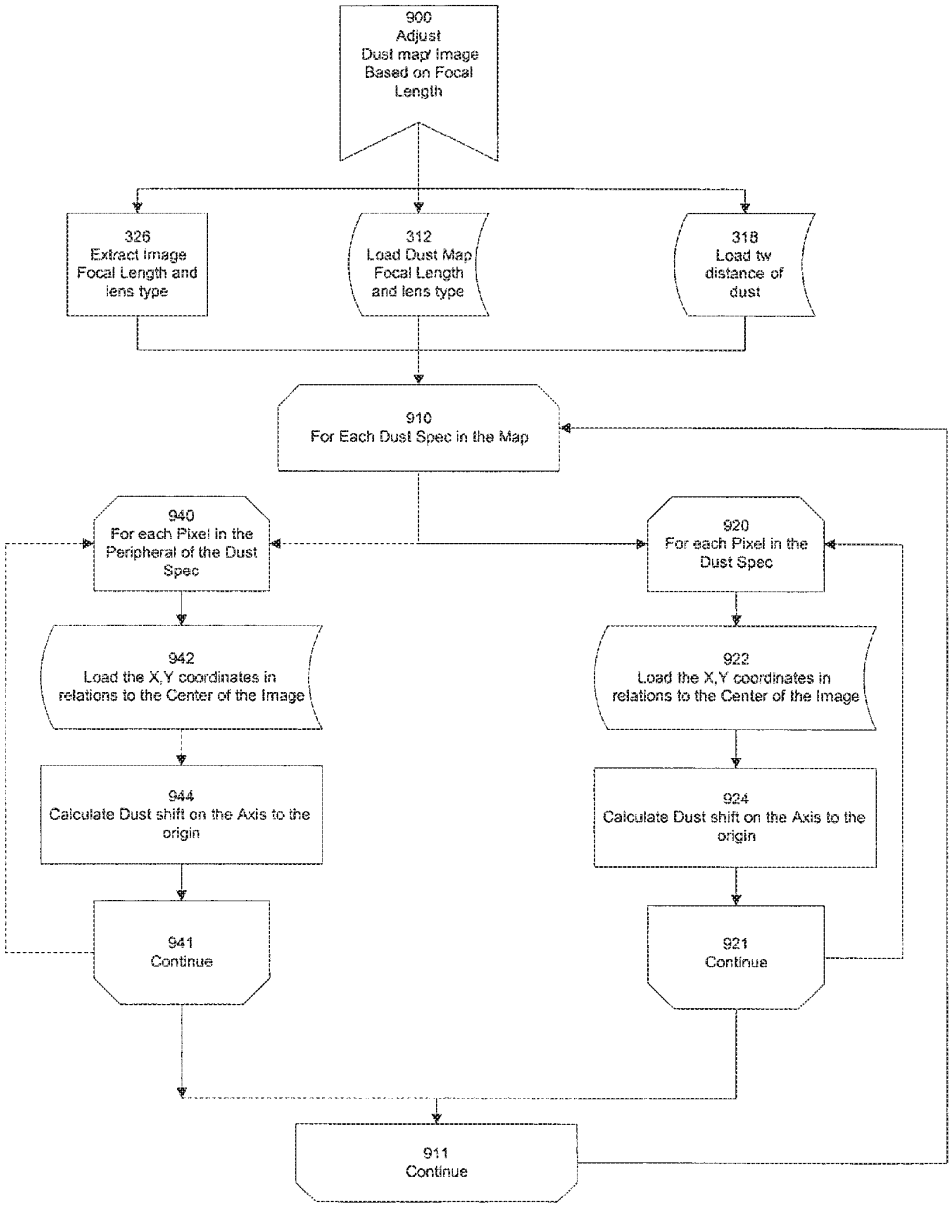

900
Adjust
Dust map image
Based on Focal
Length
326
Extract Image
Focal Length and
lens type
312
Load Dust Map
Focal Length
and lens type
318
Load tw
distance of
dust
910
For Each Dust Spec in the Map
940
For each Pixel in the
Peripheral of the Dust
Spec
920
For each Pixel in the
Dust Spec
942
Load the X,Y coordinates in
relations to the Center of the Image
922
Load the X,Y coordinates in
relations to the Center of the Image
944
Calculate Dust shift on the Axis to the
origin
924
Calculate Dust shift on the Axis to the
origin
941
Continue
921
Continue
911
Continue

Figure 6

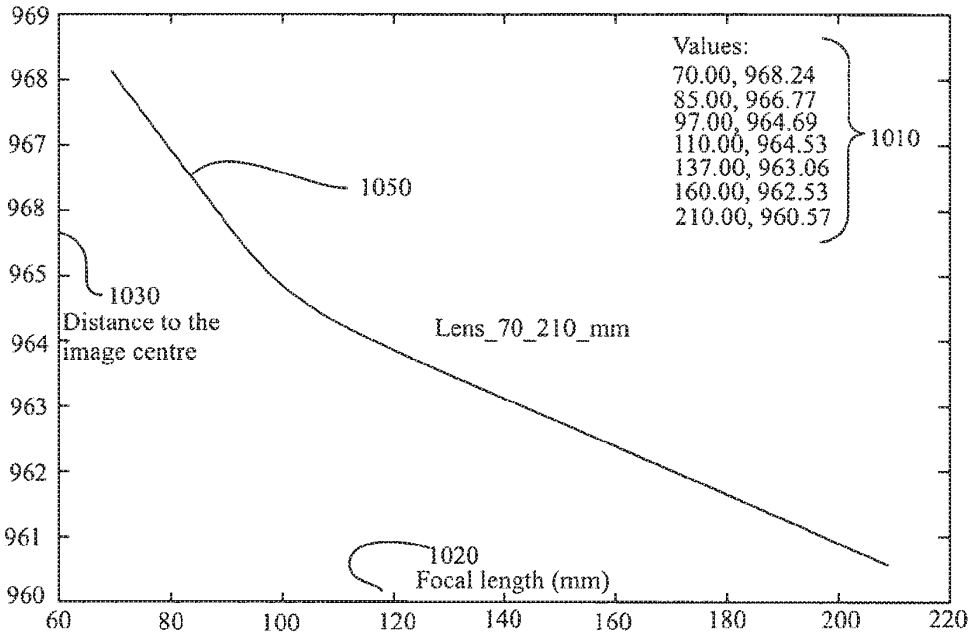

969
968
967
968
965
964
963
962
961
960
60
80
100
120
140
160
180
200
220
Values:
70.00, 968.24
85.00, 966.77
97.00, 964.69
110.00, 964.53
137.00, 963.06
160.00, 962.53
210.00, 960.57
1010
1050
1030
Distance to the image centre
Lens_70_210_mm
1020
Focal length (mm)

Figure 7

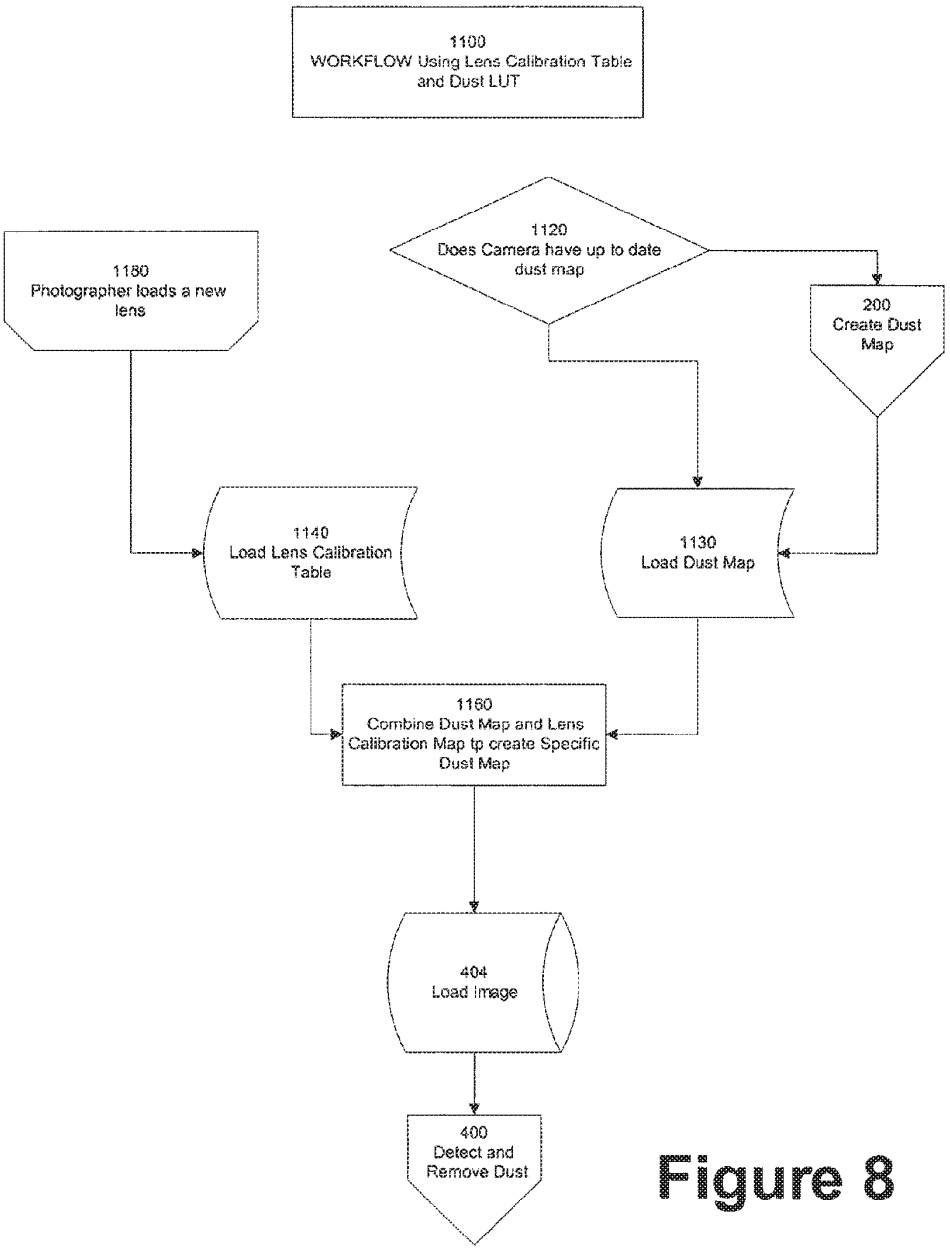

1100
WORKFLOW Using Lens Calibration Table and Dust LUT
1120
Does Camera have up to date dust map
1180
Photographer loads a new lens
200
Create Dust Map
1140
Load Lens Calibration Table
1130
Load Dust Map
1160
Combine Dust Map and Lens Calibration Map tp create Specific Dust Map
404
Load Image
400
Detect and Remove Dust

Figure 8

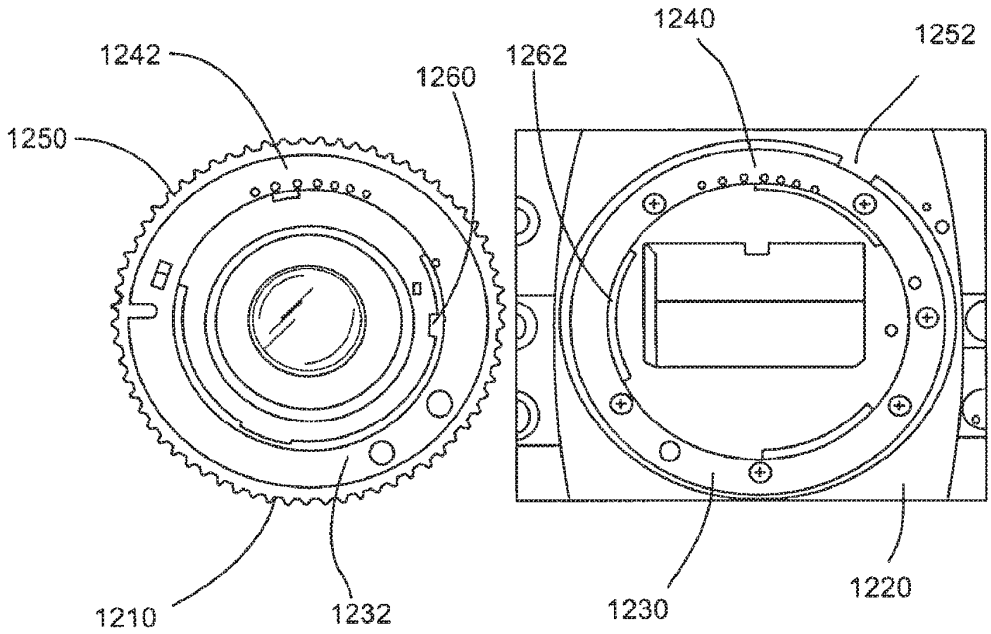


Figure 9

DIGITAL CAMERA WITH BUILT-IN LENS CALIBRATION TABLE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation in part for application Ser. No. 10/676,820, filed on Sep. 30, 2003, entitled, "Determination Of Need To Service A Camera Based On Detection of Blemishes in Digital Images", which is related to a family of patent applications filed on the same day, including U.S. application Ser. No. 10/676,823, entitled, "Automated Statistical Self-Calibrating Detection and Removal of Blemishes in Digital Images Based On Multiple Occurrences Of Dust In Images"; U.S. application Ser. No. 10/677,134, entitled, "Automated Statistical Self-Calibrating Detection and Removal of Blemishes in Digital Images Based on a Dust Map Developed From Actual Image Data"; U.S. application Ser. No. 10/677,139, entitled, "Automated Statistical Self-Calibrating Detection and Removal of Blemishes in Digital Images Dependent Upon Changes in Extracted Parameter Values"; U.S. application Ser. No. 10/677,140, entitled, "Automated Statistical Self-Calibrating Detection and Removal of Blemishes in Digital Images Based on Determining Probabilities Based On Image Analysis Of Single Images"; U.S. application Ser. No. 10/676,845, entitled, "Method Of Detecting and Correcting Dust in Digital Images Based On Aura And Shadow Region Analysis"; U.S. application Ser. No. 10/676,716, entitled, "Digital Camera"; and U.S. application Ser. No. 10/676,835, entitled, "Digital Image Acquisition And Processing System", which are all hereby incorporated by reference.

BACKGROUND

1. Field of the Invention

This invention related to digital photography and in particular, automated means of in-camera removal of blemish artifacts from images captured and digitized in a digital process.

2. Description of the Related Art

Many problems are caused by dust in particular and blemishes in general on imaging devices in general and digital imaging devices in particular. In the past, two distinct forms of image processing included providing means to detect and locate dust, scratches or similar defects and providing means to remedy the distortions caused by the defects to an image. It is desired to have an advantageous system that combines these functions, and can automatically detect and correct for the effects of dust, scratches and other optical blemishes.

Image correction has been studied in relation to display devices, output apparatuses such as printers, and digital sensors. Image correction of dust artifacts can be used to recreate missing data, also referred to as in-painting or restoration, or undoing degradation of data, which still remains in the image, also referred to as image enhancement. It is desired to have a system including a digital camera and an external device or apparatus that can facilitate a defect detection and/or correction process involving sophisticated and automated computerized programming techniques.

The manifestation of the dust in a digital image is a function of several optical parameters representing the dust. It is desired to create a system that can automatically take into account changes in such parameters without the need to manually recalibrate the camera system.

SUMMARY OF THE INVENTION

A digital camera is provided that automatically corrects dust artifact regions within acquired images by compiling a statistical dust map from multiple images acquired under different image acquisition conditions. An optical system that acquires an image includes a lens assembly and an aperture stop. The optical system may include the lens specific calibration information in the lens. An electronic sensor array is disposed approximately at an image focal plane of the optical system for collecting image data according to spectral information associated with multiple pixels that collectively correspond to the image. Digital processing electronics include a processor for converting the image data to digital data and processing the digital data according to programming instructions. A memory has programming instructions stored therein for performing a method of automatic image correction of dust defect regions.

The specific dust map can be converted between different lenses and between different focal lens setting of the same lens, using a numerical formulae. By doing so, only a single dust map needs to be maintained.

The further digitally-acquired images may include different images than the originally acquired images. The method may further include correcting pixels corresponding to correlated dust artifact regions within each of the original images based on the associated statistical dust map. The method may include correcting pixels corresponding to correlated dust artifact regions within the original images based on the associated statistical dust map. The method may include digitally-acquiring additional images with the digital camera, repeating the determining and associating, and updating the statistical dust map including updating the mapped dust regions based on the additional dust artifact determining and associating.

The image correction method may be performed on a processed image after being converted from raw format to a known red, green, blue representation. The correcting may include replacing pixels within the one or more digitally-acquired images with new pixels. The correcting may include enhancing the values of pixels within the one or more digitally-acquired images.

The dust artifact determining may include loading the statistical dust map, loading extracted parameter information of a present image, performing calculations within the statistical dust map having extracted parameter variable-dependencies, and comparing dust artifact detection data with the extracted parameter dependent statistical dust map data. The dust artifact determining may also include loading the statistical dust map, loading extracted parameter information of a present image, loading extracted parameters regarding the optical system, performing a calculation for relating the statistical dust map with the present image according to a selected value of an extracted parameter which is otherwise uncorrelated between the present image and the dust map, and comparing dust artifact detection data with the now correlated statistical dust map data. The suspected dust artifact regions of at least two images may include shadow regions and aura regions, and wherein the method may include a first comparison of the shadow regions and a second comparison of the aura regions.

The method may include digitally-acquiring further images with the digital camera, repeating the determining and associating, and updating the statistical dust map including updating the mapped dust regions based on the further dust

artifact determining and associating. The determining may include determining probabilities that certain pixels correspond to dust artifact regions within the acquired images based at least in part on a comparison of suspected dust artifact regions within two or more digitally-acquired images, or on a pixel analysis of the suspected dust artifact regions in view of predetermined characteristics indicative of the presence of a dust artifact region, or both. The determining may be based at least in part on a comparison of suspected dust artifact regions within two or more digitally-acquired images.

The correcting may further include replacing the pixels within the one or more digitally-acquired images with new pixels. The correcting may include enhancing the values of pixels within the one or more digitally-acquired images.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a main workflow of a dust removal process in accordance with a preferred embodiment.

FIG. **2** illustrates the creation of a dust map.

FIG. **3** outlines a correlation of a dust map to image shooting parameters.

FIG. **4** illustrates a procedure for detecting and removing dust from images in accordance with a preferred embodiment.

FIG. **5** illustrates an adjustment of the dust map based on aperture.

FIG. **6** illustrates an adjustment of a dust map based on focal length.

FIG. **7** illustrates the plot describing a the dust movement as a function of a lookup table for a hypothetical map.

FIG. **8** describes the workflow of correcting and detecting the dust images based on a lens lookup table and a dust map.

FIG. **9** schematically illustrates coupling components of a lens assembly with a housing of a digital image acquisition device.

BRIEF DESCRIPTION OF TABLES

Table 1 lists potential Extracted Lens Parameters.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Some Definitions

Dust specs: The preferred embodiment takes advantage of the fact that many images may have repetitive manifestation of the same defects such as dust, dead-pixels, burnt pixels, scratches etc. Collectively, for this specifications all possible defects of this nature are referred to in this application as dust-specs or dust defects. The effects of those dust specs on digital images are referred to herein as dust artifacts.

Acquisition device: the acquisition device may be a a multi-functional electronic appliance wherein one of the major functional capabilities of the appliance is that of a digital camera. Examples can be include digital camera, a hand held computer with an imaging sensor, a scanner, a hand-set phone, or another digital device with built in optics capable of acquiring images. Acquisition devices can also include film scanners with a area-capture CCDs, as contrasted, e.g., with a line scan mechanism. D-SLR: Digital Single Lens Reflex Camera. A digital camera where the viewfinder is receiving the image from the same optical system as the sensor does. Many D-SLR, as for SLR cameras have the capability to interchange its lenses, this exposing the inner regions of the camera to dust.

A few parameters are defined as part of the process:

N Number of images in a collection.

HIdp Number of images for occurrence to be high dust probability

HSdp Number of recurring specs for label a region to be high dust probability

p(hsdp) Probability threshold for high confidence of a dust spec.

N dp Number of images to determine that a region is not dust

p(ndp) Probability threshold to determine that a region is not a dust region.

Most likely HIdp<=HSdp

I—is a generic image

I(x,y) pixel in location x horizontal, y vertical of Image I

pM is a continuous tone, or a statistical representation of a dust map

dM is a binary dust map created form some thresholding of pM.

Mathematical Modeling of the Optical System

Prior to understanding the preferred embodiments described herein, it is helpful to understand the mathematical modeling of the camera optical system. This model is defined in application No. 10/676,820 filed on Sep. 30, 2003, which is incorporated by reference. With this modeling, the preferred embodiments may advantageously utilize a single dust map for dust detection and/or correction techniques rather than creating a dust map for each instance of dust artifact having its own shape and opacity depending on extracted parameters relating to the imaging acquisition process. With an ability to model the optical system and its variability, a single map may suffice for each lens or for multiple lenses. and for multiple focal lengths, multiple apertures, and/or other extracted parameters as described in more detail below. This information, which is typical to a lens and a camera combination may be stored in an external application, in the camera processing memory and or inside the lens.

The main workflow of detecting and removing the dust from an image is illustrated in FIG. **1**. The preferred embodiment is activated in four different cases. In general, this preferred embodiment works for removing dust form a collection of images having the same acquisition device. Specifically, a user may acquire a picture on her digital camera (as illustrated in Block **101**). Alternatively (**102**), a user may open a single image on a external device such as a personal computer, open (**103**) a folder of images on an external device or open a collection of images on a digital printing device (**104**).

The preferred embodiment then extracts the shooting parameters (**120**). Such parameters include, but not limited to data about: the generic device parameters such as Camera parameters (**122**) such as Camera name, Model, and conversion data specific for the camera, Lens parameters (**124**) such as Lens brand, lens type, lens focal length, and lens calibration tables; as well as parameters specific to the image (**126**) such as focal length at acquisition, aperture range, aperture at acquisition.

In addition, some parameter, in particular on the lens (**126**) and the camera (**124**) may be also stored in the device, which is the acquisition device such as the digital camera or the processing device such as the personal computer or digital printer. Such information, which may include parameters such as exit pupil, exit pupil distance regarding the lens, or distance of dust to sensor for the camera. Currently lenses store some data in the lens which can communicate this information to the camera processor. In one embodiment of

this invention the specific lens calibration tables can may be stored as part of the lens assembly. By doing so, the introduction of new lenses to the market may automatically be supported with the shipping lenses.

A table with such data may look like:

TABLE 1

Extracted Lens Parameters

Field	Example of data	Category
Lens Manufacturer	Nikon	lens
Lens Type	AF 24 mm-45 mm f2.8-f3.5	lens
Focal Length	38 mm	Acquisition data
Aperture	f-16	Acquisition data
Dust distance	0.156 mm	Camera data
Exit pupil	19 mm	Lens data
Exit pupil distance	230 mm	Lens data

Alternatively, the information may be related to the resulting dust shift, as opposed to the theoretical parameters such as an exit pupil, of which the shift is calculated. Such can be in a form of a lookup table or a analytical formulae.

FIG. **7** describes the graph created by such an analytical formulae or a lookup table describing the dust movement as a function of the focal length for a specific hypothetical lens. This plot describes a 70-210 mm zoom lens (**1000**). The interpolated values based on measured 7 points **1010**. The X-axis, **1020** defines the focal length in mm of the lens. The plot describes a dust spot in a distance of roughly 960-970 away from the optical center of the lens, as illustrated in the Y-axis, **1030**. As can be seen, the dust shifts as a function of the focal length. This extrapolated empirical result, **1050**, corroborates the analytical explanation provided in FIG. **6**. It is important to note that the plot may and is different based on the actual lens configuration and is neither predictable by the mere focal length nor is monotonicity guaranteed.

The dust map may also include meta-data that are different the list of extracted parameters. Moreover, that which is described as being extracted parameter dependent or encoded with extracted parameter value data or based on a value of an extracted parameter can be broadened to include other meta-data than just the extracted parameters listed in Table 1. For example, certain meta-data are dependent on parameters existing at the time of acquisition of the image, and can be camera-specific or not. The amount of ambient light available will depend on whether there is artificial lighting nearby or whether it is a cloudy day. Discussion of meta-data as it relates to image acquisition is found in more detail at U.S. patent application Ser. No. 10/608,810, filed Jun. 26, 2003, and is hereby incorporated by reference.

In the case that the system deals with multiple images (as defined in **102**, **103**, and **104**), the algorithm describes a loop operation on all images (**110**). The first step is to open a dust map (**130**). If non exists (**132**) the system will create a new dust map (**200**) as further described in FIG. **2**. In the case that the system has a few dust maps (**130**) the software will try to correlate one of the maps (**300**) to the image. This process is further illustrated in FIG. **3**. In particular this correlation refers to the adjustment of the shooting conditions to some accepted standard. The acquisition conditions in particular refer to the aperture and the focal length. The correlation process is interchangeable and can be done by adjusting the image to the map or adjusting the map to the image. In some cases both acquired image and dust map should be adjusted to some common ground. Such an example may happen when the ma is calculated based on a aperture that the lens does not reach or a different lens than the one used wit different optical configuration. Alternatively, such as in the case of a new lens, this process (**300**) as called by **130**, may be used to adjust the map onto a new map and from that stage onwards continue with a single map.

If no dust map corresponds with the image (**140**), a new dust map is created (**200**). When a dust map does correspond (**140**) to the image, the preferred embodiment checks if the dust specs as defined in the dust map are of high enough confidence level to being dust regions (**150**). The statistical decision as to the way such confidence level is calculated for the dust map in general and for the individual dust specs, is further discussed with reference to FIG. **2** and FIG. **3**. If the confidence level is low, the image is added to the updating of the dust map (**200**). If after the image is added, the confidence level is high enough (**152**) the software continues to the dust removal process (**160**). Otherwise, the software progresses to the next image (**170**).

For example, a dust map is considered valid after 10 images are analyzed, and a dust spec is considered valid after a dust is detected in 8 images. In this case, after analyzing 9 images, the software may continue to the stage of updating the dust map (**200**) but upon completion (10 images) there is a valid dust map, and the software will continue to the correction (**160**) stage. If however the loop (**110**) is only on its 1st to 8th image, no correction will be done.

As an additional embodiment, images can be corrected retroactively after the dust map reached high enough confidence. This can be used for batch processing or off line processing or processing where the information is gathered in parallel to the needed correction. In this embodiment, when the confidence level is not enough (**152**, NOT-YET) the images, a pointer to them, or a list of them, or a representation of them, that were used to create the dust map are stored in temporary location (**154**) and when the dust map is ready (**151**-YES), the software will retroactively remove the dust from all those images (**156**). In this fashion, all images, including ones that originally did not hold sufficient statistical information, may be corrected.

Referring to the dust detection and correction process (**160**). This process may be executed as a loop on every dust spec in the dust map, with a stage of detection and correction (**400**, followed by **166** and **168**). Alternatively, the process can be implemented where all dust specs are detected first (**162**) and then all dust specs are corrected (**164**). The decision as to the sequence of operations varies based on implementation criteria such as what regions of the image are in memory, and should not affect the nature of the preferred embodiment. In the case where the lens specific calibration table is in the lens, there is a need for a intermediate step which converts the dust map via those tables. By having this functionality, a single dust map may suffice to accommodate changes in lenses and changes in the focal length of a single zoom lens.

This workflow is illustrated in FIG. **8** which describes the workflow of correcting and detecting the dust images based on a lens lookup table and a dust map. If a dust map exists (**1120**) the system will load the dust map (**1130**). Otherwise, a new dust map needs to be created as described in FIG. **2** (**200**). The lens calibration is then loaded (**1140**). Such map can exist in the software, or as part of the lens memory, or in the camera. Together with the dust map, a specific manifestation of the dust for the specific camera, lens combination is created (**1160**). This is the dust map that will be used to remove dust specs (**400**) from an image (**404**) that was captured using the specific lens on the specific camera. In this

scenario, if a user lads a new lens, **1180**, there is no need for a new calibration stage, but rather a computational step (**1160**) is preferred to calculate the new Specific Dust Map.

Referring to FIG. **2** where the Dust map creation and updating is defined: this process can receive a collection of images as defined by FIG. **1**. blocks **108** and **109**) or one image at a time is refereed to this process, as defined by FIG. **1** block **110**. If the function is called with a single image (**220**-SINGLE IMAGE) the image is directly provided to the calculations (**270**). If multiple images are provided (240 MULTIPLE IMAGES), then an initial step is to define if there are more than enough images for defining the map. This step is designed to optimize the creation process for dust in case of large amount of images.

The sequence of the images that are to be referenced based on the original collection of N images as defined in FIG. **1** blocks **102**, **103** or **104**. The sequence of images is based on a few criteria such as: giving more weight to images shot last, and if images are shot in a relatively small time frame, allocate the sequence is large distances to try and assure minimal repetitiveness between similar images that may have been taken of the same object with little movement. The sequence will not be limited to the number of images (HIDP) because it may well be that some regions will not have enough data in them to evaluate the dust. This may happen in cases where part of the image is very dark in some of the images.

As an example: if N (number of images in a selection)=30; and HSdp (number of images needed to determining map)=10; and all images were shot in a space of an hour; then a potential sequence may be:

30,27,24,21,18,15,12,9,6,3,29,26,25 . . . ,2,28,25 . . . 1

Alternatively if the same 30 images were taken over a period of a month it may be beneficial to select images sequentially (last one shot is the first to be calculated):

30,29,28 . . . 20.19 . . . 2,1

And in some cases this process of sampling the series (**270**) may also decide not to use images that are taken too long from the last image. In this case, for example if image **1-15** were taken in July and **16-30** were taken in November, this process may limit the new map to **16-30** or even create two different maps, one for images **1-15** and the other for **16-30**.

In a different criteria, the parameters as extracted from the images will determine the sequence and the number of dust maps that are to be calculated. For example if a folder contains N=30 images, where 15 were taken with one camera and 15 with another, the sampling step (**270**) may create two map sets.

Another criteria for creating a new set or checking for new dust is the type of lens. If a lens is changed, it means that the CCD-cavity was exposed to potential new dust. This may trigger a new set of images to be looked at. It may also be an indication that the camera was serviced, or that the photographer cleaned the camera. Of course, if there is a parameter that defines when a camera was serviced, this will trigger the creation of a new dust map.

Those familiar in the art may be able to determine the right combinations of creating this sequence based on the nature of the dust, the camera and the lens. The next loop (**270-271**) defines the marking of each region and the addition of the region to the dust map if it is not already there. There are three type of regions in an image, the first are images with sufficient information to detect whether they are of dust nature. As an example, dark regions surrounded by a light background. Other criteria may be regions with a relatively small color saturation. The second group are regions that are definitely non-dust. Such regions are for example all clear, or of high color saturation. Other regions are inconclusive such as a very dark segment of the image. In this case, it will be hard to detect the dust even if it was part of the image. Alternatively when looking for over exposed or "dead pixels" the criteria may be reversed, if the pixels appear as a white spec in the image.

The criteria may be also a function of the acquisition parameter. For example an image with a open aperture may all be marked as in-decisive, because the dust may not appear on the image. Regions that are potentially dust are marked (**292**) and then added to the dust mask (**294**). The addition may be the creation of a new dust spec on the map or the modification of the probability function or the confidence level counter for the region. Regions that are most likely non-dust are marked (**282**) and then added to the dust mask (**284**). The addition may be the creation of a new dust spec on the map or the modification of the probability function or the confidence level counter for the region. The additions of the regions needs to be normalized to the shooting conditions as defined by the dust map (**300**) if this step was not performed prior to entering this function, as optionally defined in FIG. **1**.

This loop continues over all regions of the image (**271**). Alternatively (**272**), each region is compared (**500**) with the map dust to se if there is no case where the monotonicity is broken, i.e. a region that was of high probability to be dust is now non dust.

FIG. **3** illustrates the process of correlating the image to a default settings of the dust map. This process defines correlating the image o the dust map, the dust map to a new dust map of the dust map to the mage. In particular this correlation refers to the adjustment of the shooting conditions to some accepted standard. The acquisition conditions in particular refer to the aperture and the focal length. The correlation process is interchangeable and can be done by adjusting the image to the map or adjusting the map to the image. In some cases both acquired image and dust map may be adjusted to some common ground. Such an example may happen when the ma is calculated based on a aperture that the lens does not reach or a different lens than the one used wit different optical configuration. Alternatively, in case of a new lens, this process (**300**) may be used to adjust the map onto a new map and from that stage onwards continue with a single map.

To begin with, the dust map is being loaded (**112**) and the default data on which the map was generated is extracted (**310**). Such data may include the lens type, the aperture and the focal length associated wit the default state. In concurrence, the information form the acquired image (**304**) is extracted (**320**) and compared to the one of the dust map.

A explained in the mathematical model of the optical system, the two main adjustments between the dust map and the image are based on focal length, and on aperture, each creating a different artifact that should be addressed. Knowledge of the phenomena may assist in creating a better detection and correction of the dust artifact. Alternatively, in a separate embodiment, analysis of the image and the modification of the dust as changed by aperture and focal length, may provide the necessary mathematical model that describes transformation that defines the changes to the dust as a function of change in the lens type, the focal length and the aperture.

Referring to FIG. **3**, after extracting the data, the following step is modification of the map and or the image based no focal length (**900**), and based on aperture (**800**). The following steps are further defined with reference to FIG. **6** and FIG. **5**, respectively.

Following the two steps (**800** and **900**), the Image and the Dust Map are considered to be correlated. The correlated map cM is no longer binary because it defines both the shift and the

fall off which is continuous. FIG. **4** defines the preferred process of detecting and removing the dust from the image. The input is the image I is loaded, if it is not already in memory (**404**) and the correlated dust map is cM is loaded (**402**) if already not in memory.

The process of detecting and removing the dust is done per dust spec. This process is highly parallelized and can be performed as a single path over the image, or in strips. The flexibility of performing the operation on the entire image, or in portions, combined with the correlation or as a separate process, enables a flexible implementation of the algorithm based on external restrictions defined by the hardware, the run time environment, memory restrictions and processing speed.

The acquisition information and the corresponding dust map default setup are extracted in blocks **326** and **312** respectively. Then, for each dust spec in the image **810**, the size of the region that is still obscured by the dust is calculated, as defined by mathematical model. In some cases, when the aperture is very open, this region may decline to 0. In others, where the aperture is still very close, the size may be close to the size of the dust. Alternatively, This step, **820**, may be done as a preparation stage, and kept in a database, which can be loaded.

The process then splits in two. The fully obscured region will be marked in **834** pixel by pixel **832** in a loop **834**, **835** and will be treated by the in-painting process as defined in FIG. **4**. A semi opaque dust map, is created in the loop **840**, **841** for each pixel. Each of the pixels **842**, is assigned an OPACITY value **844**, based on the mathematical model as described previously. The dust spec that is only partially attenuated will go through a inverse filtering of the information already there, as described in FIG. **4** block **430**, with a specific embodiment in block **432**. The process of the inverse filtering may take into account the signal to noise ratio to avoid enhancing data which is not part of the original image. For example, the region around the dust may have a overshoot similar to a high pass filter, which may manifest itself in the form of an aura around the dust. This aura should to be taken into account before enhancing the regions.

FIG. **6** describes the adjustment of the Dust Map based on the Focal length, and the specific lens. As described before, the shift of the dust spec as a function of focal length for a specific lens is a function of equation (13 the thickness of the window—tw, which is constant for a given camera and exit pupil position—Pe, which varies based on the lens system and the variable focal length in case of a zoom lens. Given an image and a dust map, the pertinent information is loaded, as described in FIG. **3**, namely the focal lens and lens type of the camera, **326**, the focal length and lens type in the dust map **312** and the camera distance of dust to the sensor **318**.

The process then goes through all knows dust specs in the image **910** and calculates the shift of the dust. The coordinates of the pixel are calculated from the center of the optical path, **922**, and the shift is calculated **924**. Alternatively to going through each pixel, in order to speed the process, only the periphery of the dust spec can be calculated and the rest will be filled in. Moreover, because the shift is a function of the location (x,y) of the dust, in the case where dust is far enough from the origin, the dust shape will not change. It is then sufficient to calculate only a shift of a single point and displace the entire dust spec accordingly. The regions, which are only partially attenuated due to the change in aperture, may be calculated in this stage **940**, **941**, if calculated already as illustrated in FIG. **8**, or alternatively, the displacement can be calculated first as explained in blocks **942**,**944**.

In some cases, it is impossible to get the data on the exit pupil, nor the distance the dust is from the sensor. Such cases may be when the application has no a-priori knowledge of the camera or the lens that was used.

FIG. **9** schematically illustrates coupling components of a lens assembly with a housing of a digital image acquisition device, such as a Digital Single Lens Reflex Camera, or D-SLR. The lens assembly **1310** includes various optical, mechanical, electrical and/or signal connector or coupling components for coupling with a camera housing **1320** or other digital image acquisition device housing or component. In FIG. **9**, the components **1310** and **1320** are illustrated as if the lens **1310** has been uncoupled from the camera **1320** and rotated 180° about an axis running vertically within the plane of the drawing between the components **1310** and **1320**.

The physical or mechanical coupling between the lens assembly **1310** and the camera body **1320** is preferably via a bayonet type mount where the grooves on the lens bayonet mount **1332** fit into the camera body mount **1330**. When the lens is correctly held within the camera bayonet, electrical connectors **1342** on the back of the lens align and couple with the camera electrical connectors **1340** on the camera body. FIG. **9** also shows a further coupling component pair including a meter coupling ridge **1350** and an Ai coupling lever **1352**. In addition, an aperture indexing post **1360** of the lens **1310** is shown which couples with an aperture control coupling lever **1362** of the camera **1320**. Although not shown in the illustration of FIG. **9**, the interface of the camera **1320** and the lens **1310** may preferably include several other coupling or related optical system components including a focal length indexing ridge and focal length indexing pin pair, a lens-type signal notch and a lens-type signal pin pair, and a lens speed indexing post and a lens speed indexing lever pair. One or more of these coupling component pairs may be including within the electrical connectors **1340**, **1342**, or may be otherwise disposed at the interface. Moreover, an AF coupling on the lens **1310** may be coupled with an AF coupler on the camera body **1320**, e.g., in a exemplary Auto focus lens Nikkor® AF lens-type and Nikon® F4 body configuration.

Through these connectors, information may be communicated to and from the lens **1310** to the camera **1320**. Such information may include details about the lens type, magnification and/or focal length. Other parameters may include aperture size or F-number. Conversely, the camera **1320** may send information to the lens **1310** such as for setting up a focus ring or otherwise initializing or calibrating with the camera **1220** or other digital image acquisition device **1220**. The connectors illustrated at FIG. **13** and/or those just described above, may also serve to transfer lens calibration data relevant to dust or dust artifact within images. The lens parameter data may be entirely digitally-stored in a permanent memory of the lens assembly, and may be made accessible by a camera micro-processor upon electrical, optical or other signal coupling. This data may be in the form of analytical parameters, such as exit pupil dimension, exit pupil distance regarding the lens or distance of dust to the sensor (which may often include a thickness of a protective CCD sensor cover material, such as an anti-aliasing or an optical spacer), or other parameters, and may be a table, e.g., a look up table, describing the dust movement as a function of the focal length, etc., as discrete points, or a mathematical formula describing this relationship, or otherwise as set forth above or below herein. The lens calibration may include other data such as the effect of the aperture on the dust.

Values of extracted parameters relating to the optical system including the lens assembly may be embedded within the lens system, wherein by "embedded" it is meant that the information is stored or contained in whatever form within or on or in connection with the lens assembly. This embedded

information may preferably be within a Flash or EEPROM memory chip. RAM is an alternative, but is "volatile" and would utilize a back-up battery to retain data storage when powered down. Preferably, the lens system would use the power of the camera when coupled thereto, and only alternatively would have its own separate power supply or back-up battery. In that case, the battery may be charged when coupled to the camera.

Therefore, relevant data is advantageously digitally-stored in an optical calibration table, or otherwise, within a chip or other digital storage component of the lens holder **1310**, optical mount **1310** or the lens **1310** itself. The table is made accessible to a camera-resident micro-processor through the electrical or other signal connections **1340**, **1342**. When the lens is mechanically coupled to the camera, it is also electrically and/or optically coupled specifically so that the camera can access the table. There may be an automatic focusing that is facilitated by this communication, or other advantage involving this feature of camera-lens communication. The lens parameter data may be entirely digitally-stored in the table that is made accessible by the camera micro-processor upon coupling, although it may be made accessible by a switch that turns on the connection or by opening the shutter or by other preparation for taking a picture.

There are many alternatives to the preferred embodiments described above that may be incorporated into a image processing method, a digital camera, and/or an image processing system including a digital camera and an external image processing device that may be advantageous. For example, an electronic circuit may be designed to detect maximum and minimum dust detection probability thresholds while acquiring pixels in an image (see also U.S. Pat. No. 5,065,257 to Yamada, hereby incorporated by reference). Such a circuit can produce signals that may be used in processing to eliminate regions, which lie outside the expected range of signal values due to the presence of dust particles or similar optical defects, or alternatively to accept, maintain or eliminate regions as dust artifact regions based on whether a probability determination exceeds, high or low, a certain threshold or thresholds. A technique may be used to detect and provide a remedy for the effects of dust on a digitally-acquired image (see also U.S. Pat. No. 5,214,470 to Denber, hereby incorporated by reference). An image may be recorded within a digital camera or external processing device such as may be signal coupled with a digital camera for receiving digital output image information or a device that acquires or captures a digital image of a film image. The digital image may be compared with the film image, e.g., through a logical XOR operation, which may be used to remove dust spots or blemishes picked up in the acquisition of the digital image from the film image.

Multiple images may be processed and stationary components, which are common between images, may be detected and assigned a high probability of being a defect (see also U.S. Pat. No. 6,035,072 to Read, hereby incorporated by reference). Additional techniques, which may be employed to modify defect probability, may include median filtering, sample area detection and dynamic adjustment of scores. This dynamic defect detection process allows defect compensation, defect correction and alerting an operator of the likelihood of defects.

Dark field imaging may be employed to determine the location of defects in digital images from digital cameras or film scanners (see U.S. Pat. No. 5,969,372 to Stavely et al., and U.S. patent application 2001/0035491 to Ochiai et al., each hereby incorporated by reference). A normal imaging of a object with normal illumination may be followed by a second imaging using different wavelengths, e.g., infrared illumination. Dust, fingerprints, scratches and other optical defects are typically opaque to infrared light. Thus the second image produces an image with dark spots indicating the position of dust particles or other defects.

A process may involve changing any of a variety of extracted parameters (see elsewhere herein), angle of sensor relative to image plane, distance of image plane or sensor from dust specks (e.g., on window of sensor), etc., and imaging a same object with the digital camera. A comparison of the images reveals with enhanced probability the locations of dust artifact. In a camera application, the unique location of the actual dust relative to the object and to the image plane provide information about extracted parameter-dependent characteristics of dust artifact in the images. The analysis for the digital camera application depends on the "transmission"-based optical parameters of the system, i.e., the fact that light travels from a scene through the camera lens and onto the camera sensor, and not involving any substantial reflective effects. It is possible to make determinations as to where the dust actually is in the system by analyzing multiple images taken with different extracted parameters, e.g., on the sensor window, or in an image of an original object which itself is being images such as in film imaging.

In a scanning application, this technique can be use the face that a speck of dust will cast a shadow of a different color, geometry location, etc. with changes in extracted parameters, e.g., with a different color with increasing elongation of the shadow for each parallel row of pixels (a "rainbow" shadow, as it were). Multiple scans taken from various angles of illumination may be employed to produce an image which identifies dust defects from their shadows and the colors thereof (see U.S. Pat. No. 6,465,801 to Gann et al. and U.S. patent applications 2002/0195577 and 2002/0158192 to Gann et al, hereby incorporated by reference). A linear scanning element moves across a document (or the document is moved across the scanning element) and an image of the document is built up as a series of rows of pixels. This differs from the physical configuration of a camera in which a shutter illuminates a X-Y sensor array with a single burst of light. In both cases, though, dust may lie close to the imaging plane of the sensor.

Technique may be applied as part of a photofinishing process to eliminate blemishes on a film image obtained by a digital camera (see also U.S. patent application 2001/0041018 to Sonoda, hereby incorporated by reference). Such techniques may import previous acquired information about defects in images from a blemish detection procedure. A technique for correcting image defects from a digital image acquisition device such as a digital camera may involve repeated imaging of an object or other image, where each successive image-acquisition involves different properties or extracted parameters or meta-data related properties, such as variable angles of incidence or variable lighting or contrast parameters, and the results of these repeated scans may be combined to form a reference image from which defect corrections are made (see also U.S. patent application 2003/0118249 to Edgar, hereby incorporated by reference).

A decision on whether a defect in a image acquired by a field-based digital camera is to be corrected or not may be based on a balancing of considerations. For example, the likely damage to surrounding defect-free portions of the image may be balanced against the likelihood of successfully achieving correction of the defect.

Image processing means may be employed where the detection or correction of defects in a digital image may be based solely on analysis of the digital image, or may employ techniques directly related to the image acquisition process.

or both. Anomalous image regions may be determined based on the difference between the gradient of an image at a set of grid points and the local mean of the image gradient (e.g., see U.S. Pat. No. 6,233,364 to Krainiouk et al., hereby incorporated by reference). Such technique can reduce the number of false positives in "noisy" regions of an image such as those representing leaves in a tree, or pebbles on a beach. After determining an initial defect list by this means, the technique may involve culling the list based on a one or more or a series of heuristic measures based on color, size, shape and/or visibility measures where these are designed to indicate how much an anomalous region resembles a dust fragment or a scratch.

Techniques and means to correct scratches in a digitized images may employ a binary mask to indicate regions requiring repair or noise removal, and sample and repair windows to indicate (i) the region requiring repair and/or (ii) a similar "sample" area of the image (see also U.S. Pat. No. 5,974,194 to Hirani et al., hereby incorporated by reference). Data from a sample window may be converted to a frequency domain and combined with frequency domain data of the repair window. When a low-pass filter is applied, it has the effect to remove the sharp, or high-frequency, scratch defect.

Techniques and means of detecting potential defect or "trash" regions within an image may be based on a comparison of the quadratic differential value of a pixel with a predetermined threshold value (see U.S. Pat. No. 6,125,213 to Morimoto, hereby incorporated by reference). The technique may involve correcting "trash" regions within an image by successively interpolating from the outside of the "trash" region to the inside of this region.

Techniques and means to automate the removal of narrow elongated distortions from a digital image may utilize the characteristics of image regions bordering the distortion (see also U.S. Pat. No. 6,266,054 to Lawton et al., hereby incorporated by reference). User input may be used to mark the region of the defect, or automatic defect detection may be employed according to a preferred embodiment herein, while the process of delineating the defect is also preferably also performed automatically.

Techniques and means to allow automatic alteration of defects in digital images may be based upon a defect channel having a signal proportional to defects in the digital image (see also U.S. Pat. No. 6,487,321 to Edgar et al., hereby incorporated by reference). This allows areas of strong defect to be more easily excised without causing significant damage to the area of the image surrounding the defect.

Techniques and means may be employed to generate replacement data values for an image region (see also U.S. Pat. No. 6,587,592 to Georgiev et al., hereby incorporated by reference) Image defect may be repaired as facilitated by the replacement data. Moreover, the repairing of the unwanted image region may preserves image textures within the repaired (or "healed") region of the image.

Techniques and means may be employed to detect defect pixels by applying a median filter to an image and subtracting the result from the original image to obtain a difference image (see also U.S. patent application 2003/0039402 and WIPO patent application WO-03/019473, both to Robins et al., each hereby incorporated by reference). This may be used to construct at least one defect map. Correction of suspected defect pixels may be achieved by replacing those pixel values with pixel values from the filtered image and applying a smoothing operation. User input may or may not be utilized to further mitigate the effects of uncertainty in defect identification.

Techniques and means for retouching binary image data which is to be presented on a view-screen or display apparatus may be employed to eliminate local screen defects such as dust and scratch artifacts (see also U.S. patent application 2002/0154831 to Hansen et al., hereby incorporated by reference). The production of visible moiréeffects in the retouched image data may be avoided by the replacement of small areas.

A digital video camera with sensor apparatus may incorporate a defect detecting mode (see also U.S. Pat. No. 5,416,516 to Kameyama et al., hereby incorporated by reference). The locations of detected defect pixels may be retained in the memory of the camera apparatus and replacement pixel values may be interpolated by processing algorithms, which convert the sensor data into digital image pixel values. Techniques may be employed to automatically detect and compensate for defective sensor pixels within a video camera (see also U.S. Pat. No. 5,625,413 to Katoh et al., hereby incorporated by reference). The camera may perform a dark current measurement on start-up when the camera iris is closed and by raising the gain can determine pixels which exhibit abnormally high dark current values. The location of these pixels is recorded in camera memory as a LUT with associated threshold brightness values associated with each pixel depending on its dark current value; defect compensation depends on input image brightness and ambient temperature.

An image pickup apparatus, such as a digital camera, may have a detachable lens (see also U.S. patent application 2003/0133027 to Itoh, hereby incorporated by reference). The camera may incorporate a defect detecting section and a compensation section for sensor defects. Further the defect detection operation may become active when the camera lens is detached so that the user will not miss an opportunity to take a picture due to the operation of the defect detection process.

The techniques of the preferred and alternative embodiments described herein may be applied to cameras with interchangeable lens units (see also U.S. patent application Ser. No. 5,003,399 to Masayoshi et. al., hereby incorporated by reference). The camera and lens have first and second computers in the camera body and lens device, respectively, which are programmed so that, in an initial communication sequence there between after the selected lens device is mounted on the camera body, the second microcomputer transmits optical characteristic data for the respective lens device to the first microcomputer in response to a data transmission request signal from the latter.

The techniques of the preferred and alternative embodiments described herein may be applied to printers and to imaging devices such as a digital cameras which incorporate a focusing lens system. A process may be employed for detecting and mapping dust on the surface of a photographic element (see also U.S. Pat. No. 5,436,979 to Gray et al., hereby incorporated by reference). This may be applied in the context of a verification procedure to follow a cleaning process for a range of photographic elements including film negatives and slides. Statistical information may be obtained and presented to an operator to allow control of the cleaning process. Detailed location information may be also recorded and/or correction means may be also provided for dust defects on a photographic element.

Techniques and means to create a defect map for a digital camera or similar imaging device may use an all-white reference background (see also U.S. patent application 2002/0093577 to Kitawaki et al., hereby incorporated by reference). The location of any dust or scratch defects may be recorded in the memory of the imaging apparatus when the camera is in a dust detection mode and when a dust correction circuit is active any image data co-located with a defect may be corrected for the presence of dust by elimination, color

correction or interpolation based on the surrounding pixels. Further, where the position of a dust defect changes with f-stop of the camera a list of dust locations corresponding to f-stop settings is pre recorded at the time of manufacturing in a LUT in the camera memory. Any effect of different focal length may be simplified to the effect of the change in dust due to magnification of the lens. In addition, techniques for dynamically obtaining a defect map based on the processing of a plurality of images may be employed with this technique.

Techniques may be also employed involving correcting for dust defects based on the geometry of said dust or of the camera. Further techniques may involve utilizing camera metadata to enhance the detection and correction processes for defects. Further techniques may involve alerting the user that the camera requires servicing due to excessive levels of dust contamination, or the fact that it is not only magnification but the actual lens that is mounted.

A method of filtering dust artifacts form an acquired digital image including multiplicity of pixels indicative of dust, the pixels forming various shapes in the image, may be employed. The method may include analyzing image information including information describing conditions under which the image was acquired and/or acquisition device-specific information. One or more regions may be determined within the digital image suspected as including dust artifact. Based at least in part on said meta-data analysis, it may be determined whether the regions are actual dust artifact.

A method may further include analyzing the images in comparison to a predetermined dust map to establish the validity of the dust over progressions of time. The method may further involve mapping the acquired image to a predetermined default acquisition condition based on a lens and camera calibration tables, as a function of the lens type and the focal length that was used at acquisition.

A method may further include mapping a dust spec as depicted in the dust map and the suspected dust specs in the acquired image based on a calculated transformation of the dust as a function of the lens and the aperture, or other extracted parameter, used to acquire the image. The actual removal of dust artifacts from an image may include a step where missing data as obscured by the dust specs is regenerated and in-painted based on analysis of the region in the image surrounding the dust spec. The actual removal of the dust artifacts from the image may also include a step where deteriorated regions primarily in the periphery of the dust spec are enhanced and restored based on knowledge of the deterioration function. The actual image retouching may include both in-painting and restoration or either one of these operations, or another image correction technique as may be understood by those skilled in the art.

A method of detecting and removing dust artifacts may be performed in the acquisition device as a post-processing stage prior to saving the image. This method may further include an analysis of the image in its raw format immediately followed by the acquisition stage. The method of detecting and removing dust artifacts can be performed on an external device as part of a download or capture process. Such external device may be a personal computer, a storage device, and archival device, a display or a printing device or other device. The method of detecting and removing dust artifacts can be performed in part in the acquisition device and the external device.

A dust detection and/or correction technique may be applied post priori to a collection of images, or individually to images as they are added to a collection. The map may be generated a priori to the introduction of an image, or dynamically and in concurrence to the introduction of new images. The method may further include steps of providing a statistical confidence level as to the fact that a certain region is indeed part of a dust spec. The method may further provide tools to determine whether the acquisition device may benefit from some maintenance. A method may be employed that may be implemented as part of a digitization process, such as correcting defects on scanning device, whether flat bed or drum, whether for hard copy documents or for film digitization. A method may be further applied to other recurring image imperfections such as dead pixels on the sensor, burnt pixels on the sensor, scratches, etc. A method of automatically determining whether to recommend servicing a digital image acquisition system including a digital camera based on dust analysis may be advantageously employed. A method of calculating parameters of an optical system may be based on analysis of the dust.

While an exemplary drawings and specific embodiments of the present invention have been described and illustrated, it is to be understood that that the scope of the present invention is not to be limited to the particular embodiments discussed. Thus, the embodiments shall be regarded as illustrative rather than restrictive, and it should be understood that variations may be made in those embodiments by workers skilled in the arts without departing from the scope of the present invention as set forth in the claims that follow and their structural and functional equivalents.

In addition, in methods that may be performed according to preferred embodiments herein, the operations have been described in selected typographical sequences. However, the sequences have been selected and so ordered for typographical convenience and are not intended to imply any particular order for performing the operations, unless a particular ordering is expressly provided or understood by those skilled in the art as being necessary.

Many references have been cited above herein, and in addition to that which is described as background, the invention summary, brief description of the drawings, the drawings and the abstract, these references are hereby incorporated by reference into the detailed description of the preferred embodiments, as disclosing alternative embodiments of elements or features of the preferred embodiments not otherwise set forth in detail above. A single one or a combination of two or more of these references may be consulted to obtain a variation of the preferred embodiments described in the detailed description above.

What is claimed is:

1. A digital camera that automatically corrects dust artifact regions within acquired images, comprising:

(a) an optical system for acquiring an image including a lens assembly and an aperture stop;

(b) an electronic sensor array for collecting image data with multiple pixels that collectively correspond to the acquired image;

(c) a lens calibration table corresponding to said optical system that includes information describing dust location and appearance as a function of optical parameters at least including exit pupil dimension of the lens assembly, or distance of dust from a surface of the electronic sensor array that corresponds to a focal plane of the lens assembly, or both;

(d) a master dust map describing a physical manifestation of dust artifacts on said sensor array;

(e) a manifestation of the master dust map for a specific lens and focal length, calculated as a transformation of the master dust map based on the lens calibration table; and

(f) digital processing electronics including a processor for converting processing the digital data according to programming instructions; and

(g) wherein said dust artifacts are corrected for said acquired image based on the manifestation of the master dust map.

2. The camera of claim 1, wherein said lens calibration table comprises processor-readable digital code embedded within a memory component that is located inside the lens.

3. The camera of claim 1, wherein said lens calibration table is located in an external application.

4. The camera of claim 1, wherein said lens calibration table is downloadable from a server.

5. The camera of claim 1, wherein said master dust map comprises a statistical dust map.

6. The camera of claim 5, wherein additional images are digitally-acquired with said digital camera, and said statistical dust map is dynamically updated.

7. The camera of claim 6, wherein said statistical map comprises probabilities based on comparisons with suspected equivalent dust artifact regions within said additional images.

8. The camera of claim 7, wherein determining of said probabilities is based on a pixel analysis of the suspected dust artifact regions in view of predetermined characteristics indicative of the presence of a dust artifact region.

9. The camera of claim 5, wherein whether said additional digitally-acquired images have non-contradicting data that said probability that certain pixels correspond to dust artifact regions within said images is validated prior to correcting pixels corresponding to correlated dust artifact regions within said images based on the manifestation of said master statistical dust map.

10. The camera of claim 1, wherein said dust artifacts are corrected on a image from raw format.

11. The camera of claim 1, wherein said dust artifacts are corrected on a processed image after being converted from raw format to a known red, green, blue representation.

12. The camera of claim 1, wherein said dust artifacts are corrected by replacing said pixels within said one or more digitally-acquired images with new pixels.

13. The camera of claim 1, wherein said dust artifacts are corrected by enhancing values of pixels within said one or more digitally-acquired images.

14. A method performed within a digital image acquisition device including a sensor array that is coupled with a lens assembly including optical and signal coupling, the method for automatically correcting dust artifact within images acquired by the device, comprising:

(a) acquiring one or more initial digital images within said digital acquisition device;

(b) determining that certain pixels correspond to dust artifact regions within said mages;

(c) receiving through said signal coupling one or more values of one or more extracted parameters relating to the optical system that are embedded within the lens assembly at least including exit pupil dimension of the lens assembly, or distance of dust from a surface of the electronic sensor array that corresponds to a focal plane of the lens assembly, or both;

(d) based on a master dust map describing a physical manifestation of dust artifacts on the sensor array, generating manifestation of the master dust map for a specific lens and focal length, calcufated as a transformation of the master dust map based on the extracted parameters; and

(e) correcting pixels corresponding to correlated dust artifact regions within further digitally-acquired images based on the determining and the one or more extracted parameter values.

15. The method of claim 14, wherein said receiving further comprises receiving data based on a lens calibration table corresponding to said lens assembly that includes information describing the dust location and appearance as a function of the extracted parameters relating to the optical system.

16. The method of claim 14, wherein the one or more extracted parameters comprise magnification, lens type, or focal length, or combinations thereof.

17. The method of claim 14, wherein the correcting comprises:

(i) associating dust artifact regions with one or more values of one or more extracted parameters relating to the optical system of the digital acquisition device when the images were acquired; and

(ii) forming a statistical dust map including mapped dust regions based on the dust artifact determining and associating,

(iii) wherein the correcting is based on the statistical dust map.

18. The method of claim 17, wherein the correcting further comprises:

(i) loading the statistical dust map;

(ii) loading extracted parameter information of a present image;

(iii) performing calculations within the statistical dust map having extracted parameter variable-dependencies; and

(iv) comparing dust artifact detection data with the extracted parameter dependent statistical dust map data.

19. A method performed within a digital image acquisition device including a sensor array that is coupled with a lens assembly including optical and signal coupling, the method for automatically correcting imaging artifacts within images acquired by the device, comprising:

(a) acquiring one or more initial digital images within said digital acquisition device;

(b) determining that certain pixels correspond to artifact regions within said images;

(c) receiving through said signal coupling data based on a lens calibration table corresponding to said lens assembly that includes information describing artifact location and appearance as a function of one or more values of one or more extracted parameters relating to the optical system that are embedded within the lens assembly at least including exit pupil dimension of the lens assembly, or distance of dust from a surface of the electronic sensor array that corresponds to a focal plane of the lens assembly, or both:

(d) based on a master dust map describing a physical manifestation of dust artifacts on the sensor array, generating a manifestation of the master dust map for a specific lens and focal length, calculated as a transformation of the master dust map based on the extracted parameters; and

(e) correcting pixels corresponding to correlated artifact regions within further digitally-acquired images based on the determining and the one or more extracted parameter values.

20. The method of claim 19, wherein the one or more extracted parameters comprise magnification, lens type, or focal length, or combinations thereof.

21. The method of claim 19, wherein the correcting comprises:

(i) associating artifact regions with one or more values of one or more extracted parameters relating to the optical system of the digital acquisition device when the images were acquired; and

(ii) forming a statistical map including mapped artifact regions based on the artifact determining and associating,

(iii) wherein the correcting is based on the statistical map.

22. The method of claim 21, wherein the correcting further comprises:

(i) loading the statistical map;

(ii) loading extracted parameter information of a present image;

(iii) performing calculations within the statistical map having extracted parameter variable-dependencies; and

(iv) comparing artifact detection data with the extracted parameter dependent statistical map data.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,590,305 B2
APPLICATION NO. : 10/842244
DATED : September 15, 2009
INVENTOR(S) : Steinberg et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

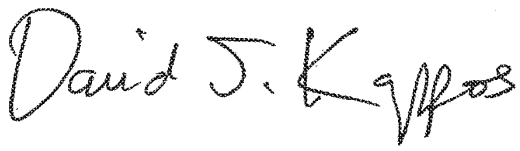
On the Title Page:

The first or sole Notice should read --

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1349 days.

Signed and Sealed this

Twenty-first Day of September, 2010



David J. Kappos
Director of the United States Patent and Trademark Office

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(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2004/0207733 A1

Nose et al. (43) Pub. Date: Oct. 21, 2004

(54) IMAGE PROCESSING METHOD, IMAGE PROCESSING APPARATUS AND IMAGE PICKUP APPARATUS AND DISPLAY APPARATUS SUITABLE FOR THE APPLICATION OF IMAGE PROCESSING METHOD

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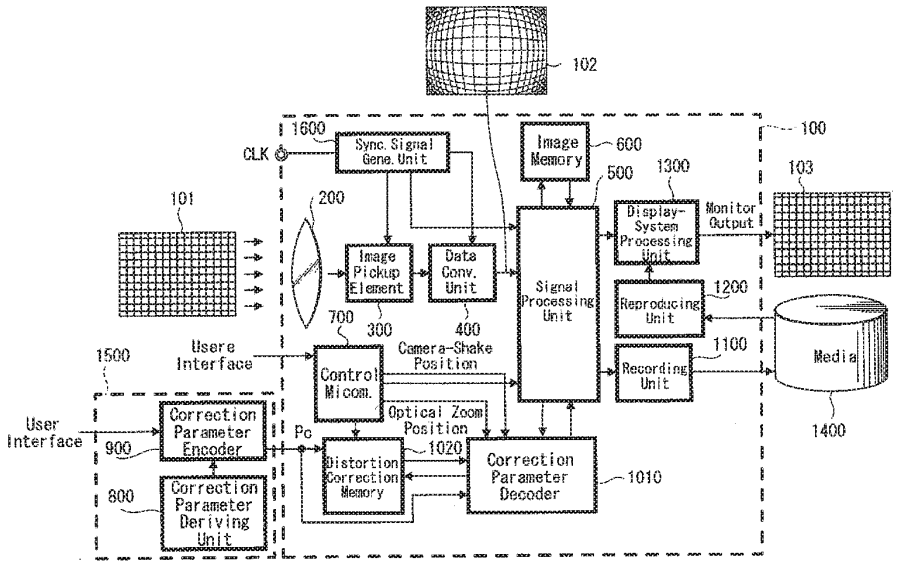
Publication Classification

(51) **Int. Cl.**[7] **H04N 5/228**

(52) **U.S. Cl.** **348/222.1**

(57) **ABSTRACT**

A lattice dividing unit **911** determines lattice lines to divide parameters of all points of a picture at every division and supplies distortion correction parameters (distortion correction coordinates) on the lattice points to a distortion correction memory (not shown). A polynomial of degree n coefficient deriving unit **902** expresses all distortion correction coordinates on each lattice line in the form of a function relative to positions on lattice lines and approximates the distortion correction coordinates by desired division polynomial of degree n. Further, a sample point deriving unit **903** compresses distortion correction parameters based upon the division polynomial of degree n obtained from the polynomial of degree n coefficient deriving unit **902**. In the derived division polynomial of degree n, internal points which result from dividing both ends of the division polynomial of degree n by n is supplied to the distortion correction memory as new distortion correction parameters (approximated distortion correction coordinates). Thus, a memory capacity of a required memory can be reduced in the image processing for correcting distortion of an image.



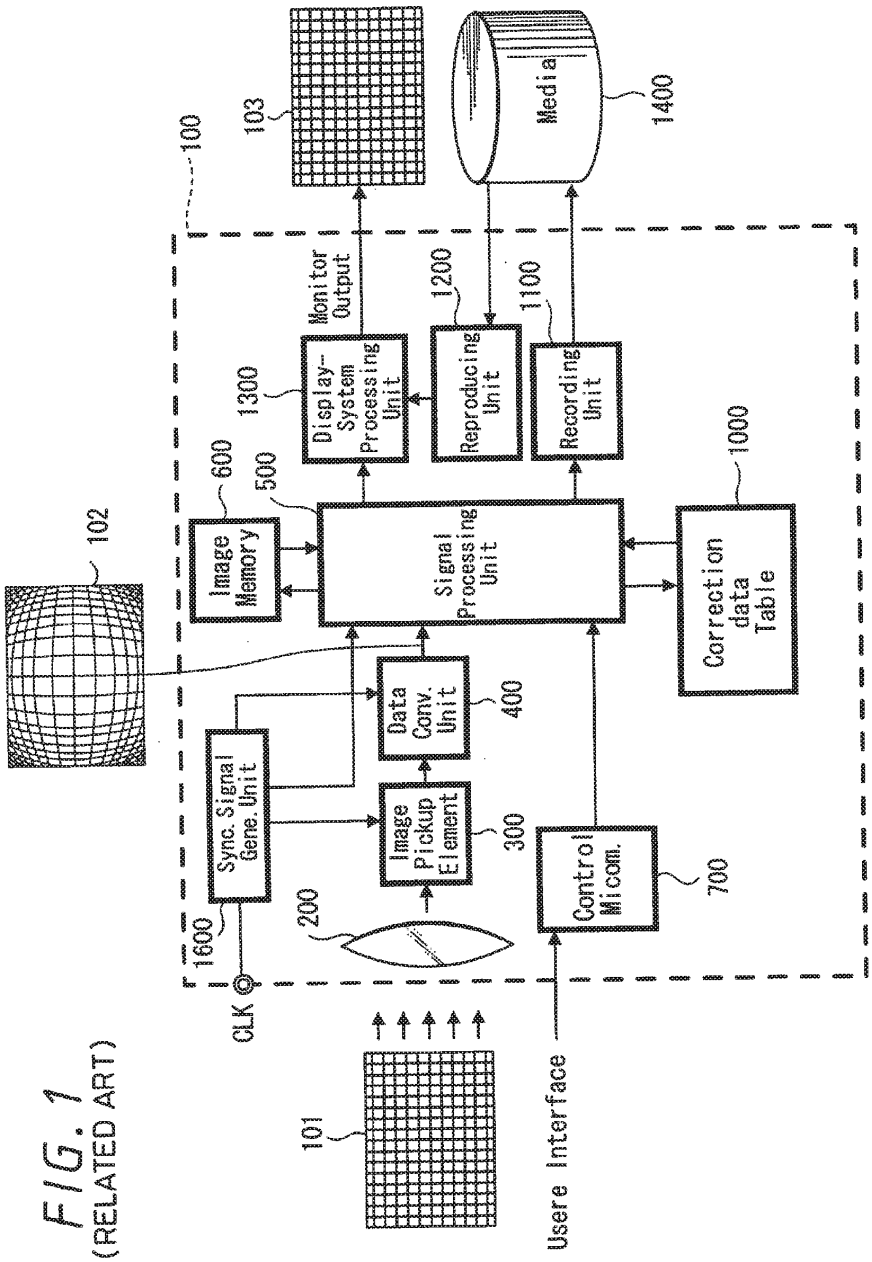
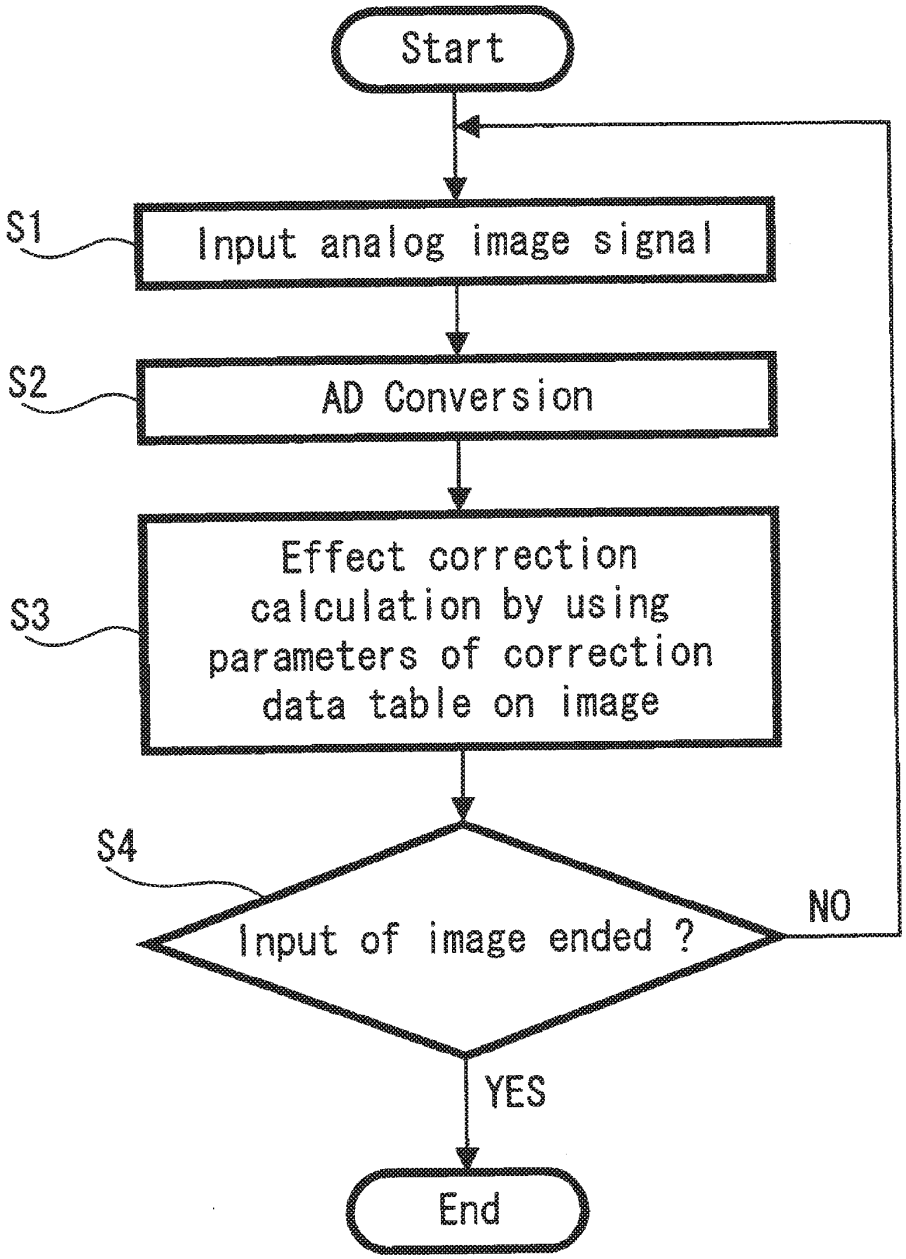


FIG. 1
(RELATED ART)

EX1002 - Page 415

FIG. 2


Start
S1
Input analog image signal
S2
AD Conversion
S3
Effect correction calculation by using parameters of correction data table on image
S4
Input of image ended ?
NO
YES
End

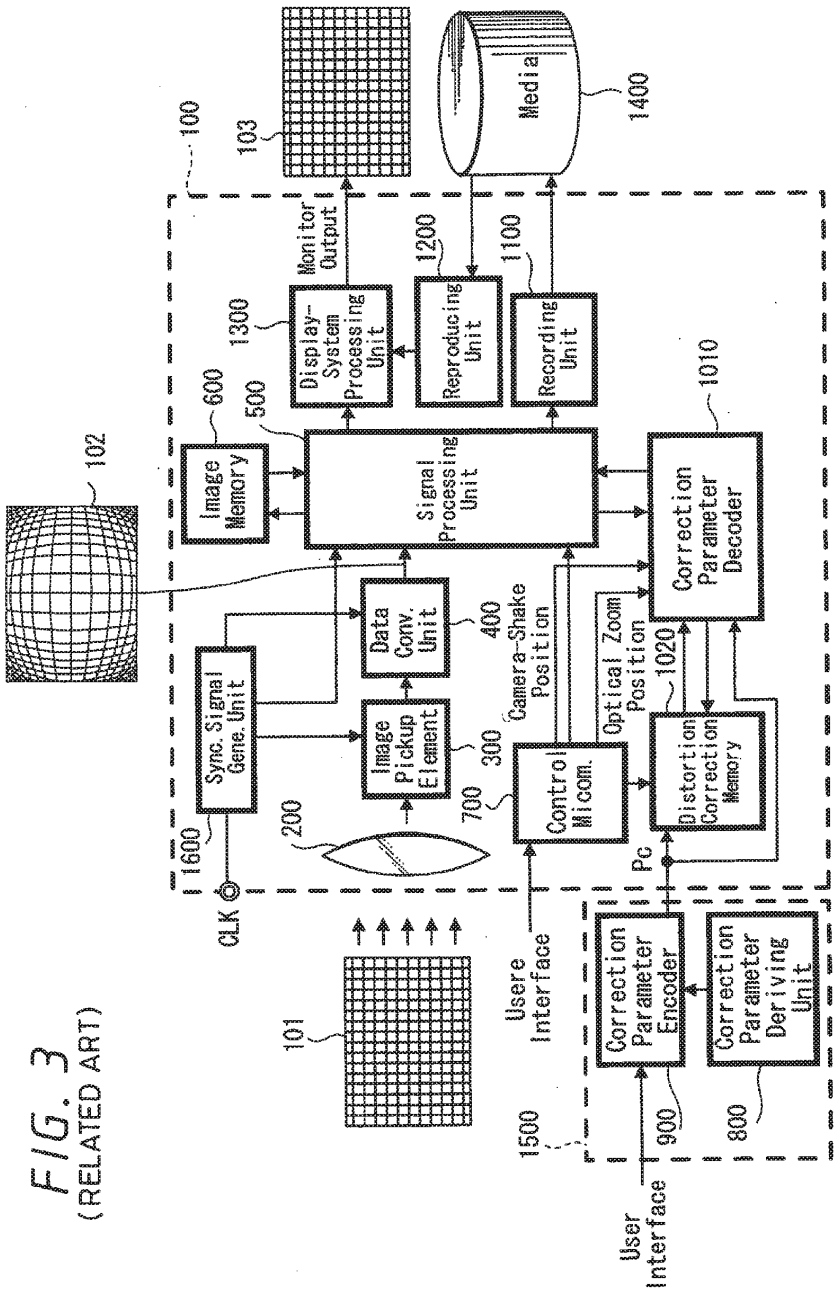
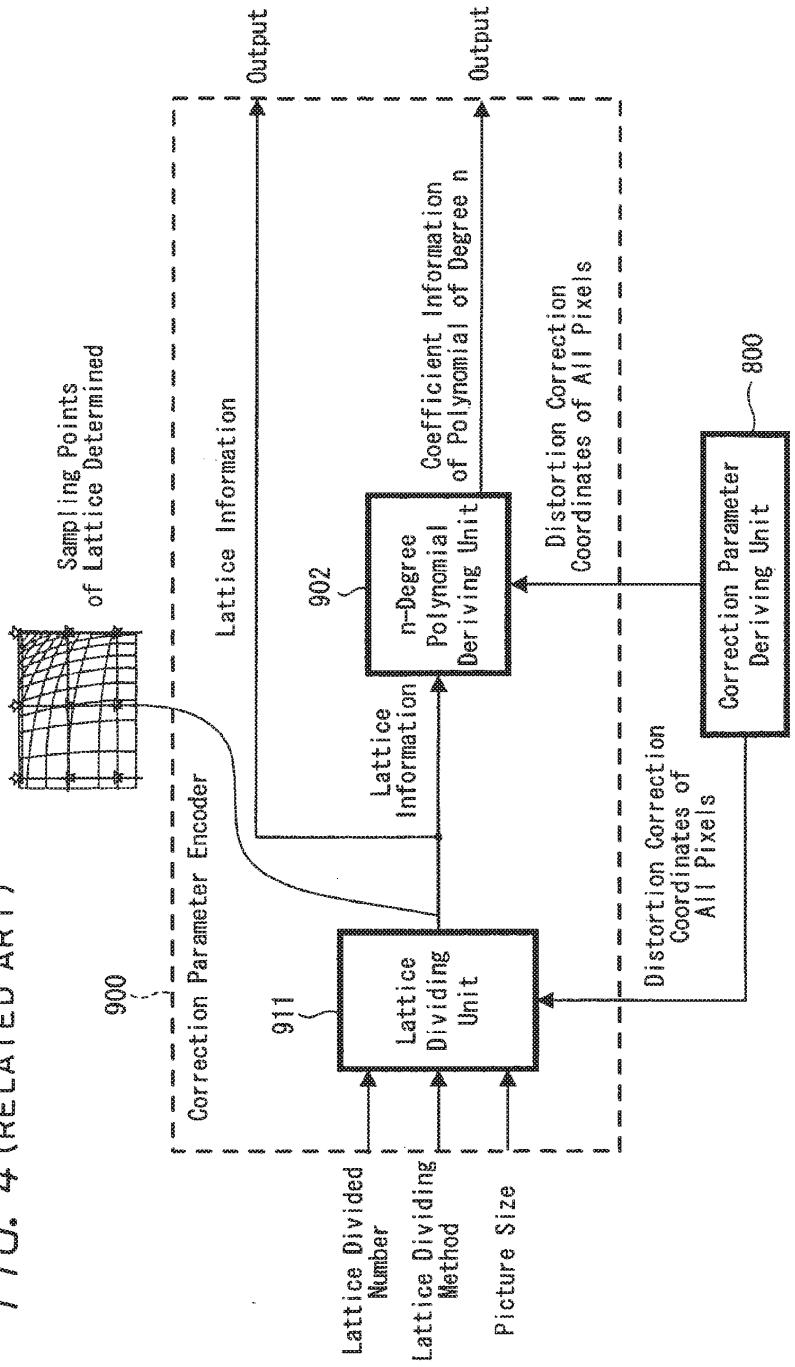


FIG. 3
(RELATED ART)

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FIG. 4 (RELATED ART)



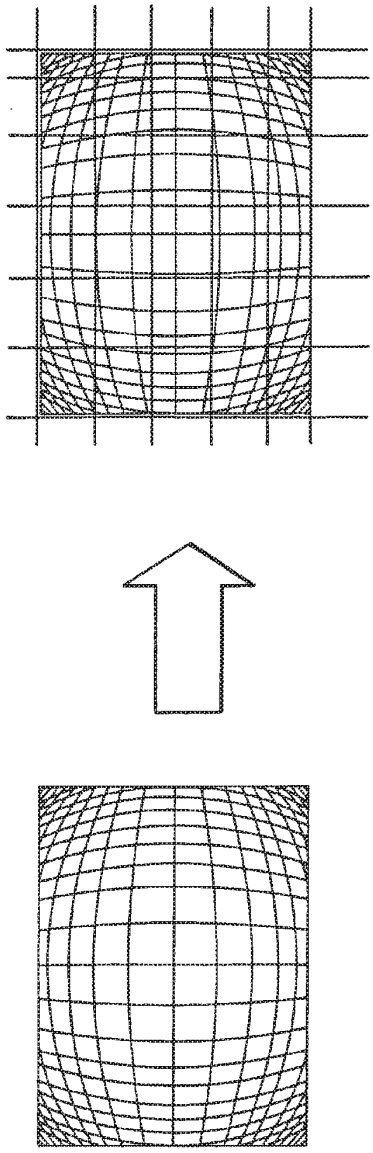


FIG. 5A
(RELATED ART)

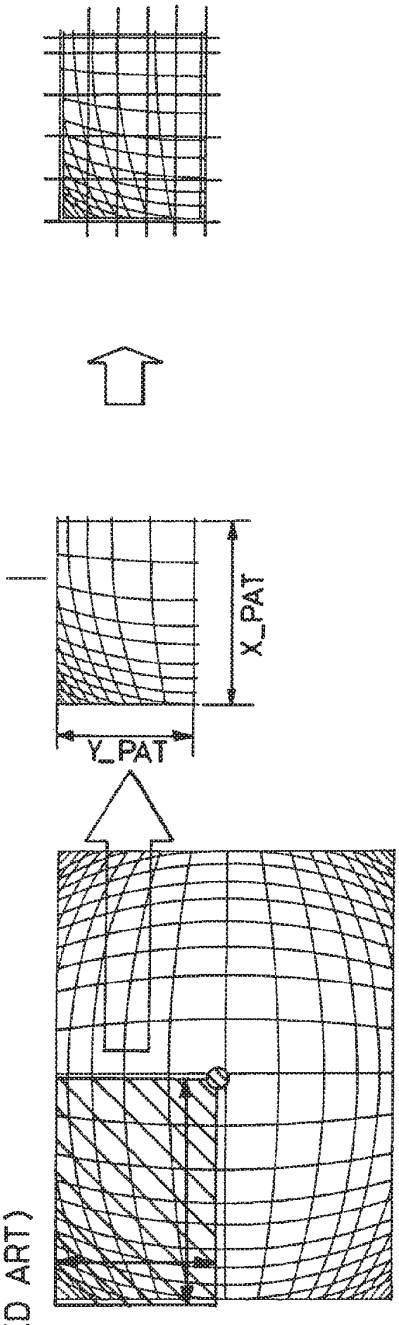


FIG. 5B
(RELATED ART)

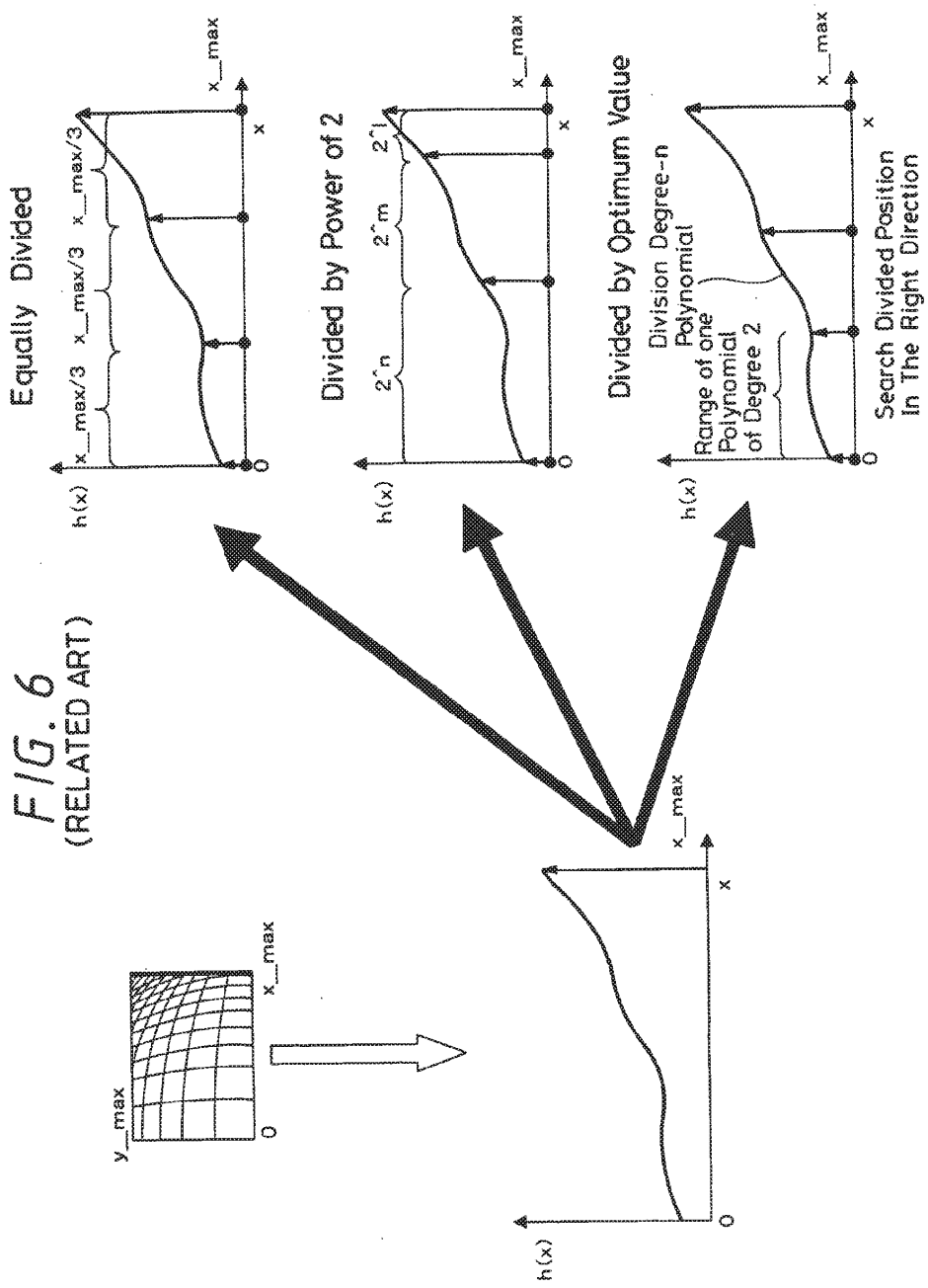


FIG. 6
(RELATED ART)

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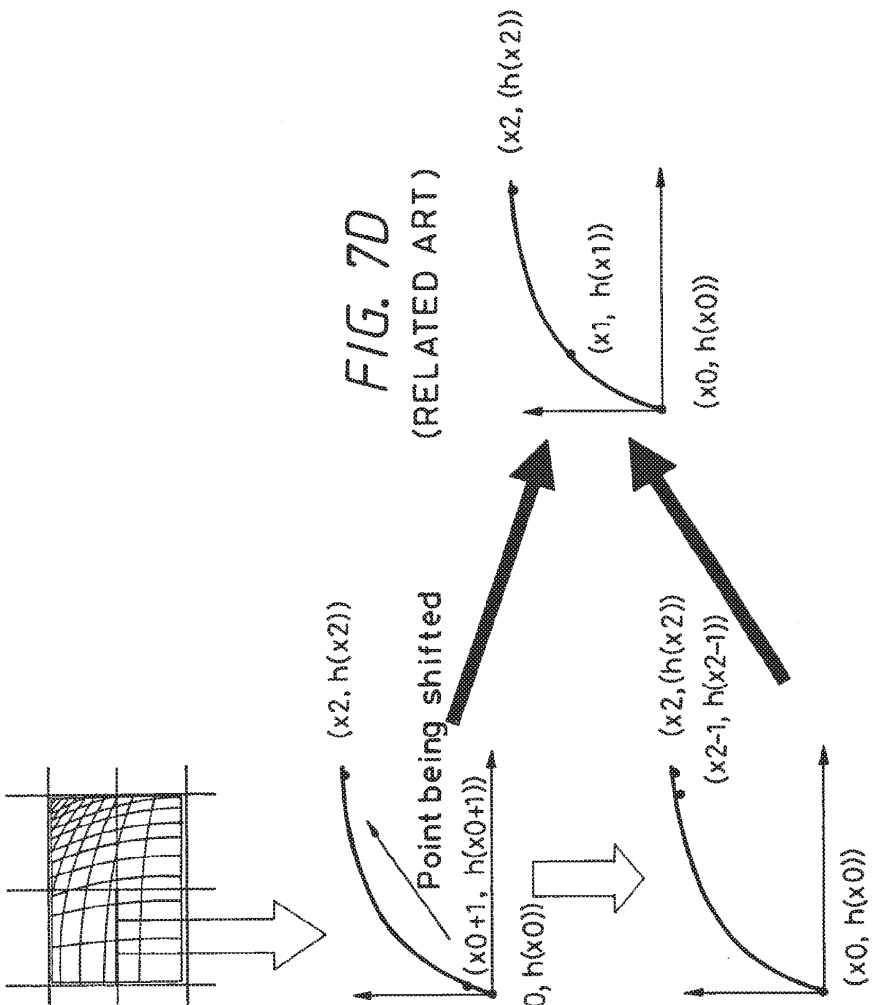


FIG. 7A
(RELATED ART)

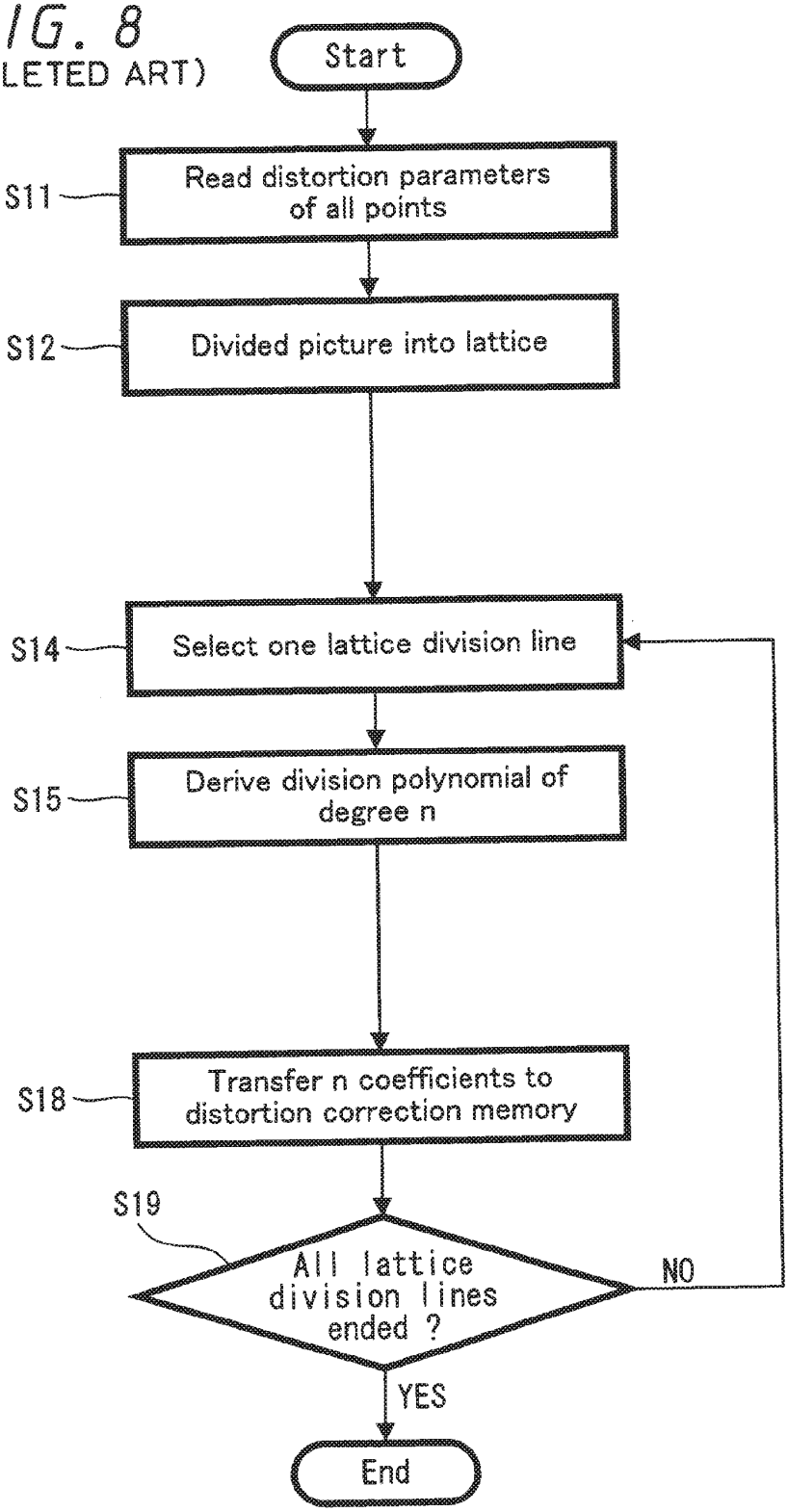
FIG. 7B
(RELATED ART)

FIG. 7C
(RELATED ART)

FIG. 7D
(RELATED ART)

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FIG. 8
(RELETED ART)



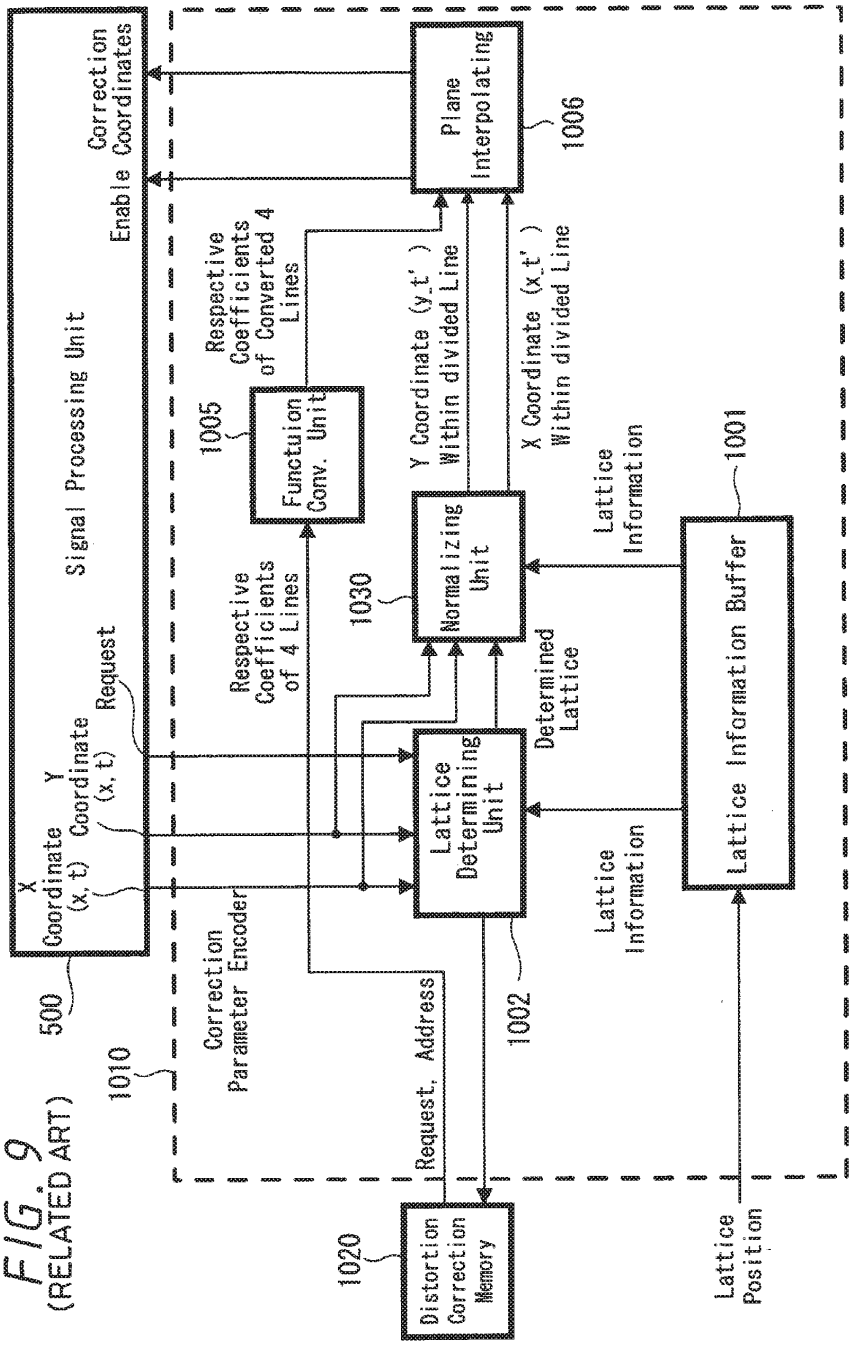
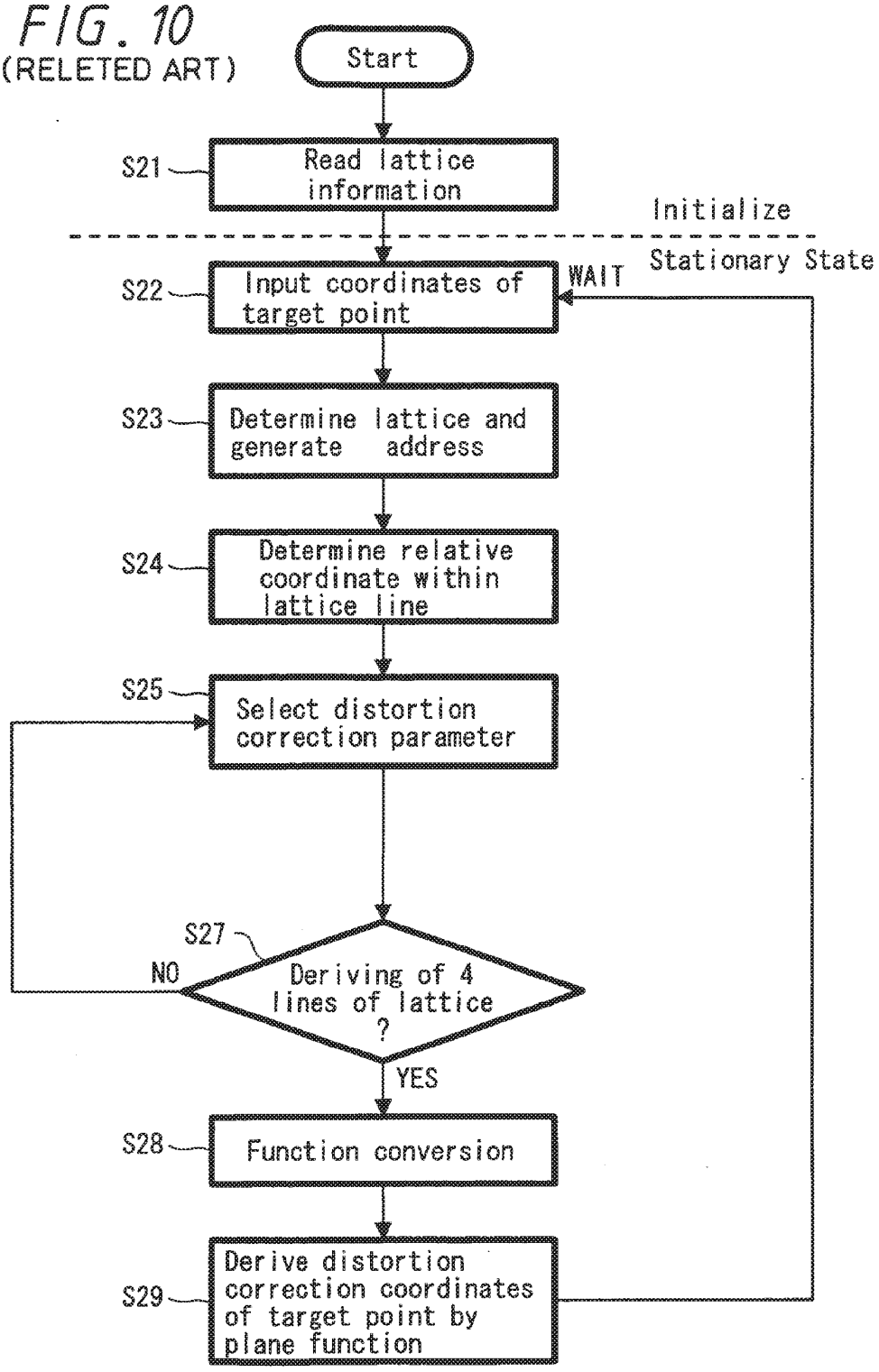


FIG. 9
(RELATED ART)

FIG. 10
(RELETED ART)



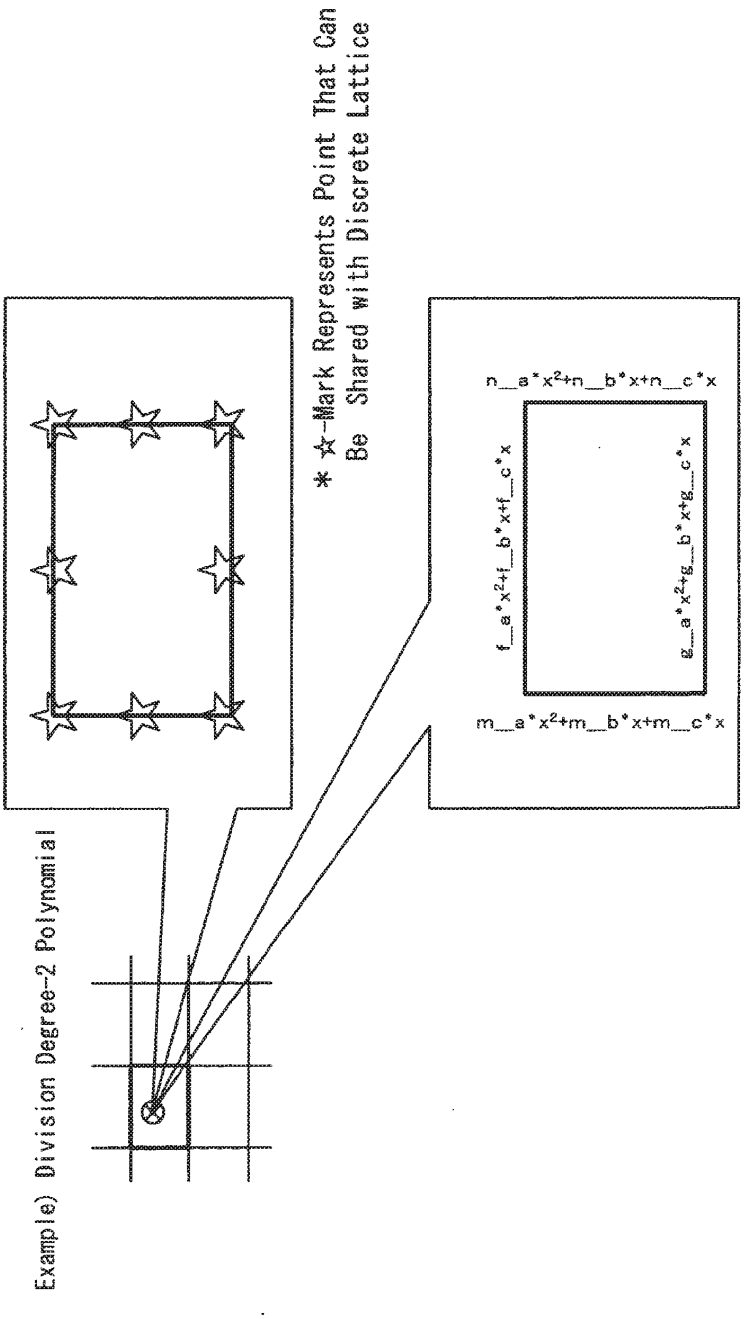


FIG. 11
(RELATED ART)

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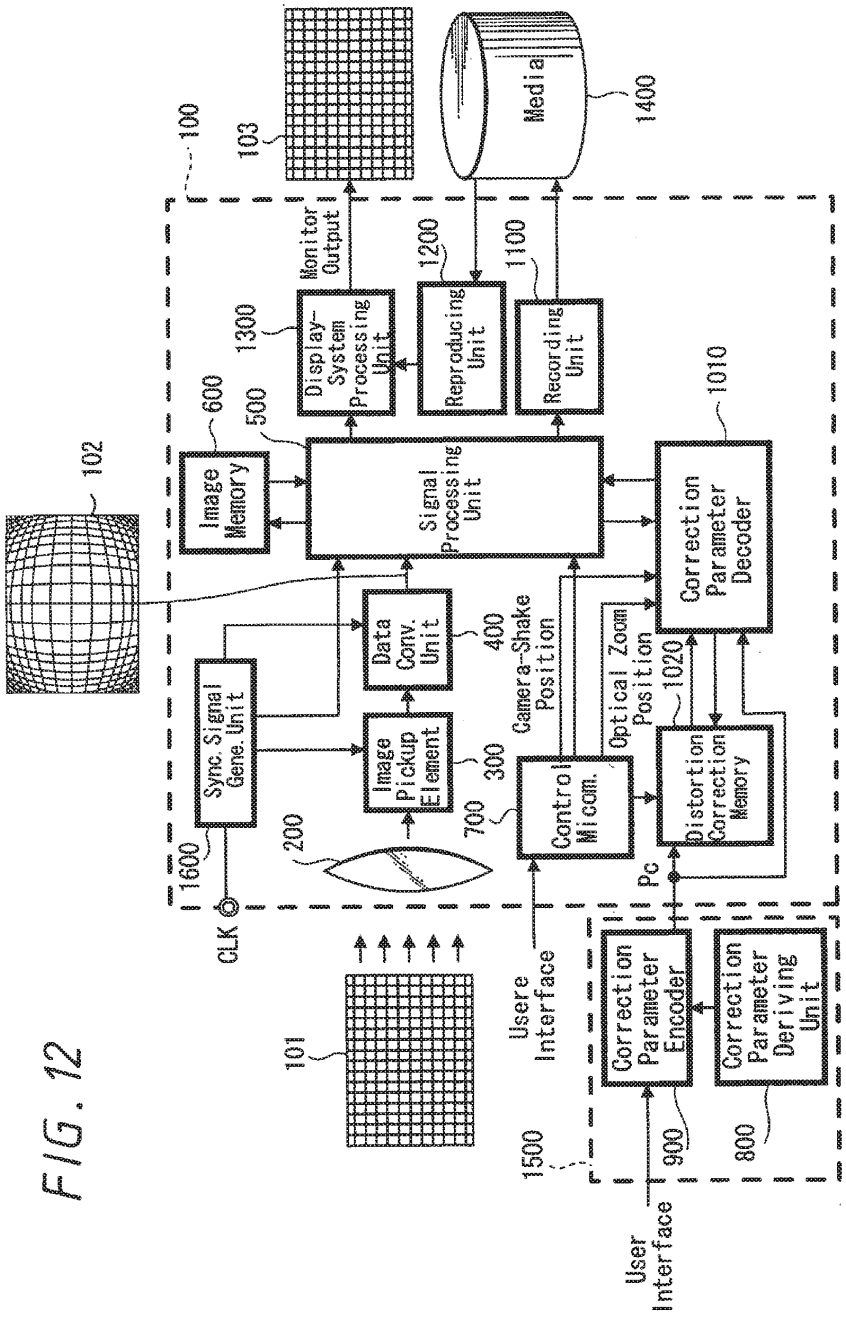
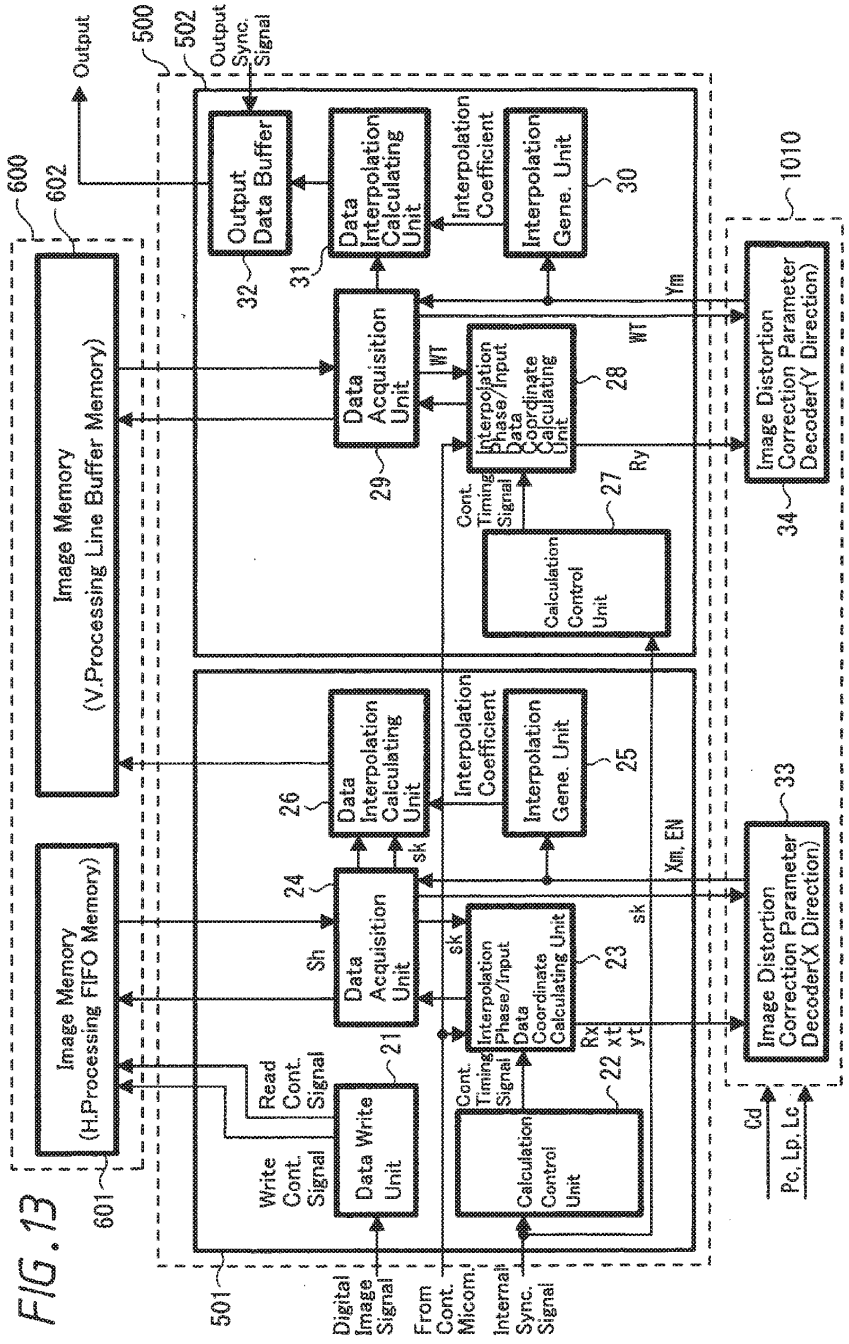
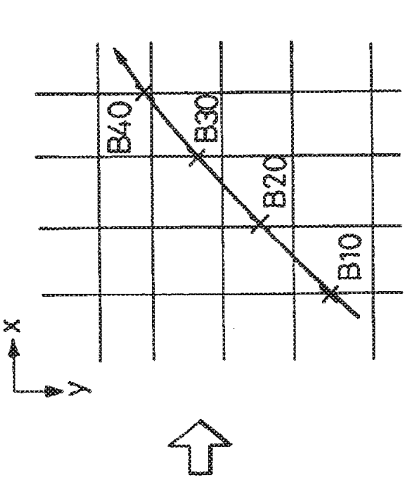


FIG. 12

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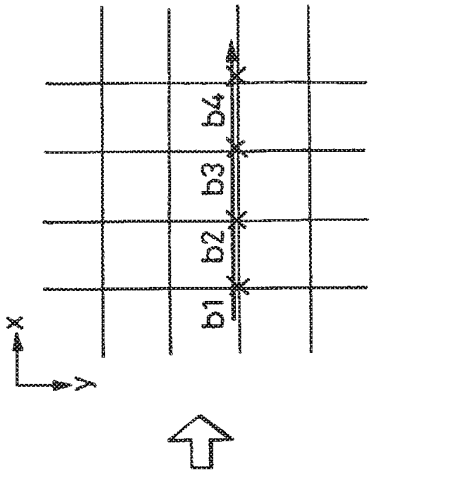
FIG. 13


Output
500
502
Output Sync. Signal
600
602
Image Memory (V.Processing Line Buffer Memory)
Output Data Buffer
32
Data Interpolation Calculating Unit
31
Interpolation Coefficient
Interpolation Gene. Unit
30
1010
Data Acquisition Unit
29
WT
Interpolation Phase/Input Data Coordinate Calculating Unit
28
Ym
Ry
Cont. Timing Signal
Calculation Control Unit
27
Image Distortion Correction Parameter Decoder(Y Direction)
34
Image Memory (H.Processing FIFO Memory)
601
Data Write Unit
21
Write Cont. Signal
Read Cont. Signal
Data Acquisition Unit
24
Sh
sk
Data Interpolation Calculating Unit
26
Interpolation Coefficient
Interpolation Gene. Unit
25
Xm, EN
Interpolation Phase/Input Data Coordinate Calculating Unit
23
Rx
xt
yt
22
Image Distortion Correction Parameter Decoder(X Direction)
33
Cd
Pc, Lp, Lc
501
Digital Image Signal
From Cont. Micom.
Internal Sync. Signal



x Direction Correction

FIG. 14A



y Direction Correction

FIG. 14B

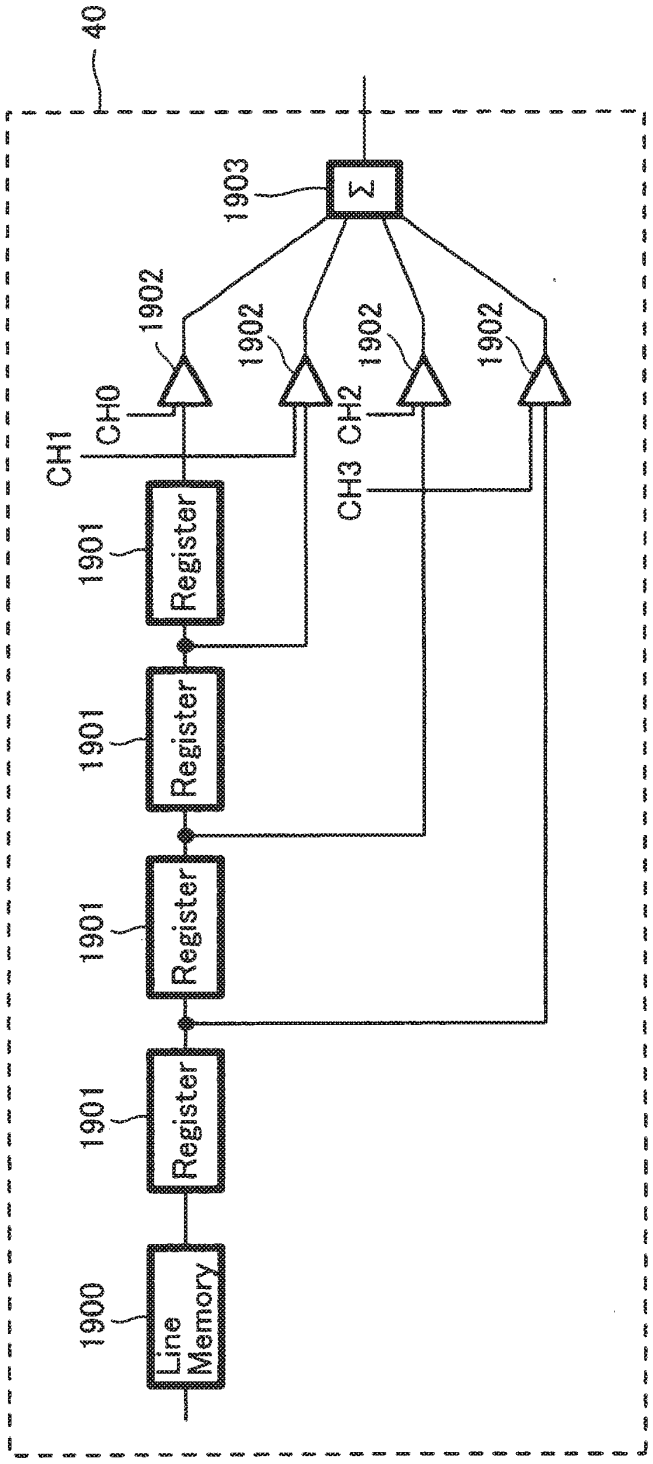

40
1903
Σ
1902
1902
1902
1902
CH0
CH1
CH2
CH3
1901
Register
1901
Register
1901
Register
1901
Register
1900
Line Memory

FIG. 15

FIG. 16

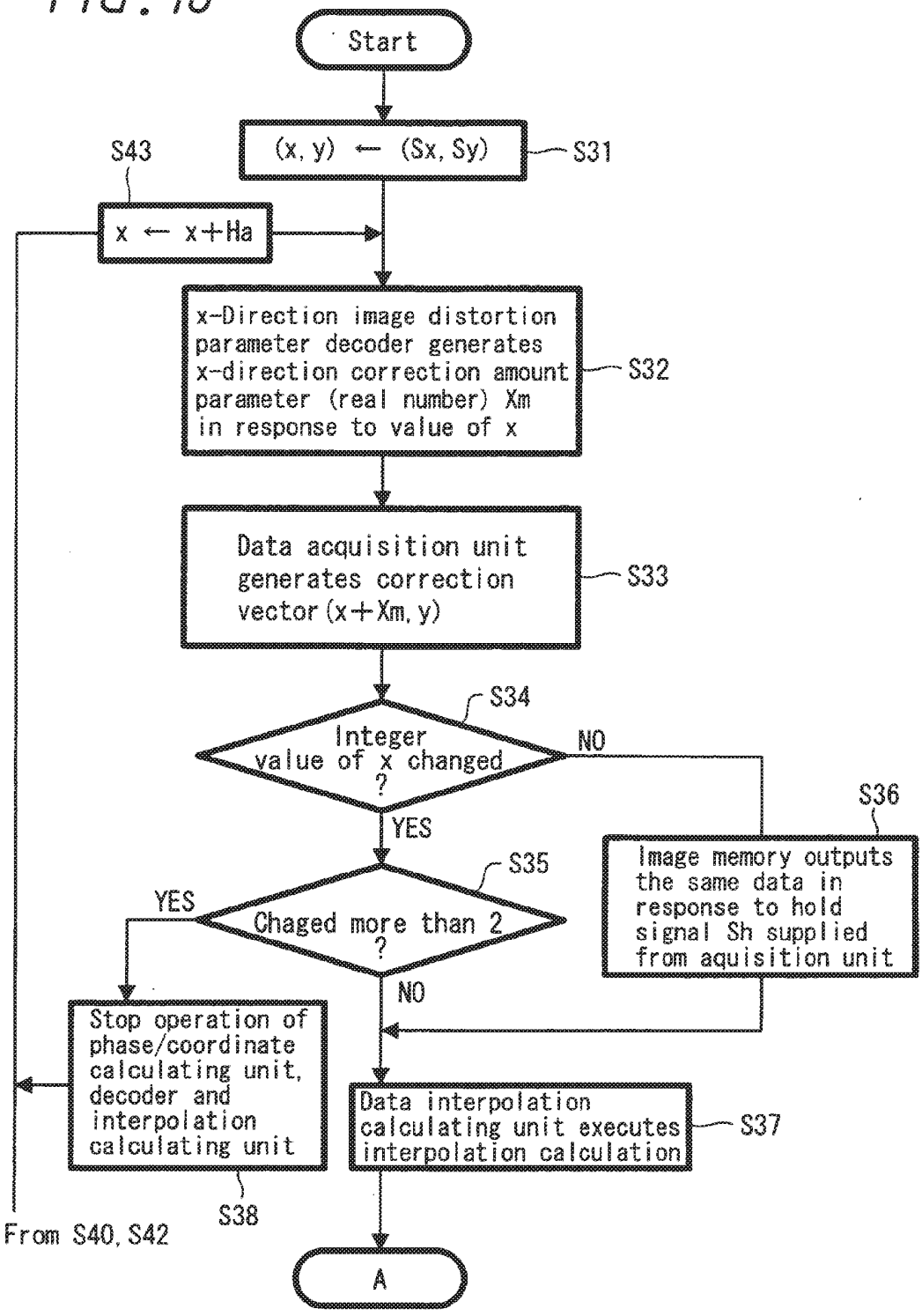

Start
(x, y) ← (Sx, Sy)
S31
S43
x ← x+Ha
x-Direction image distortion parameter decoder generates x-direction correction amount parameter (real number) Xm in response to value of x
S32
Data acquisition unit generates correction vector (x+Xm, y)
S33
S34
Integer value of x changed ?
NO
YES
S36
Image memory outputs the same data in response to hold signal Sh supplied from aquisition unit
S35
YES
Chaged more than 2 ?
NO
Stop operation of phase/coordinate calculating unit, decoder and interpolation calculating unit
S38
Data interpolation calculating unit executes interpolation calculation
S37
From S40, S42
A

FIG. 17

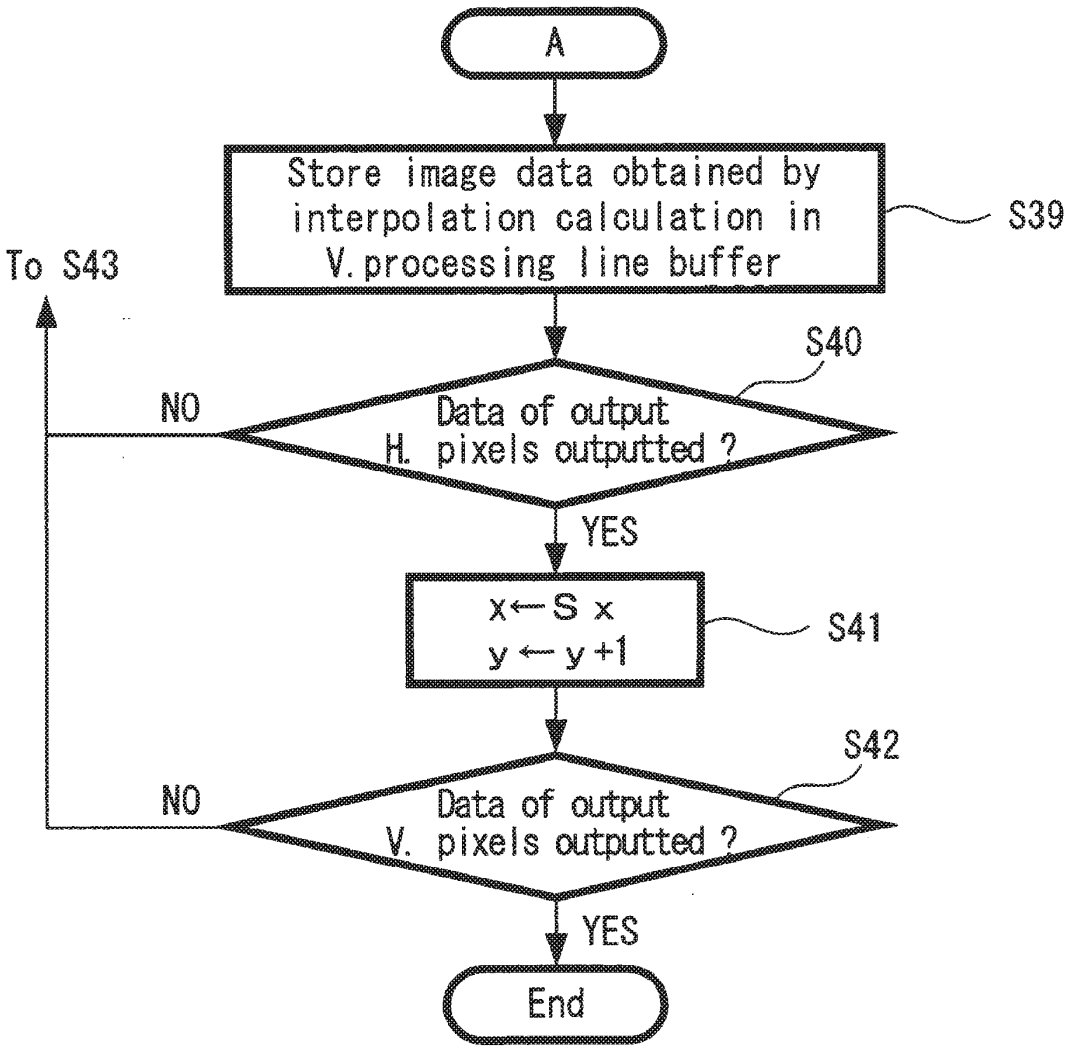

A
Store image data obtained by interpolation calculation in V. processing line buffer
S39
To S43
S40
NO
Data of output H. pixels outputted ?
YES
x ← S x
y ← y +1
S41
S42
NO
Data of output V. pixels outputted ?
YES
End

FIG. 18A

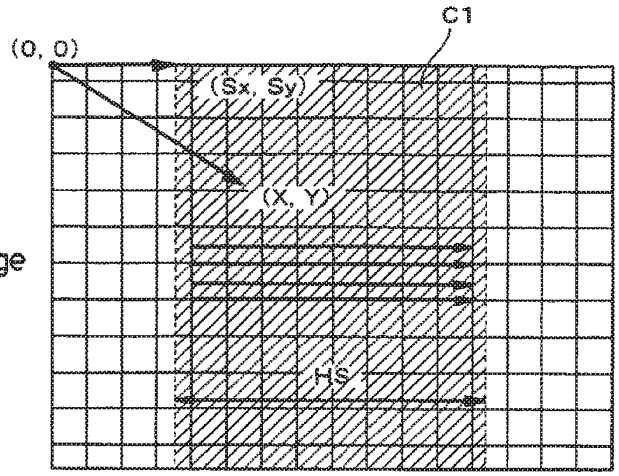


FIG. 18B

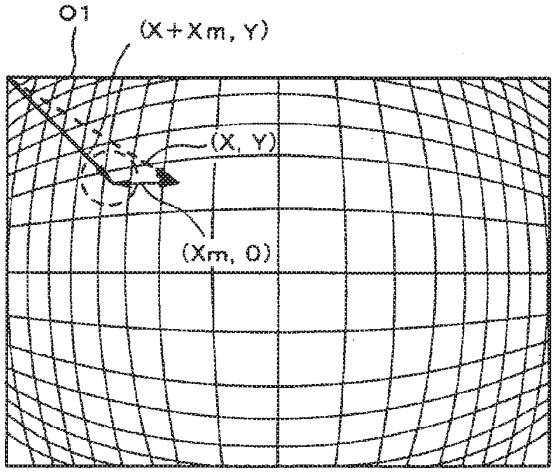
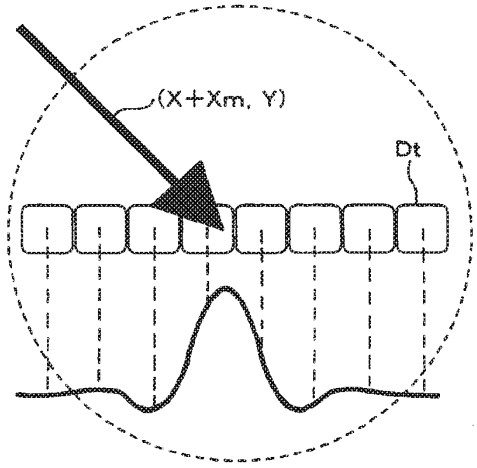


FIG. 18C



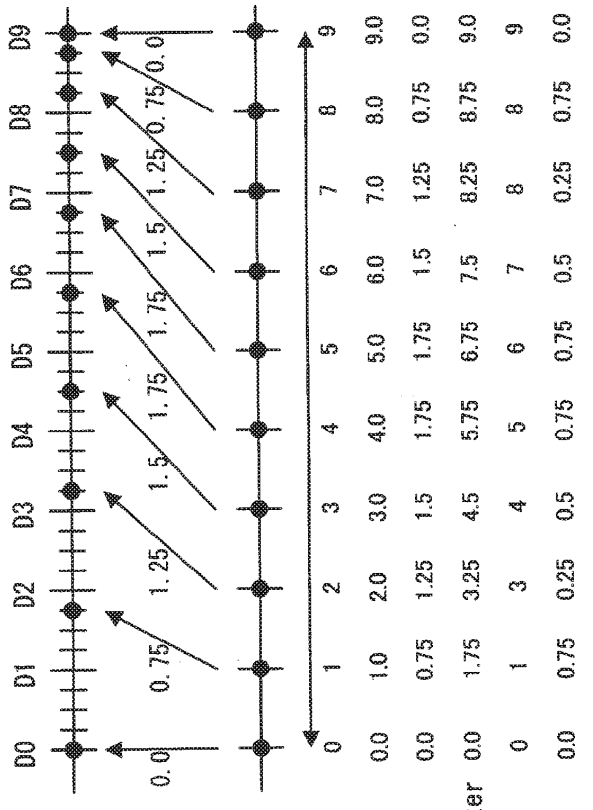


FIG. 19A

FIG. 19B

FIG. 19C

FIG. 19D

FIG. 19E

FIG. 19F

FIG. 19G

FIG. 19H

FIG. 19I

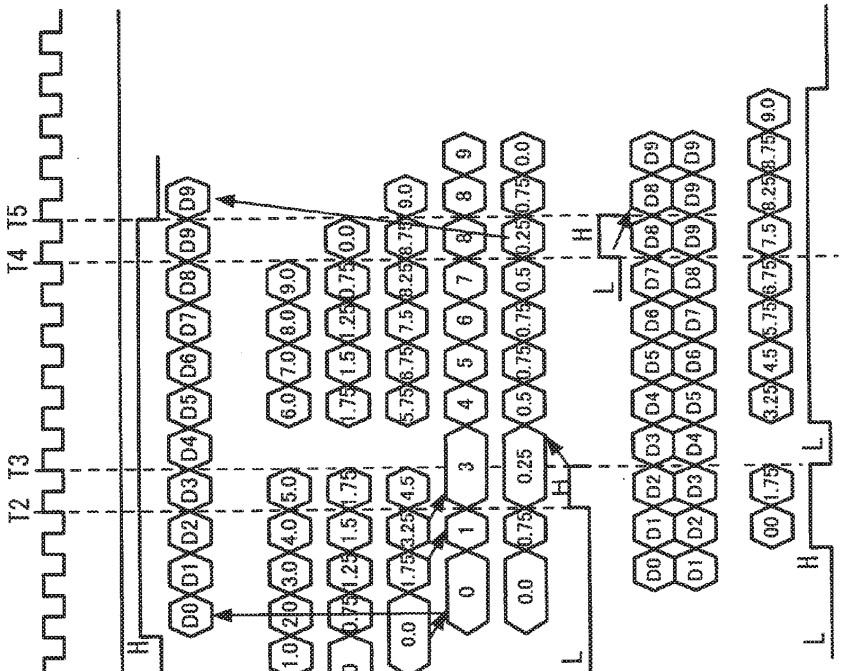


FIG. 20A Internal Sync. Signal
FIG. 20B Control Timing Signal
FIG. 20C Read Control Signal
FIG. 20D Interpolation Data
FIG. 20E xt
FIG. 20F Xm
FIG. 20G Interpolation Parameter
FIG. 20H Address
FIG. 20I Interpolation Phase
FIG. 20J sk
FIG. 20K Sh
FIG. 20L 2-Tap Data
FIG. 20M Output Data
FIG. 20N Output Enable Signal

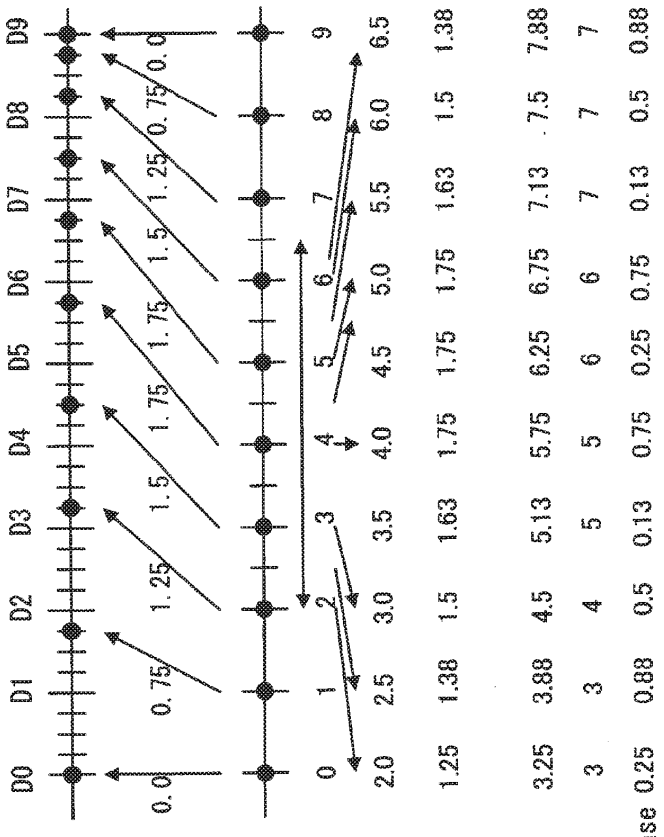


FIG. 21A
FIG. 21B
FIG. 21C
FIG. 21D
FIG. 21E
FIG. 21F
FIG. 21G
FIG. 21H
FIG. 21I

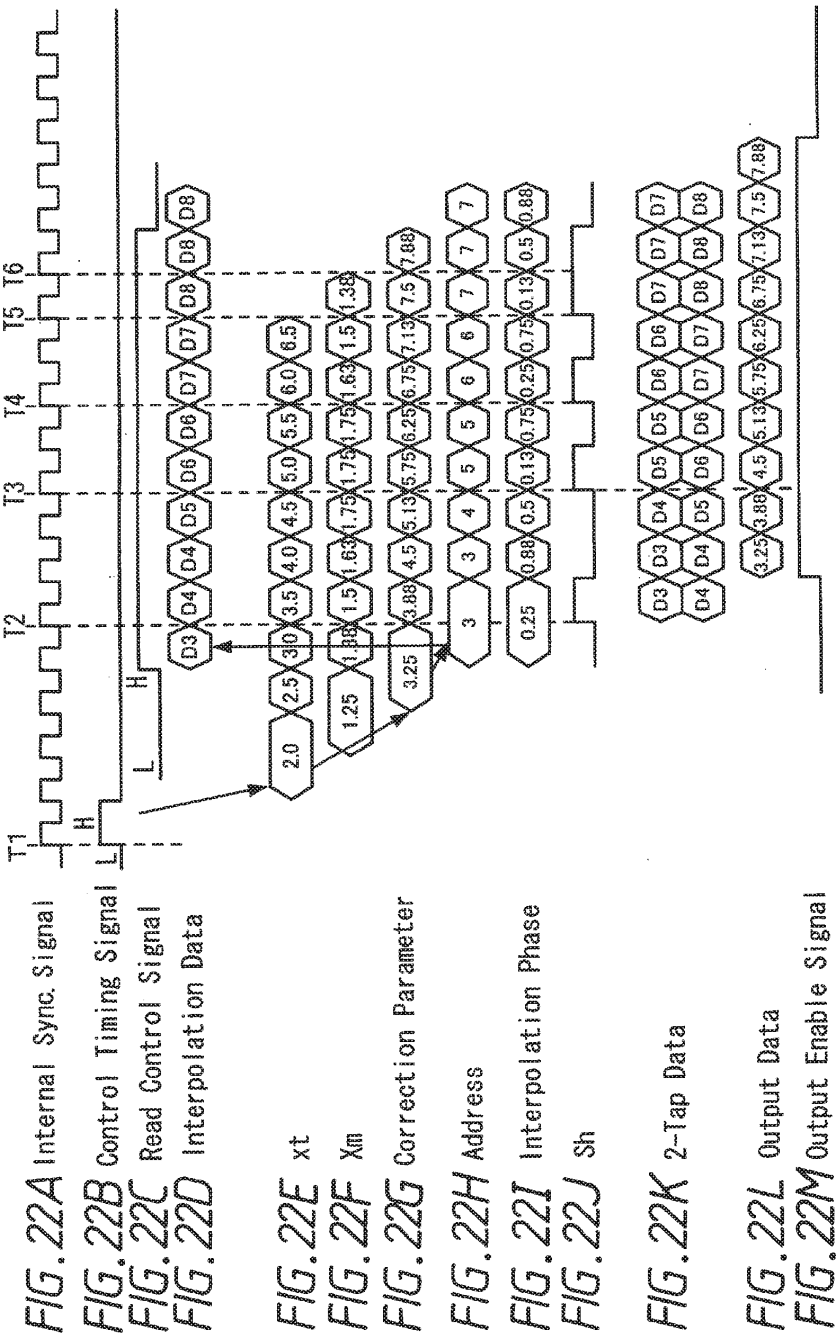


FIG. 22A Internal Sync. Signal
FIG. 22B Control Timing Signal
FIG. 22C Read Control Signal
FIG. 22D Interpolation Data
FIG. 22E xt
FIG. 22F Xm
FIG. 22G Correction Parameter
FIG. 22H Address
FIG. 22I Interpolation Phase
FIG. 22J Sh
FIG. 22K 2-Tap Data
FIG. 22L Output Data
FIG. 22M Output Enable Signal

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FIG. 23

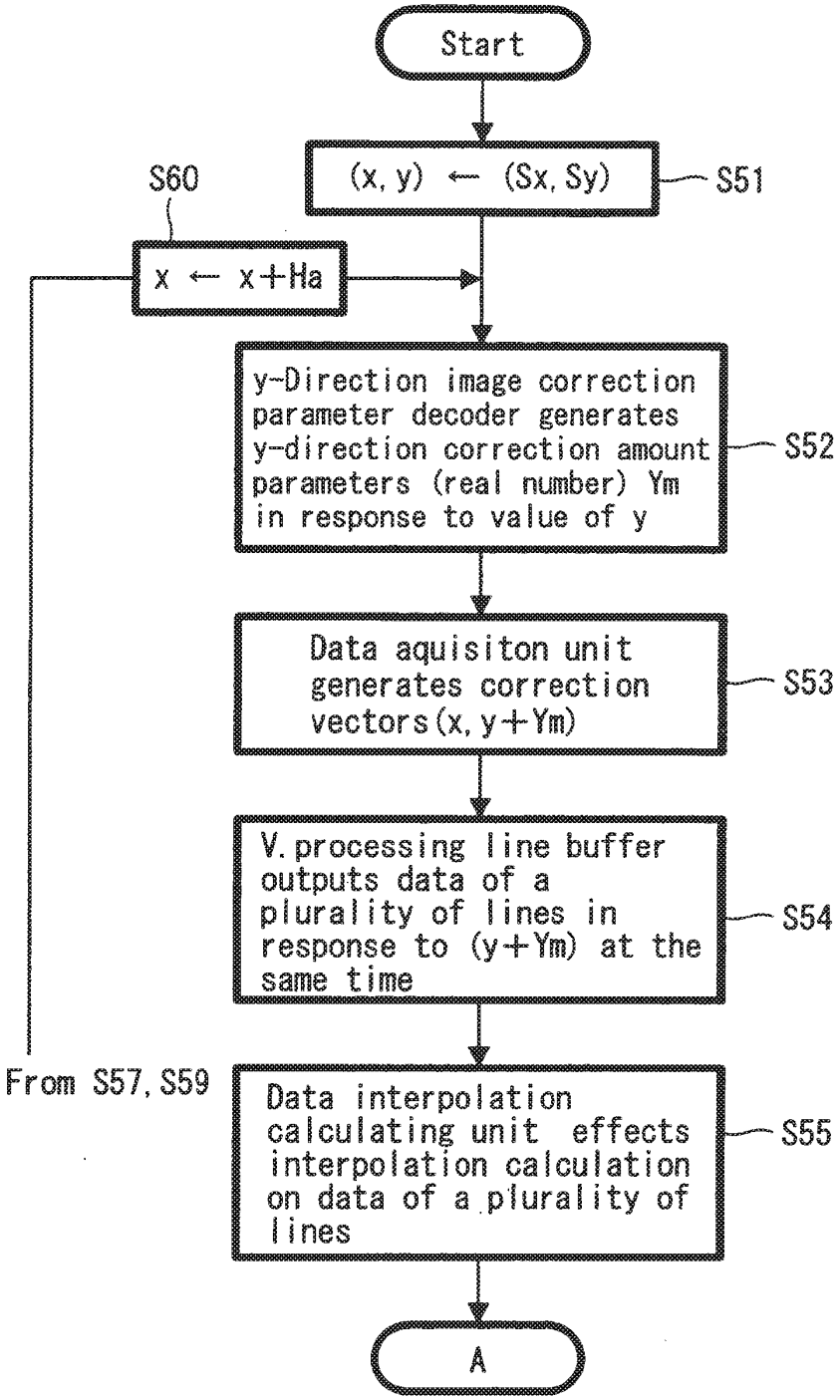

Start
(x, y) ← (Sx, Sy)
S51
S60
x ← x+Ha
y-Direction image correction parameter decoder generates y-direction correction amount parameters (real number) Ym in response to value of y
S52
Data aquisiton unit generates correction vectors(x, y+Ym)
S53
V. processing line buffer outputs data of a plurality of lines in response to (y+Ym) at the same time
S54
From S57, S59
Data interpolation calculating unit effects interpolation calculation on data of a plurality of lines
S55
A

FIG. 24

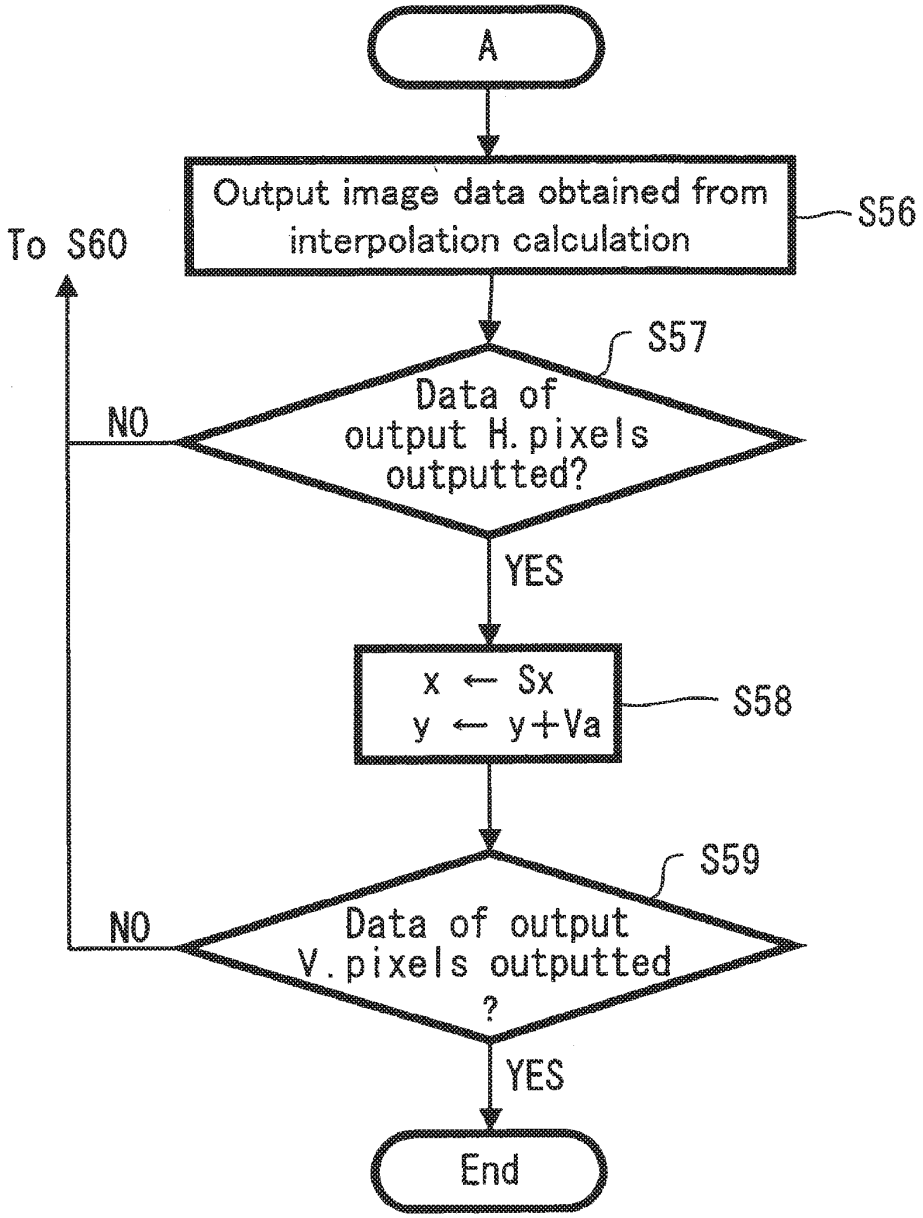
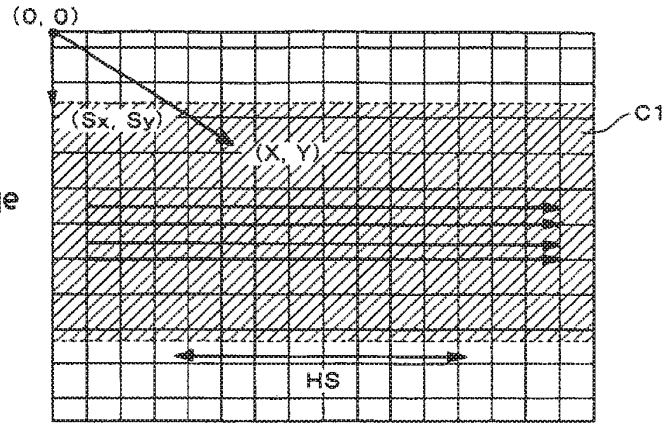

A
Output image data obtained from interpolation calculation
S56
To S60
S57
Data of output H.pixels outputted?
NO
YES
x ← Sx
y ← y+Va
S58
S59
Data of output V.pixels outputted ?
NO
YES
End

FIG. 25A



Corrected Image

FIG. 25B

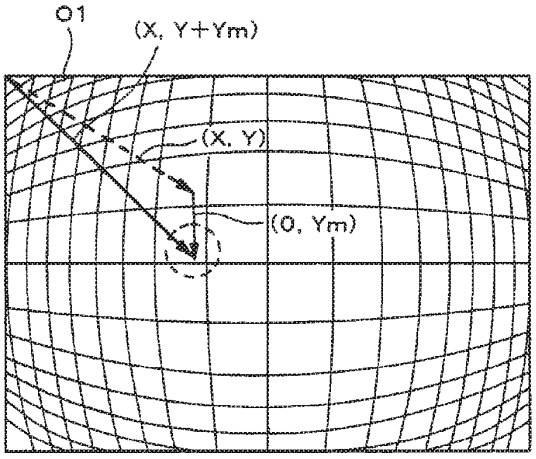
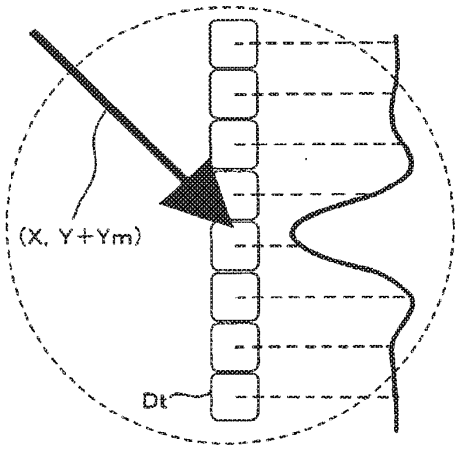


Image Obtained Before Being Corrected

FIG. 25C



Luminance Signal

FIG. 26

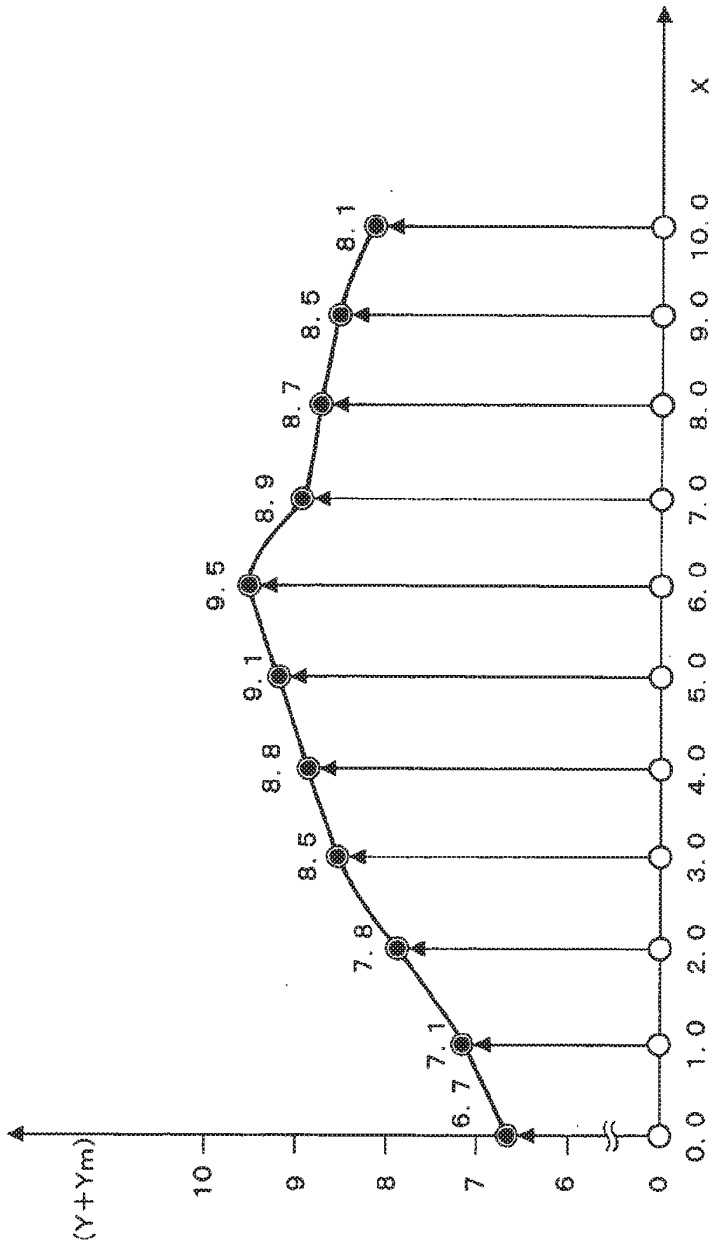

(Y+Ym)
10
9
8
7
6
0
X
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
6.7
7.1
7.8
8.5
8.8
9.1
9.5
8.9
8.7
8.5
8.1

FIG. 27

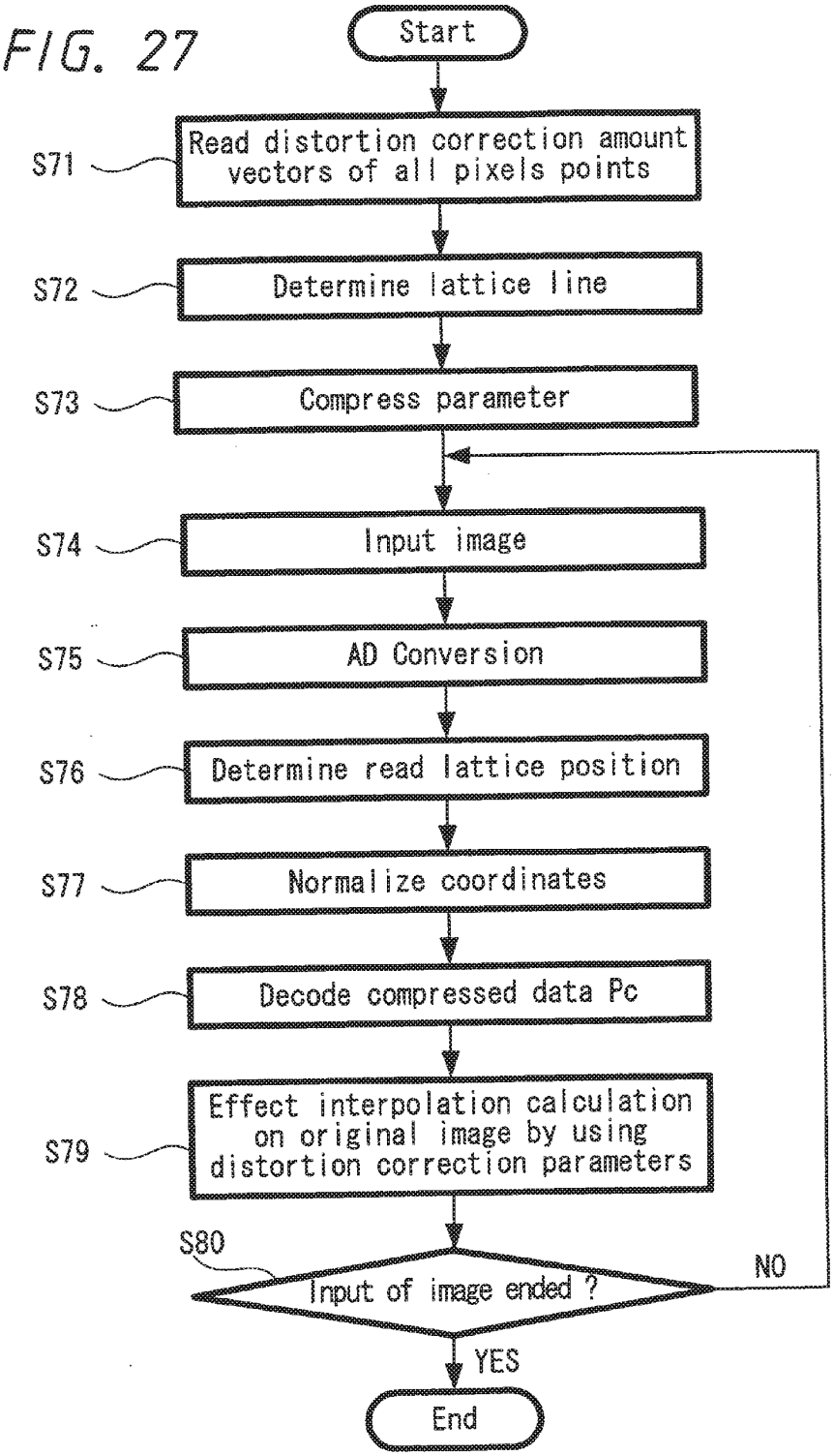
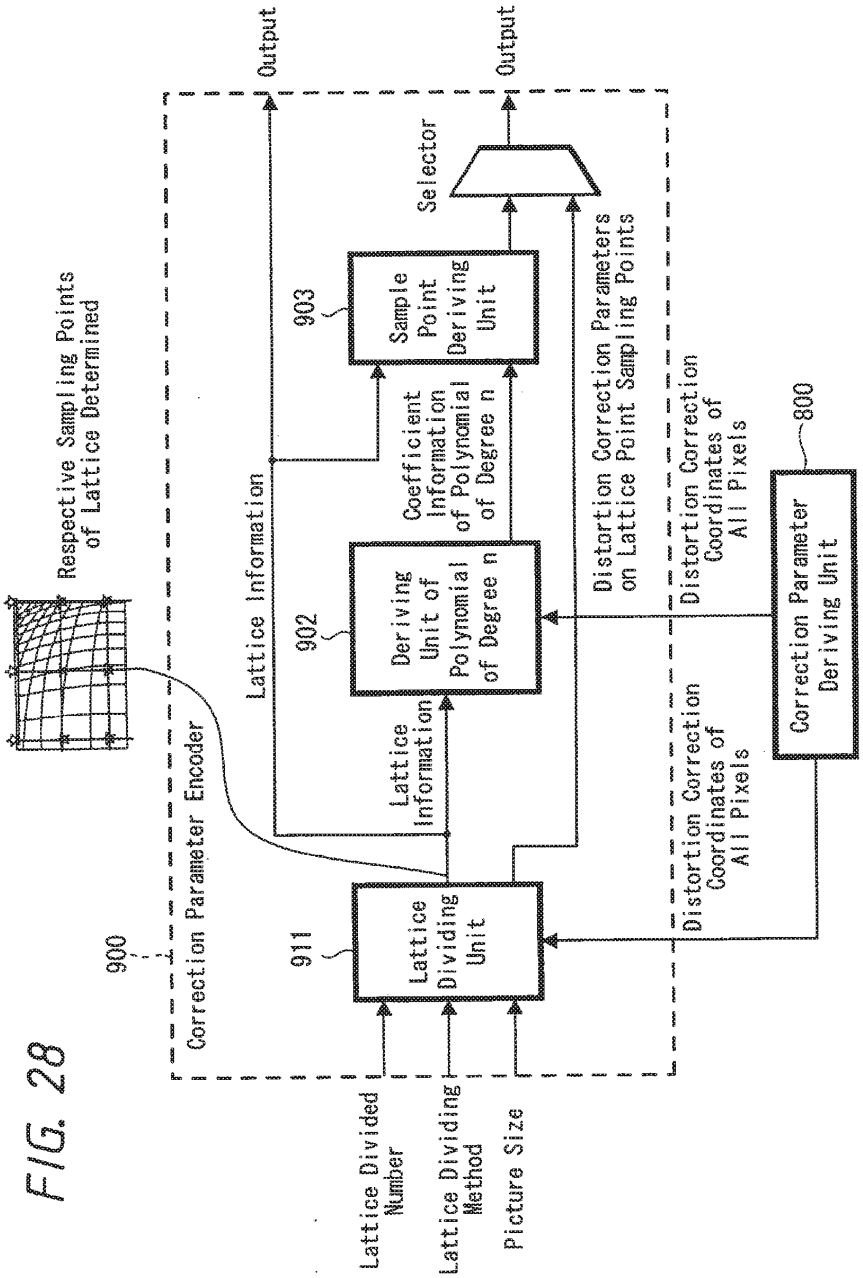

Start
S71
Read distortion correction amount vectors of all pixels points
S72
Determine lattice line
S73
Compress parameter
S74
Input image
S75
AD Conversion
S76
Determine read lattice position
S77
Normalize coordinates
S78
Decode compressed data Pc
S79
Effect interpolation calculation on original image by using distortion correction parameters
S80
Input of image ended ?
NO
YES
End

FIG. 28



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FIG. 29A

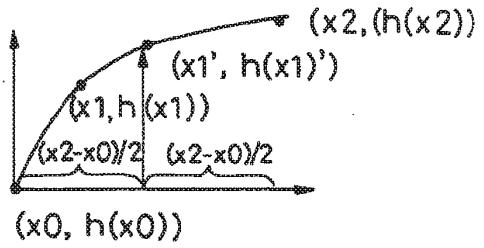


FIG. 29B

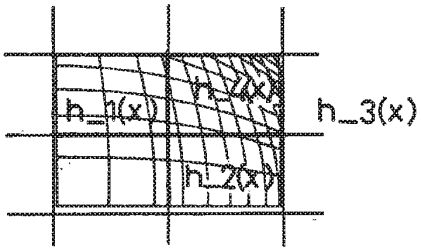


FIG. 29C

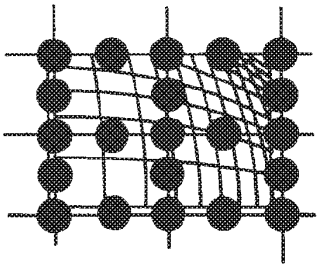


FIG. 30

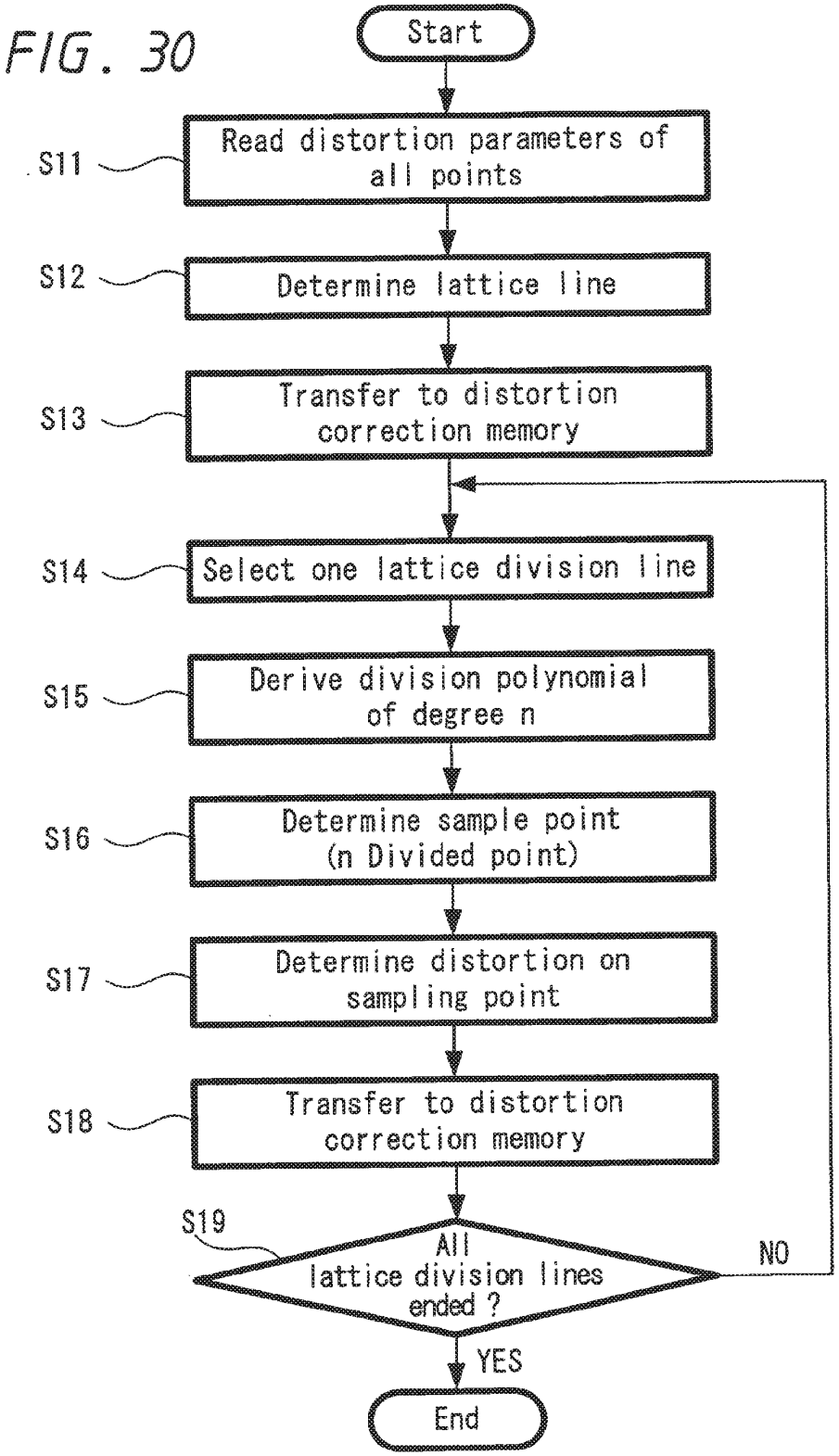

Start
S11
Read distortion parameters of all points
S12
Determine lattice line
S13
Transfer to distortion correction memory
S14
Select one lattice division line
S15
Derive division polynomial of degree n
S16
Determine sample point (n Divided point)
S17
Determine distortion on sampling point
S18
Transfer to distortion correction memory
S19
All lattice division lines ended ?
NO
YES
End

FIG. 31

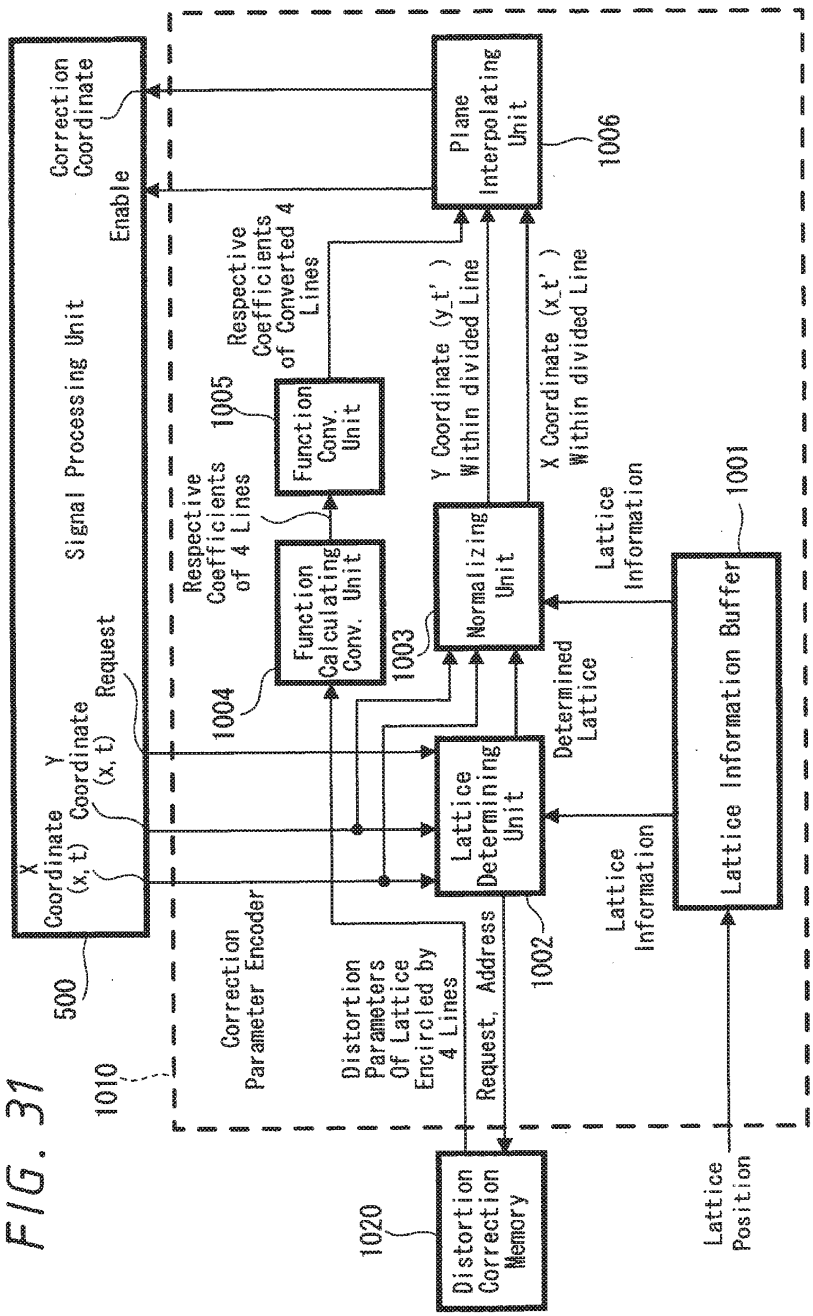
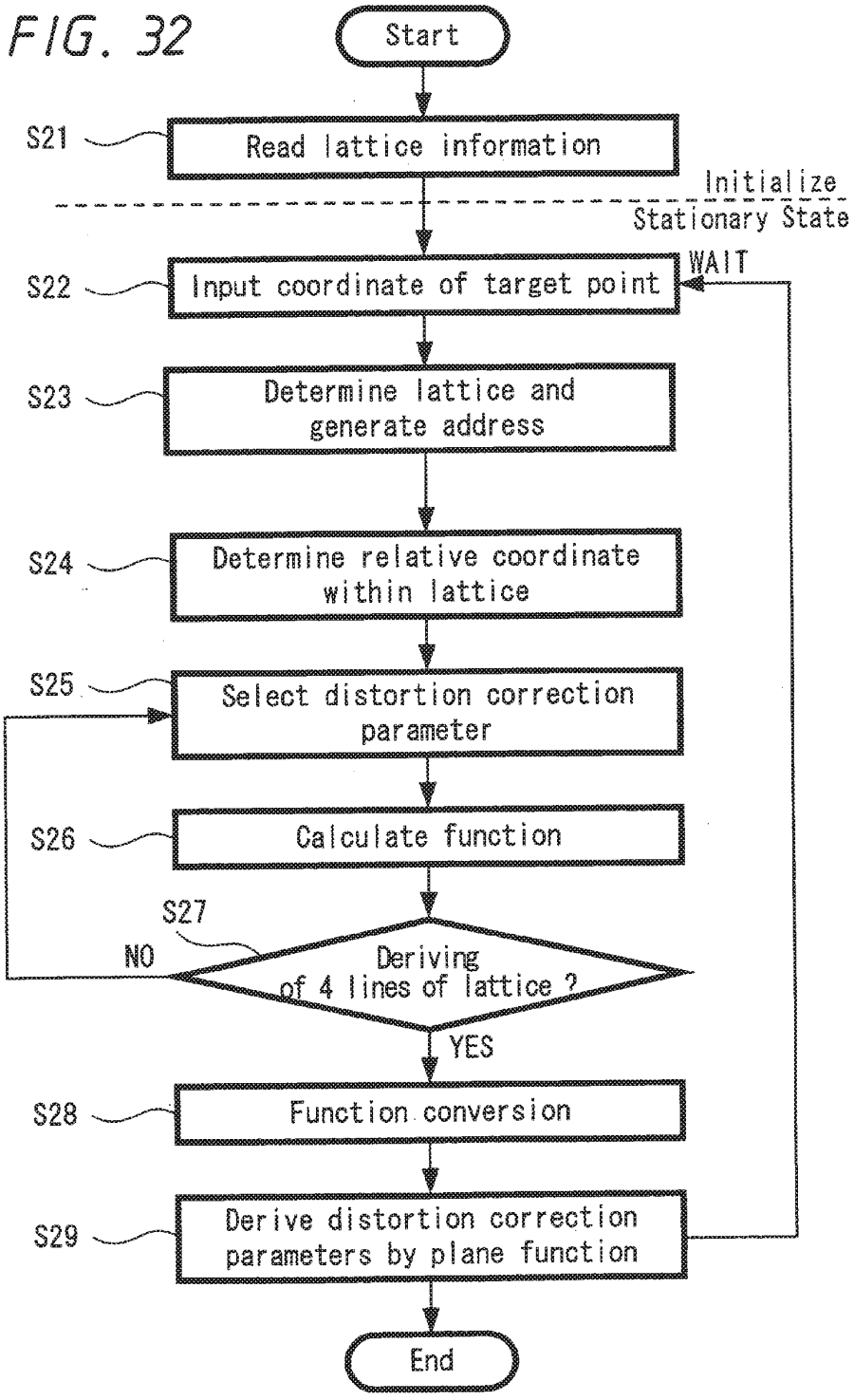

Signal Processing Unit
X Coordinate (x, t)
Y Coordinate (x, t)
Request
Correction Coordinate
Enable
500
1010
Correction Parameter Encoder
Distortion Parameters Of Lattice Encircled by 4 Lines
Request, Address
1002
Lattice Determining Unit
Determined Lattice
Lattice Information
Lattice Information Buffer
1001
Lattice Position
1020
Distortion Correction Memory
1004
Function Calculating Conv. Unit
Respective Coefficients of 4 Lines
1005
Function Conv. Unit
Respective Coefficients of Converted 4 Lines
1003
Normalizing Unit
Y Coordinate (y_t')
Within divided Line
X Coordinate (x_t')
Within divided Line
Lattice Information
1006
Plane Interpolating Unit

FIG. 32


Start
S21
Read lattice information
Initialize
Stationary State
WAIT
S22
Input coordinate of target point
S23
Determine lattice and generate address
S24
Determine relative coordinate within lattice
S25
Select distortion correction parameter
S26
Calculate function
S27
NO
Deriving of 4 lines of lattice ?
YES
S28
Function conversion
S29
Derive distortion correction parameters by plane function
End

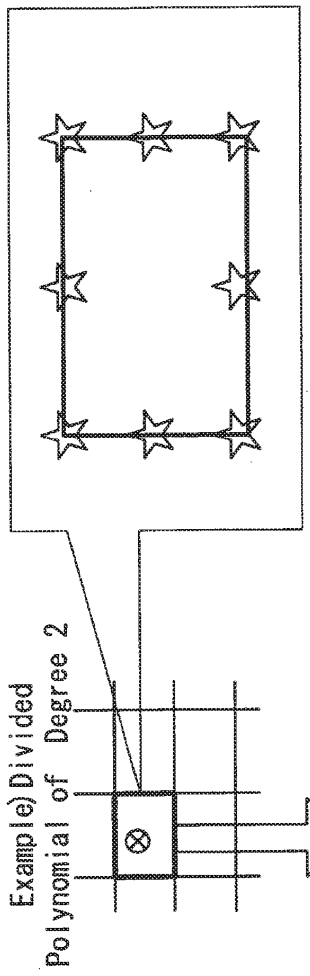


FIG. 33A

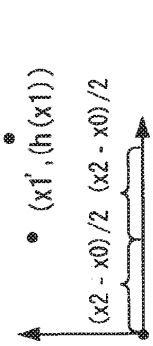


FIG. 33B

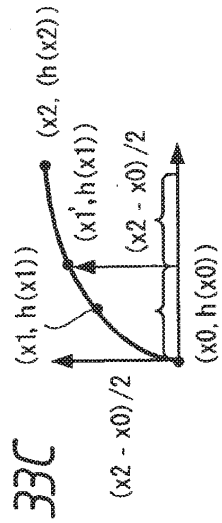


FIG. 33C

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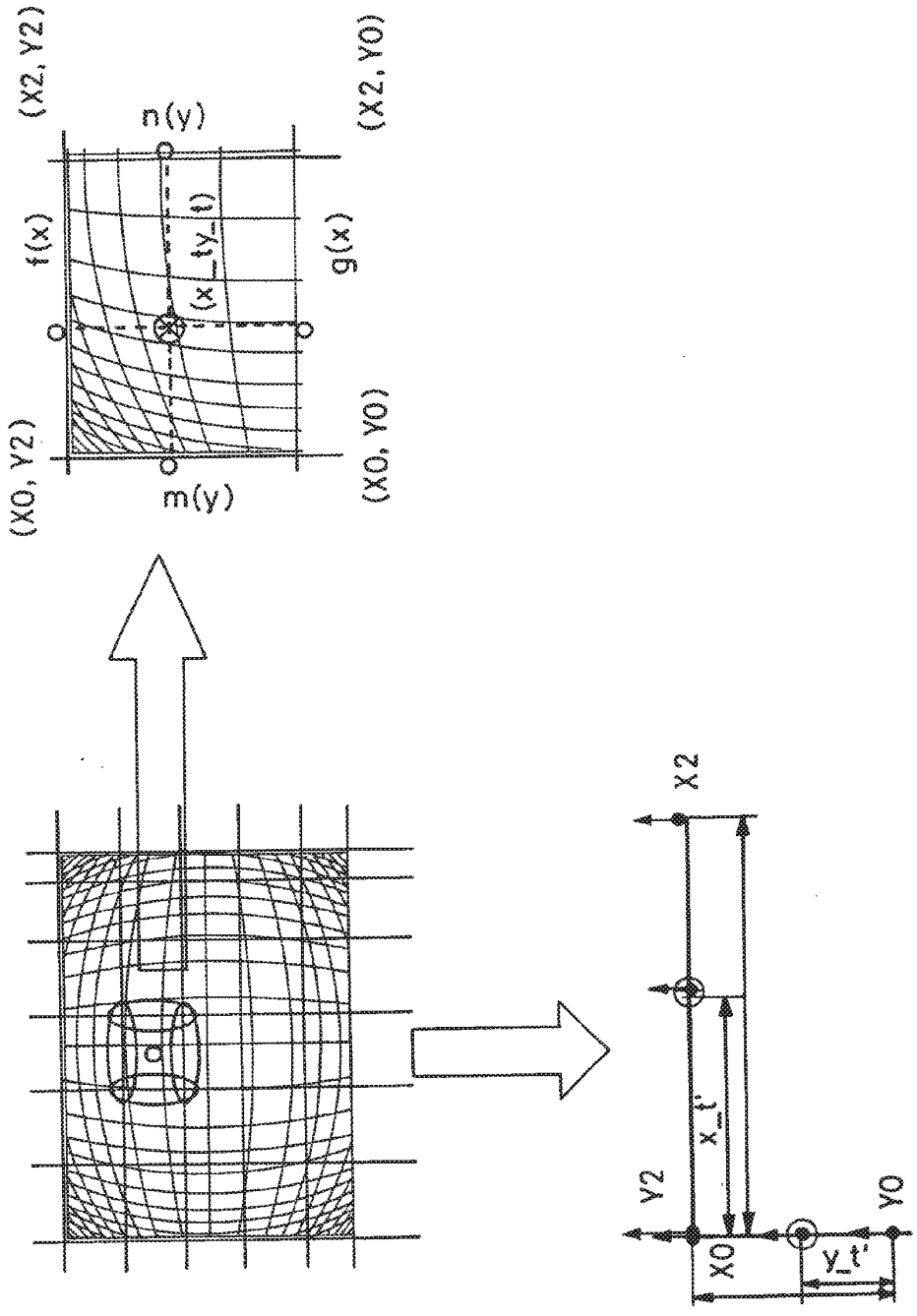
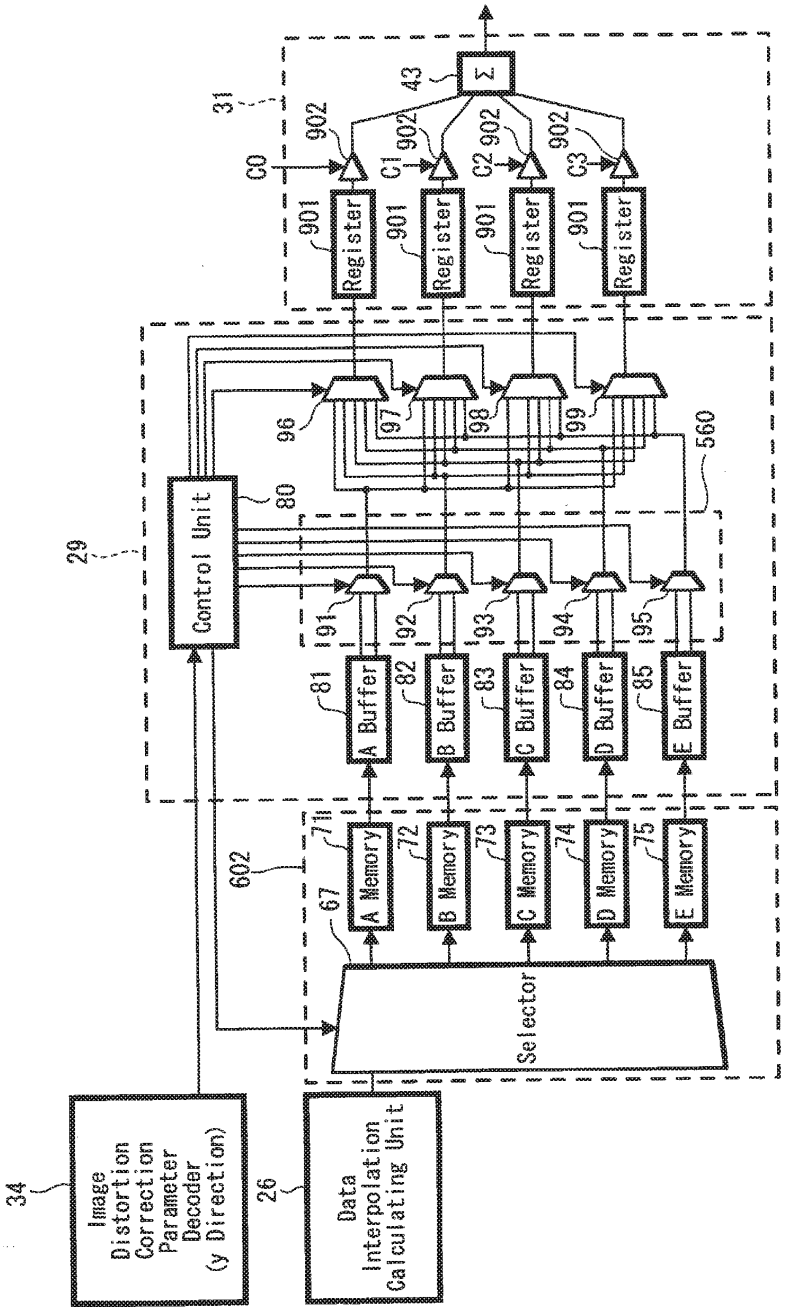


FIG. 34

FIG. 35



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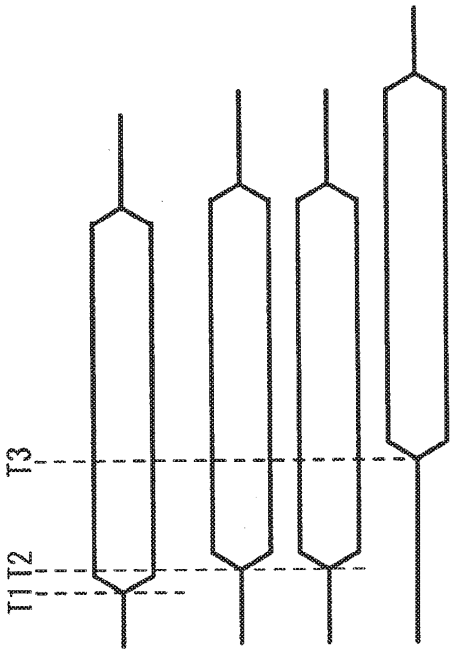


FIG. 36A

FIG. 36B

FIG. 36C

FIG. 36D

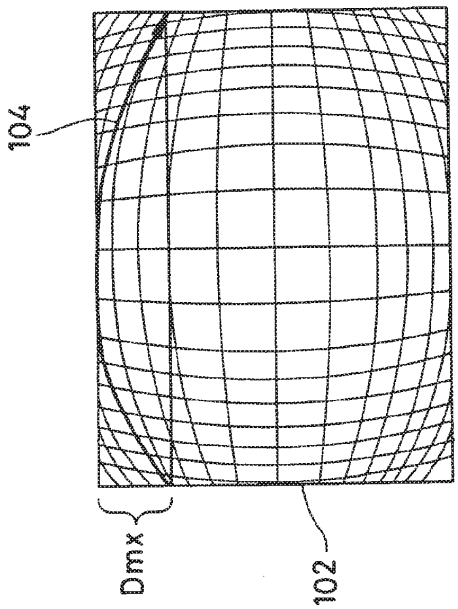
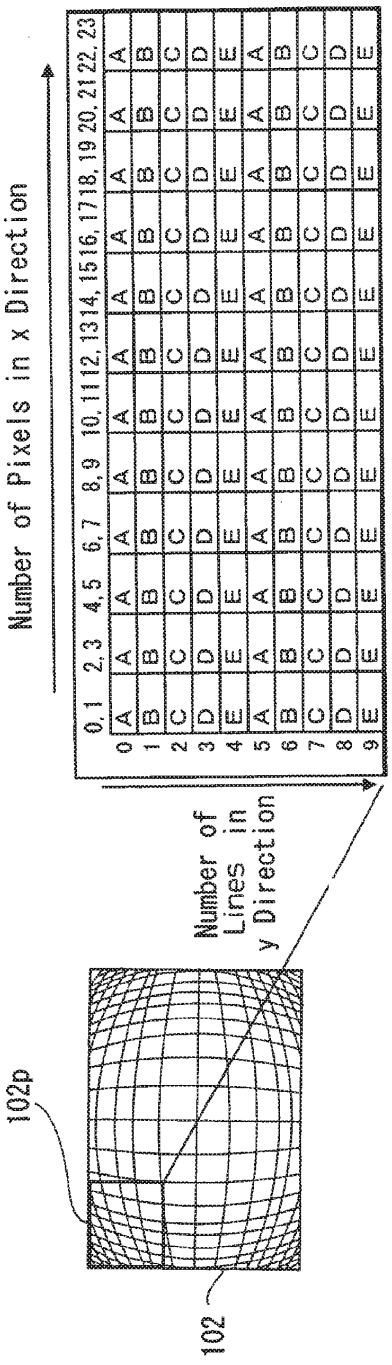


FIG. 37

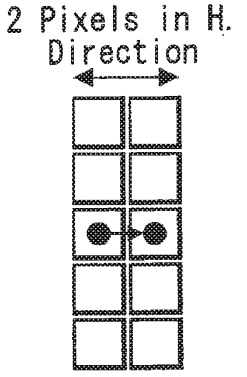
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FIG. 38



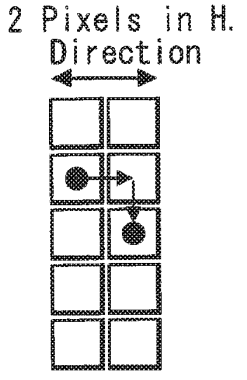
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FIG. 39A



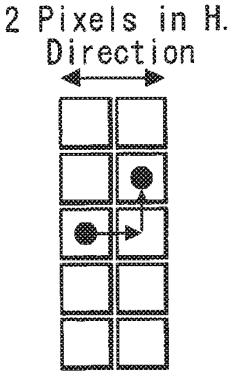
Pattern1

FIG. 39B



Pattern2

FIG. 39C



Pattern3

FIG. 40A

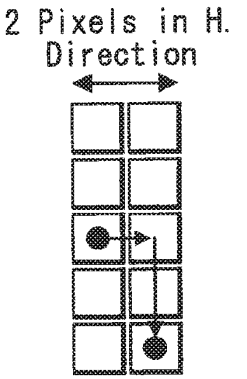


FIG. 40B

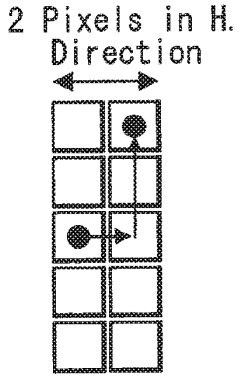


FIG. 41

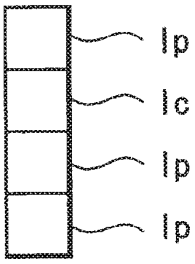
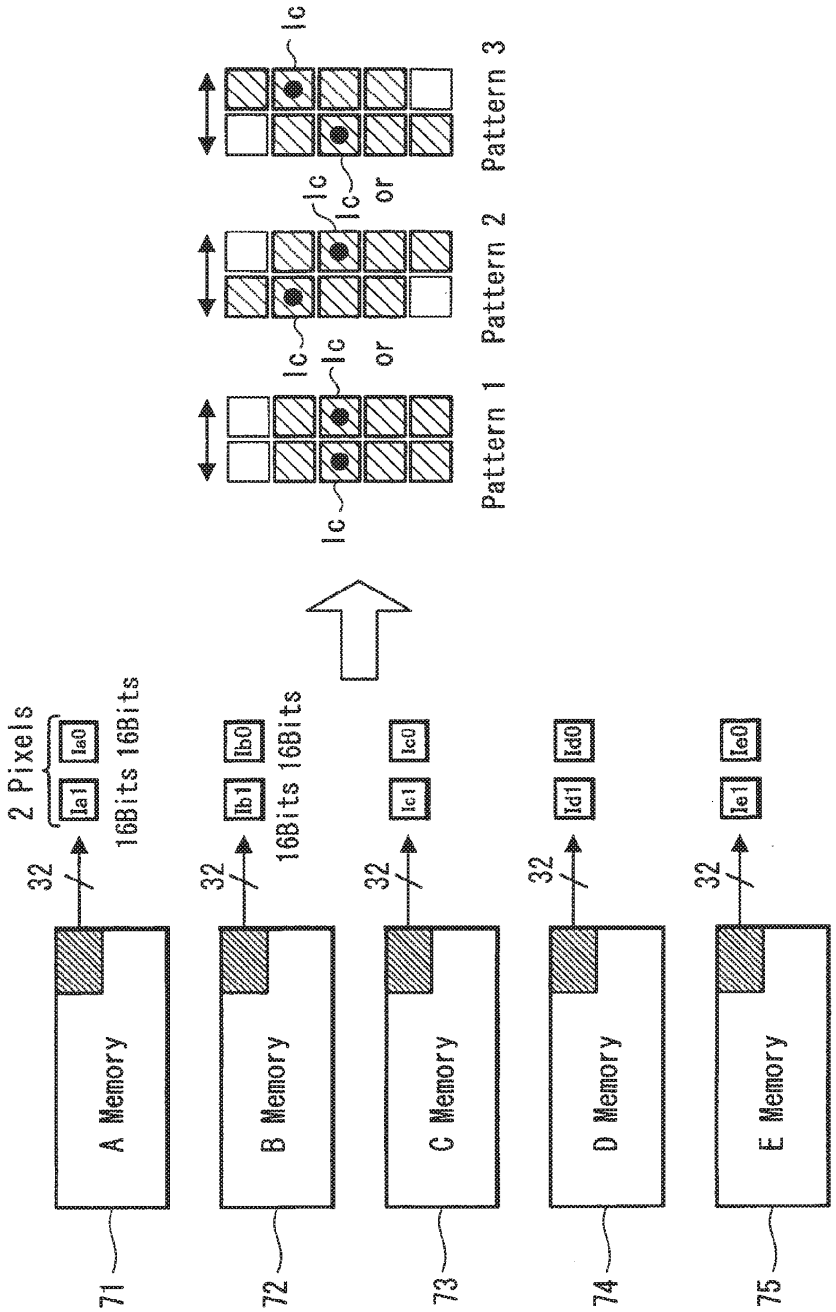


FIG. 42



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IMAGE PROCESSING METHOD, IMAGE PROCESSING APPARATUS AND IMAGE PICKUP APPARATUS AND DISPLAY APPARATUS SUITABLE FOR THE APPLICATION OF IMAGE PROCESSING METHOD

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to an image processing method, an image processing apparatus for use with a video camera, a digital still camera and a silver halide camera and an image pickup apparatus and a display apparatus suitable for the application of this image processing method.

[0003] 2. Description of the Related Art

[0004] So far distortion has been caused in an image picked up by a video camera, a digital still camera or a silver halide camera by influences of distortion characteristics of an image pickup lens. While such distortions are inconspicuous in highly-accurate and high-performance lenses, when an inexpensive lens or an optical zoom lens is in use, it is difficult to avoid influences exerted by distortions completely.

[0005] To avoid these defects, in recent years, an image processing apparatus has been proposed to correct distortions by signal processing.

[0006] **FIG. 1** of the accompanying drawings is a block diagram showing an arrangement of an image processing apparatus **100** according to the related art. As shown in **FIG. 1**, the image processing apparatus **100** according to the related art includes a lens **200**, an image pickup element **300**, a data converting unit **400**, a signal processing unit **500**, an image memory **600**, a control microcomputer **700**, a synchronizing signal generating unit **800**, a correction data table **1000**, a recording unit **100**, a reproducing unit **1200** and a display-system processing unit **1300**.

[0007] Outlines of operations of the above-described image processing apparatus **100** will be described with reference to a flowchart of **FIG. 2**.

[0008] Referring to **FIG. 2**, and following the start of operation, control goes to a step **S1**, whereat an analog image signal for an object **100** is inputted to the image processing apparatus **100** through the lens **200** and the image pickup element **300**. Control goes to the next step **S2**, whereat the data converting unit **400** converts the analog image signal to a digital image signal to thereby generate an image **102**.

[0009] In the next step S3, the signal processing unit **500** effects correction calculation on the distorted image **102** by using a distortion correction vector (hereinafter simply referred to as a "correction vector") stored in the correction data table **1000**. In the next decision step **S4**, it is determined by the control microcomputer **700** whether or not inputting of the analog image signal should be ended. If inputting of the analog image signal is not ended as represented by a NO at the decision step **S4**, control goes back to the step **S1**. If a YES is outputted at the decision step **S4**, control is ended.

[0010] The outline of the operations of the related-art image processing apparatus **100** has been described so far, and those operations will be described below more fully.

[0011] Referring back to **FIG. 1**, the lens **200** focuses reflected light from an object **101** and maps the focused reflected light on the image pickup element **300**. The image pickup element **300** is composed of a suitable device such as a CCD (charge-coupled device) and a CMOS (complementary metal oxide semiconductor) sensor, and captures the mapped image to generate the analog image signal. The data converting unit **400** converts the analog image signal supplied from the image pickup element **300** to provide the digital image signal to thereby generate the image **102**. On the other hand, the control microcomputer **700** issues a command for instructing a predetermined operation in response to data inputted to an external user interface.

[0012] The signal processing unit **500** stores the digital image signal generated from the data converting unit **400** in the image memory **600** in response to the command supplied thereto from the control microcomputer **700**. Then, the signal processing unit **500** reads out correction vectors corresponding to all pixels from the correction data table **1000** and obtains a necessary image signal from the image memory **600** in response to the correction information. Then, the signal processing unit **500** corrects a distortion of the image **102** outputted from the data converting unit **400** by effecting two-dimensional interpolation system geometric correction on the image signal.

[0013] The image signal generated by the signal processing unit **500** is supplied to the display-system processing unit **1300** and thereby the image **103** is displayed on a monitor (not shown). Alternatively, the image signal generated by the signal processing unit **500** is supplied to the recording unit **1100** and thereby the image is recorded on a media **1400** such as an external magnetic tape or a disc or a memory. The image signal recorded on the media **1400** is reproduced by the reproducing unit **1200** and the reproduced signal is supplied to the display-system processing unit **1300**, whereby the reproduced image **103** is displayed on the monitor.

[0014] Further, the synchronizing signal generating unit **1600** generates an internal synchronizing signal in response to a clock signal CLK supplied thereto from the outside and supplies the thus generated internal synchronizing signal to the image pickup element **300**, the data converting unit **400** and the signal processing unit **500**.

[0015] In this manner, the distortion can be corrected by signal processing. In the technical fields of similar kind, the following cited references have been laid open.

[0016] [Cited patent reference 1]

[0017] Japanese laid-open patent application No. 5-172531

[0018] [Cited patent reference 2]

[0019] Japanese laid-open patent application No. 6-165024

[0020] [Cited patent reference 3]

[0021] Japanese laid-open patent application No. 6-181530

[0022] The assignee of the present application has previously proposed Japanese patent application No. 2002-239865. FIG. **3** shows an arrangement of an image processing system that the assignee of the present application has

previously proposed (Japanese patent application No. 2002-239865). In **FIG. 3**, elements and parts identical to those of **FIG. 1** are denoted by identical reference numerals.

[0023] As shown in **FIG. 3**, the image processing system according to the previously-proposed patent application comprises the image processing apparatus **100**, a pre-processing apparatus **1500** and the media **1400**. The image processing apparatus **100** includes the lens **200**, the image pickup element **300**, the data converting unit **400**, the signal processing unit **500**, the image memory **600**, the control microcomputer **700**, a correction parameter decoder **1010**, the synchronizing signal generating unit **1600**, the recording unit **1100**, the reproducing unit **1200** and the display-system processing unit **1300**. The pre-processing apparatus **1500** includes a correction parameter encoder **900** and a correction parameter deriving unit **800**.

[0024] The lens **200** focuses reflected light from the object **101** and maps the focused reflected light on the image pickup element **300**. The lens **200** is not limited to a single focal point lens and may be a lens with zoom function. The image pickup element **300** is composed of a suitable means such as a CCD and a CMOS sensor and captures a mapped image in response to the internal synchronizing signal supplied thereto from the synchronizing signal generating unit **1600** to generate an analog image signal.

[0025] The data converting unit **400** is connected to the image pickup element **300** and converts the analog image signal generated from the image pickup element **300** in response to the internal synchronizing signal supplied thereto from the synchronizing signal generating unit **1600** into a digital image signal to thereby generate the image **102**. The signal processing unit **500** is connected to the control microcomputer **700**, the data converting unit **400**, the image memory **600**, the correction parameter decoder **1010** and the synchronizing signal generating unit **1600**.

[0026] Then, the signal processing unit **500** stores the digital image signal supplied thereto from the data converting unit **400** in the image memory **600** in response to the command supplied from the control microcomputer **700** and also effects correction processing on the stored image signal based on the correction amount parameter supplied from the correction parameter decoder **1010**. Then, the signal processing unit **500** supplies an image signal obtained by the above correction to the display-system processing unit **1300** and the recording unit **1100**.

[0027] On the other hand, the correction parameter deriving unit **800** calculates in advance correction amount vectors corresponding to respective positions of all pixels from data concerning distortion of the lens **200**. The correction parameter encoder **900** is connected to the correction parameter deriving unit **800** and the user interface and compresses (encodes) the correction amount vectors supplied from the correction parameter deriving unit **800** in response control signals Ln, Lw supplied from the user interface and supplies compressed data Pc to the correction parameter decoder **1010**.

[0028] Although calculation and encoding in the correction parameter deriving unit **800** become calculations having very large calculation loads, such calculations may be executed separately by other suitable means such as a personal computer, and hence may not exert an influence upon real-time processing done by the image processing apparatus **100**. Information such as the compressed data Pc supplied from the correction parameter encoder **900** is also stored in the distortion correction memory **1020** so that information stored in the distortion correction memory **1020** is used in the processing made in actual practice by the correction parameter decoder **1010**.

[0029] Further, the control microcomputer **700** supplies a command for instructing predetermined operations and the like to the signal processing unit **500** in response to the control signal from the user interface and also supplies position information of the lens **200** to the correction parameter decoder **1010**.

[0030] The correction parameter decoder **1010** is connected to the correction parameter encoder **900**, the distortion correction memory **1020**, the control microcomputer **700** and the signal processing unit **500**. Then, in response to the information supplied from the control microcomputer **700** and the like, the correction parameter decoder **1010** expands (decodes) the thus encoded compressed data Pc supplied from the correction parameter encoder **900** or the distortion correction memory **1020** to provide correction amount parameters corresponding to respective pixels and supplies the correction parameters to the signal processing unit **500**.

[0031] The recording unit **1100** is connected to the signal processing unit **500** and records the image signal generated from the signal processing unit **500** on the media (recording medium) **1400** such as a magnetic tape, a flexible disc, a DVD (digital versatile disc), a hard disk and a memory. Alternatively, the image signal generated by the signal processing unit **500** may be recorded on the media **1400** by using a suitable means such as the Internet and wireless communication.

[0032] The reproducing unit **1200** is connected to the media **1400** and reproduces the image signal from the media **1400**, thereby supplying the reproduced image signal to the display-system processing unit **1300**. The display-system processing unit **1300** is connected to the signal processing unit **500** and the reproducing unit **1200** and displays the image signal supplied from the signal processing unit **500** or the reproducing unit **1200** to the monitor (not shown).

[0033] The synchronizing signal generating unit **800** generates an internal synchronizing signal in response to a clock signal CLK supplied thereto from the outside and supplies the thus generated internal synchronizing signal to the image pickup element **300**, the data converting unit **400** and the signal processing unit **500**.

[0034] Further, the details of the correction parameter encoder **900** will be described below. As shown in **FIG. 4**, a lattice dividing unit **901** determines a dividing method of distortion correction coordinates of the whole picture. A polynomial of degree n coefficient deriving unit **902** expresses all distortion correction coordinates of respective lattice segments divided by the lattice dividing unit **901** by function with the position on the lattice segment and approximates all distortion correction coordinates by target division polynomial of degree n. The distortion correction parameters are data retained in order to carry out distortion correction processing.

[0035] Polynomial of degree n is an equation expressed as:

$$F(x)=a(n)*x^n+a(n-1)*x^{(n-1)}+a(n-2)*x^{(n-2)}+a(0)$$

[0036] The division polynomial of degree n is to express only an interval divided by a certain effective range with polynomial of degree n. The lattice segment represents a lattice segment divided by lattice segments (segment between lattice points).

[0037] For reference, the dividing method will be described below with reference to **FIGS. 5A, 5B** and **FIG. 6**. Specifically, when the lattice is divided, there are available a method of using the whole picture as a picture dividing target as shown in **FIG. 5A** and a method of using only ¼ of picture, as shown in **FIG. 5B**, because the distortion of lens has point symmetry. These two methods may be selected based upon distortion characteristics.

[0038] As a method of dividing the distortion correction coordinates into lattices, mainly three methods are proposed. Specifically, the equal dividing method of the first method is to equally divide the distance from the center to the end by the number of divided lattices as shown on the upper right of **FIG. 6**. The dividing method using power of 2 of the second method is to divide the distance from the center to the end at every power of 2 as shown on the middle of **FIG. 6**. This dividing method using power of 2 is able to alleviate calculation processing.

[0039] Further, the optimum value dividing method of the third method is to use distortion correction coordinates of the upper end and right end of the picture where distortions of figure shown on the upper left in **FIG. 6** are largest to create function h(x) in which Y axis represents the distortion correction coordinates and X axis represents the distance from the center as shown on the lower right of **FIG. 6**. Then, by using the division polynomial of degree n, a dividing position in which an error between the function h(x) and the division polynomial of degree n may be minimized is searched for.

[0040] With respect to the method of calculating the polynomial of degree n, **FIGS. 7A** to **7D** show an example of the division polynomial of degree n for reference. Specifically, as shown in **FIG. 7A**, one lattice segment is selected. Here, assuming that x1=x0+1, a division polynomial of degree 2 that passes through three points of (x0, h(x0)), (x1, h(x1)), (x2, h(x2)) is calculated. As shown in **FIGS. 7B, 7C**, between both ends x0, x2 of the selected lattice segment, x1 is shifted one by one from x0 to x2 and the above-described calculation is carried out until the point of x2−1. In this manner, the division polynomial of degree 2 of which the error relative to the original function is smallest is calculated from all division two-dimensional polynomial is calculated. Further, the above-mentioned processing is carried out with respect to all lattice segments shown in **FIG. 7D**.

[0041] **FIG. 8** is a flowchart showing operations of the parameter encoder **900**. Referring to **FIG. 8**, and following the start of operation, control goes to a step **S11**, whereat distortion correction coordinates relative to all pictures on the target picture are read out. In the next step **S12**, the picture is divided into lattices in accordance with the lattice dividing method. Then, control goes to a step **S14**, whereat one lattice segment encircled by lattice points is selected.

[0042] Control goes to the next step **S15**, whereat y axis represents all distortion correction coordinates on the selected lattice segment and x axis represents the distance on the lattice line to create a discrete function, and the discrete function is approximated by the division polynomial of degree n. Further, at a step **S18**, n coefficients of division polynomial of degree n are transferred to the distortion correction memory **1020** as decoded distortion correction parameters. Then, control goes the next decision step **S19**, whereat it is determined whether or not deriving of distortion correction parameters with respect to all lattice segments is ended. If deriving of distortion correction parameters is not yet finished as represented by a NO at the decision step **S19**, then control goes back to the step **S14**. If on the other hand deriving of distortion correction parameters is finished as represented by a YES at the decision step **S19**, then control is ended.

[0043] The coefficients of the division polynomial of degree n that is the thus calculated approximate expression are stored in the distortion correction memory **1020** as distortion correction parameters. The lattice information is stored in the lattice information buffer **1001** disposed within the correction parameter decoder **1000**.

[0044] Further, the correction parameter decoder **1000** is the block that decodes the distortion correction coordinates of respective points of the picture by the distortion correction parameters obtained from the correction parameter encoder **900** in accordance with the request from the signal processing unit **500**. The correction parameter decoder **1000** will be described in detail with reference to **FIG. 9**.

[0045] As shown in **FIG. 9**, lattice information indicative of division positions of X,Y directions are inputted to the correction parameter decoder **1000** from the correction parameter encoder **900**. The inputted lattice information is stored in the lattice information buffer **1001**. Then, when the correction parameter decoder **1000** receives request of coordinates (xt, yt) which should be corrected in distortion from the signal processing unit **500**, the lattice determining unit **1002** compares lattices containing target coordinates (xt, yt) with lattice position information of the lattice information buffer **1001** and calculates the compared result.

[0046] Further, the lattice determining unit **1002** generates addresses at which the respective coefficients of the division polynomial of degree n that are four lattice segments encircling the calculated lattice and requests the distortion correction memory **1020** to read the thus generated addresses. At the same time, the lattice determining unit **1002** supplies the determined lattice position information to the normalizing unit **1003**. The normalizing unit **1003** calculates relative coordinates (xt', yt') used in the four lines of the encircled lattice from the target coordinates (xt, yt), the lattice positions and lattice information.

[0047] The function converting unit **1005** converts the coefficient of the function received from the distortion correction memory **1020** into the form of the function that is used in the plane interpolation. Further, the plane interpolation unit **1006** creates a plane function by using the plane interpolation obtained by the function converting unit **1005** and obtains respective coordinates from the normalizing unit **1003** to thereby calculate desired distortion correction coordinates. Then, calculated results are supplied to the signal processing unit **500**.

[0048] Accordingly, the flowchart of the correction parameter decoder **1000** is presented as shown in **FIG. 10**. Referring to **FIG. 10**, and following the start of operation, at a step **S21**, lattice information is read as initialization. Further, at a step **S22**, the signal processing unit **500** is placed in the standby mode (WAIT) until the distortion request signal is issued.

[0049] When it is requested at the step **S22** to decode the distortion correction parameters, the distortion correction memory **1020** receives coordinates of a target point from the signal processing unit **500**. Further, at a step **S23**, a lattice containing the coordinates of the target point is determined. At a step **S24**, relative coordinates are calculated from lattice lines of the target point. At the next step **S25**, one line amount is selected from four line amounts encircled as the lattice and distortion correction parameters (coefficients) of the division polynomial of degree n are read.

[0050] If processing concerning the four line amount is not yet ended as represented by a NO at the decision step **S27**, then control goes back to the step **S25**. Further, at a step **S28**, a plane function made by the four division polynomials of degree n is derived. Then, at a step **S29**, distortion correction coordinates of the target point are derived by using the plane function, and control goes back to the step **S22**, whereat the signal processing apparatus **500** is set to the standby mode (WAIT) until the next request signal is supplied.

[0051] The target points are pixels that are to be corrected in distortion by the signal processing unit **500**. Since the distortion correction coordinates are different at respective points, all target points can be held by the register or can be obtained by using a variety of calculations whose circuit scales are larger than functions for use with lens.

[0052] However, the above-mentioned signal processing apparatus encounters with problems in which a memory capacity of a memory is large, real-time processing being difficult. Specifically, since the memory capacity is large, the scale of hardware is large. Hence, reduction of power consumption is difficult and the related-art signal processing apparatus is costly. Furthermore, the related-art signal processing apparatus cannot cope with the case in which characteristics of distortion of an image pickup lens are changed such as when the position of optical zoom is fluctuated or when a lens is exchanged.

SUMMARY OF THE INVENTION

[0053] In view of the aforesaid aspects, it is an object of the present invention to provide an image processing method, an image processing apparatus and an image pickup apparatus, a display apparatus suitable for the application of the image processing method according to the present invention and in which the aforesaid defects can be obviated.

[0054] According to the present invention, the lattice position determined by lattice dividing means is used and data necessary for calculation is compressed by using crossing positions of lattice and data obtained from parameter deriving means. Thus, a capacity of a necessary memory can be reduced. According to the present invention, assuming that the picture is divided in the x direction by m and also divided in the y direction by n, then memory capacity reduction effect of 3n*m+n+m−1 can be achieved.

[0055] Specifically, assuming that the picture is divided by polynomial of degree k, divided in the x direction by m and also divided in the y direction by n, then as shown in **FIG. 11**, we can have the divided lattice line n*(m+1)+m*(n+1). In this case, according to the present invention, the number of required distortion correction parameters can be reduced from the related-art (k+1){n*(m+1)+m*(n+1)} to the inventive (n+1)*(m+1)+(k−1){n*(m+1)+m*(n+1)}, and hence the memory capacity reduction effect of 3n*m+n+m−1 can be achieved.

[0056] According to an aspect of the present invention, there is provided an image processing method realized by using an input device for inputting an image, a signal processing unit for effecting signal processing on the image, a parameter deriving unit for deriving distortion correction data, a lattice dividing unit for dividing a picture with lattices, a parameter compressing unit for compressing data necessary for calculation by using lattice positions determined by the lattice dividing unit, positions at which the lattices are crossing each other and data obtained from the parameter deriving unit, a parameter holding unit for holding the compressed necessary data, a parameter decoding unit for expanding compressed data at every division and using the expanded data to correct distortion, a control unit for controlling the signal processing and decoding operation and an output unit for outputting or saving an image.

[0057] According to other aspect of the present invention, there is provided an image processing apparatus which is comprised of an input device for inputting an image, a signal processing unit for effecting signal processing on the image, a parameter deriving unit for deriving distortion correction data, a lattice dividing unit for dividing a picture with lattices, a parameter compressing unit for compressing data necessary for calculation by using lattice positions determined by the lattice dividing unit, positions at which the lattices are crossing each other and data obtained from the parameter deriving unit, a parameter holding means for holding the compressed necessary data, a parameter decoding unit for expanding compressed data at every division and using the expanded data to correct distortion, a control unit for controlling the signal processing and decoding operation and an output unit for outputting or saving an image.

[0058] According to a further aspect of the present invention, there is provided an image pickup apparatus suitable for the application of an image processing method realized by using an input device for inputting an image, a signal processing unit for effecting signal processing on the image, a parameter deriving unit for deriving distortion correction data, a lattice dividing means for dividing a picture with lattices, a parameter compressing unit for compressing data necessary for calculation by using lattice positions determined by the lattice dividing unit, positions at which the lattices are crossing each other and data obtained from the parameter deriving unit, a parameter holding unit for holding the compressed necessary data, a parameter decoding unit for expanding compressed data at every division and using the expanded data to correct distortion, a control unit for controlling the signal processing and decoding operation and an output unit for outputting or saving an image.

[0059] In accordance with yet a further aspect of the present invention, there is provided a display apparatus suitable for the application of an image processing method realized by using an input device for inputting an image, a signal processing unit for effecting signal processing on the

image, a parameter deriving unit for deriving distortion correction data, a lattice dividing unit for dividing a picture with lattices, a parameter compressing unit for compressing data necessary for calculation by using lattice positions determined by the lattice dividing unit, positions at which the lattices are crossing each other and data obtained from the parameter deriving unit, a parameter holding unit for holding the compressed necessary data, a parameter decoding unit for expanding compressed data at every division and using the expanded data to correct distortion, a control unit for controlling the signal processing and decoding operation and a display device for displaying an image.

BRIEF DESCRIPTION OF THE DRAWINGS

[0060] **FIG. 1** is a block diagram showing an arrangement of an image processing apparatus according to the related art;

[0061] **FIG. 2** is a flowchart to which reference will be made in explaining an outline of operations of the image processing apparatus shown in **FIG. 1**;

[0062] **FIG. 3** is a block diagram showing an arrangement of an image processing system that has been proposed previously;

[0063] **FIG. 4** is a block diagram showing an arrangement of a correction parameter encoder shown in **FIG. 3**;

[0064] **FIGS. 5A and 5B** are diagrams useful for explaining an outline of operations of the lattice dividing unit shown in **FIG. 4**, respectively;

[0065] **FIG. 6** is a diagram useful for explaining an outline of operations of the lattice dividing unit shown in **FIG. 4**;

[0066] **FIGS. 7A** to **7D** are diagrams useful for explaining an outline of operations of the lattice dividing unit shown in **FIG. 4**, respectively;

[0067] **FIG. 8** is a flowchart showing an image distortion correcting method;

[0068] **FIG. 9** is a block diagram showing an arrangement of an x-direction image distortion correction parameter decoder shown in **FIG. 3**;

[0069] **FIG. 10** is a flowchart to which reference will be made in explaining operations of the correction parameter decoder;

[0070] **FIG. 11** is a diagram to which reference will be made in explaining the correction parameter decoder shown in **FIG. 10**;

[0071] **FIG. 12** is a block diagram showing an arrangement of an image processing system according to an embodiment of the present invention;

[0072] **FIG. 13** is a block diagram showing an arrangement of a signal processing unit shown in **FIG. 12**;

[0073] **FIGS. 14A and 14B** are diagrams to which reference will be made in explaining an outline of one-dimensional interpolation calculation executed by the signal processing unit shown in **FIG. 13**, respectively;

[0074] **FIG. 15** is a diagram showing an arrangement of a horizontal processing circuit contained in the data interpolation calculating unit shown in **FIG. 13**;

[0075] **FIG. 16** is a first flowchart showing operations of the horizontal one-dimensional interpolating unit shown in **FIG. 13**;

[0076] **FIG. 17** is a second flowchart showing operations of the horizontal one-dimensional interpolating unit shown in **FIG. 13**;

[0077] **FIGS. 18A, 18B** and **18C** are diagrams to which reference will be made in explaining operations shown in the first and second flowcharts more fully, respectively;

[0078] **FIGS. 19A** to **19I** are diagrams showing an example in which a picture is converted at a magnification of ×1 by the horizontal one-dimensional interpolation, respectively;

[0079] **FIGS. 20A** to **20N** are timing charts showing operation timings in which a picture is converted at a magnification of x1 by the horizontal one-dimensional interpolation shown in **FIGS. 19A** to **19I**, respectively;

[0080] **FIGS. 21A** to **21I** are diagrams showing an example of horizontal enlargement conversion in the horizontal one-dimensional interpolation, respectively;

[0081] **FIGS. 22A** to **22M** are timing charts showing operation timings of the horizontal enlargement conversion shown in **FIGS. 21A** to **21I**, respectively;

[0082] **FIG. 23** is a first flowchart showing operations of the vertical one-dimensional interpolating unit shown in **FIG. 13**;

[0083] **FIG. 24** is a second flowchart showing operations of the vertical one-dimensional interpolating unit shown in **FIG. 13**;

[0084] **FIGS. 25A, 25B** and **25C** are diagrams to which reference will be made in explaining operations shown in the flowcharts of **FIGS. 23 and 24** more fully, respectively;

[0085] **FIG. 26** is a diagram showing an example of vertical enlargement conversion in the vertical one-dimensional interpolation;

[0086] **FIG. 27** is a flowchart showing outlines of operations of the pre-processing apparatus and the correction parameter decoder shown in **FIG. 12**;

[0087] **FIG. 28** is a block diagram showing an arrangement of the correction parameter encoder shown in **FIG. 12**;

[0088] **FIGS. 29A, 29B** and **29C** are diagrams to which reference will be made in explaining operations of the lattice dividing unit shown in **FIG. 28**, respectively;

[0089] **FIG. 30** is a first flowchart showing an optimum dividing method;

[0090] **FIG. 31** is a block diagram showing an arrangement of the x-direction image distortion correction parameter decoder shown in **FIG. 13**;

[0091] **FIG. 32** is a second flowchart showing the optimum dividing method;

[0092] **FIGS. 33A, 33B** and **33C** are diagrams used to explain the operations shown in **FIGS. 30 and 31**, respectively;

[0093] **FIG. 34** is a diagram used to explain operations of the correction parameter decoder shown in **FIG. 13**;

[0094] **FIG. 35** is a block diagram showing arrangements of the image memory, the data acquisition unit and the data interpolation calculating unit shown in **FIG. 13**;

[0095] **FIGS. 36A** to **36D** are timing charts showing timings of horizontal one-dimensional interpolation processing and vertical one-dimensional interpolation processing, respectively;

[0096] **FIG. 37** is a diagram to which reference will be made in explaining a memory capacity necessary for executing the horizontal one-dimensional interpolation processing and the vertical one-dimensional interpolation processing;

[0097] **FIG. 38** is a diagram to which reference will be made in explaining the manner in which data are stored in the image memory shown in **FIG. 35**;

[0098] **FIGS. 39A, 39B** and **39C** are diagrams showing patterns that the adjacent pixels can take in the vertical direction, respectively;

[0099] **FIGS. 40A and 40B** are diagrams showing patterns that the adjacent two pixels cannot take in the vertical direction, respectively;

[0100] **FIG. 41** is a diagram used to explain vertical 4-tap processing; and

[0101] **FIG. 42** is a diagram to which reference will be made in explaining the manner in which data is to be read out from the image memory shown in **FIG. 35**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0102] An embodiment of the present invention will be described below in detail with reference to the drawings. In the drawings, identical reference numerals denote identical elements and parts.

[0103] **FIG. 12** is a block diagram showing an arrangement of an image processing system according to an embodiment of the present invention. The arrangement of the hardware shown in **FIG. 12** is exactly the same as the arrangement of the image processing system that the assignee of the present invention has previously proposed (see **FIG. 3**). While the image processing apparatus according to the present invention is realized by mainly software, this software comprising the image processing apparatus of the present invention will be described below in the form of a functional block diagram for simplicity.

[0104] As shown in **FIG. 12**, the image processing system according to this embodiment comprises the image processing apparatus **100**, the pre-processing apparatus **1500** and the media **1400**. The image processing apparatus **100** includes the lens **200**, the image pickup element **300**, the data converting unit **400**, the signal processing unit **500**, the image memory **600**, the control microcomputer **700**, the correction parameter decoder **1010**, the synchronizing signal generating unit **1600**, the recording unit **1100**, the reproducing unit **1200** and the display-system processing unit **1300**. The pre-processing apparatus **1500** includes the correction parameter encoder **900** and the correction parameter deriving unit **800**.

[0105] The lens **200** focuses reflected light from the object **101** and maps the focused reflected light on the image pickup element **300**. The lens **200** is not limited to the single focal point lens but may be a lens with zoom function. The image pickup element **300** is comprised of a suitable means such as a CCD and a CMOS sensor, and captures a mapped image in response to the internal synchronizing signal supplied from the synchronizing signal generating unit **1600** to thereby generate an analog image signal.

[0106] The data converting unit **400** is connected to the image pickup element **300** and converts the analog image signal generated from the image pickup element **300** into the digital image signal to generate the image **102**. The signal processing unit **500** is connected to the control microcomputer **700**, the data converting unit **400**, the image memory **600**, the correction parameter decoder **1010** and the synchronizing signal generating unit **1600**.

[0107] The signal processing unit **500** stores the digital image signal supplied from the data converting unit **400** in the image memory **600** in response to the command supplied from the control microcomputer **700**. Simultaneously, the signal processing unit **500** effects correction processing on the stored image signal by correction amount parameters supplied from the correction parameter decoder **1010**. Then, the signal processing unit **500** supplies the image signal, obtained by this correction, to the display-system processing unit **1300** and the recording unit **1100**.

[0108] On the other hand, the correction parameter deriving unit **800** calculates in advance correction amount vectors corresponding to respective positions of all pixels from data and the like concerning the distortion of the lens **200**. The correction parameter encoder **900** is connected to the correction parameter deriving unit **800** and the user interface, and compresses (encodes) the correction amount vectors supplied from the correction parameter deriving unit **800** in response to the control signals Ln, Lw supplied thereto from the user interface, thereby supplying the compressed data Pc to the parameter decoder **1010**.

[0109] Although calculation and encoding in the correction parameter deriving unit **800** become calculations with very large loads, such calculations may be separately made by a suitable means such as a personal computer and may not influence real time processing done by the image processing apparatus **100**. Information such as the compressed data Pc supplied from the correction parameter encoder **900** is stored in the distortion correction memory **1020**. Information stored in the distortion correction memory **1020** is used in actual processing at the correction parameter decoder **1010**.

[0110] Further, the control microcomputer **700** outputs the command and the like for instructing predetermined operations to the signal processing unit **500** in response to the control signal from the user interface, and supplies position information of the lens **200** and the like to the correction parameter decoder **1010**.

[0111] The correction parameter decoder **1010** is connected to the correction parameter encoder **900**, the distortion correction memory **1020**, the control microcomputer **700** and the signal processing unit **500**. In response to the information supplied from the control microcomputer **700** and the like, the correction parameter decoder **1010** expands (decodes) the encoded compressed data Pc supplied from the correction parameter encoder **900** or the distortion correction memory **1020** to provide correction amount parameters and supplies the correction amount parameter to the signal processing unit **500**.

[0112] The recording unit **1100** is connected to the signal processing unit **500** and records the image signal generated from the signal processing unit **500** on the media (recording medium) **1400** such as the magnetic tape, the flexible disc, the DVD (digital versatile disc), the hard disk and the memory. Alternatively, the image signal generated from the signal processing unit **500** may be recorded on the media **1400** by a suitable means such as the Internet and wireless communication.

[0113] The reproducing unit **1200** is connected to the media **1400** and reproduces the image signal from the media **1400** and supplies the reproduced image signal to the display-system processing unit **1300**. The display-system processing unit **1300** is connected to the signal processing unit **500** and the reproducing unit **1200** and displays the image signal supplied from the signal processing unit **500** or the reproducing unit **1200** on the monitor (not shown).

[0114] The synchronizing signal generating unit **800** generates the internal synchronizing signal in response to the clock signal CLK supplied thereto from the outside, and supplies the thus generated internal synchronizing signal to the image pickup element **300**, the data converting unit **400** and the signal processing unit **500**.

[0115] Further, **FIG. 13** is a block diagram showing the arrangement of the signal processing unit **500** shown in **FIG. 12**. As shown in **FIG. 13**, the signal processing unit **500** includes a horizontal one-dimensional interpolating unit **501** and a vertical one-dimensional interpolating unit **502**. The image memory **600** includes an image memory **601** composed of a horizontal processing FIFO (fast-in fast-out) memory and an image memory **602** composed of a vertical processing line buffer. The correction parameter decoder **1010** includes an x-direction image distortion correction parameter decoder **33** and a y-direction image distortion correction parameter decoder **34**.

[0116] The image memory **602** may have a capacity large enough to store data of data amount corresponding to minimum lines necessary for realizing the vertical direction distortion correction, which will be described later on. It is customary that the above-described memory capacity is determined in response to a frequency of an output synchronizing signal supplied to the output data buffer **32**.

[0117] Then, the horizontal one-dimensional interpolating unit **501** includes a data writing unit **21**, a calculation control unit **22**, an interpolation phase/input data coordinate calculating unit **23**, a data acquisition unit **24**, an interpolation coefficient generating unit **25** and a data interpolation calculating unit **26**. The vertical one-dimensional interpolating unit **502** includes a calculation control unit **27**, an interpolation phase/input data coordinate calculating unit **28**, a data acquisition unit **29**, an interpolation coefficient generating unit **30**, a data interpolation calculating unit **31** and an output data buffer **32**.

[0118] The data writing unit **21** is connected to the data converting unit **400**, and the calculation control unit **22** is connected to the synchronizing signal generating unit **800**. The interpolation phase/input data coordinate calculating unit **23** is connected to the calculation control unit **22** and the control microcomputer **700**. The data acquisition unit **24** is connected to the interpolation phase/input data coordinate calculating unit **23**, the image memory **601** and the image distortion correction parameter decoder **33**. The data interpolation calculating unit **26** is connected to the data acquisition unit **24** and the interpolation coefficient generating unit **25**.

[0119] The image memory **601** is connected to the data writing unit **21** and the data acquisition unit **24**, and the image memory **602** is connected to the data interpolation calculating unit **26** and the data acquisition unit **29**. The image distortion correction parameter decoder **33** is connected to the interpolation phase/input data coordinate calculating unit **23** and the data acquisition unit **24**.

[0120] On the other hand, the calculation control unit **27** is connected to the synchronizing signal generating unit **1600**, and the interpolation phase/input data coordinate calculating unit **28** is connected to the calculation control unit **27** and the control microcomputer **700**. The data acquisition unit **29** is connected to the interpolation phase/input data coordinate calculating unit **28**, the image memory **602** and the image distortion correction parameter decoder **34**, and the interpolation coefficient generating unit **30** is connected to the image distortion correction parameter decoder **34**. The data interpolation calculating unit **31** is connected to the data acquisition unit **29** and the interpolation coefficient generating unit **30**, and the output data buffer **32** is connected to the data interpolation calculating unit **31** and the synchronizing signal generating unit **1600**.

[0121] The output node of the output data buffer **32** is connected to the display-system processing unit **1300** and the recording unit **1100**. The image distortion correction parameter decoder **34** is connected to the interpolation phase/input data coordinate calculating unit **28**.

[0122] In the signal processing unit **500** having the above-described arrangement, first, the horizontal one-dimensional interpolating unit **501** executes one-dimensional interpolation calculation of the horizontal direction (x direction), and the vertical one-dimensional interpolating unit **502** execute one-dimensional interpolation calculation of the vertical direction (y direction). An outline of the calculation done by the signal processing unit **500** will be described with reference to **FIGS. 14A and 14B**. **FIGS. 14A and 14B** illustrate the case in which image data of respective points of the output image are determined by using totally **16** image data of (4×4) image data composed of four image data arrayed in the x direction and y direction.

[0123] **FIG. 14A** shows the case in which image data of respective points **B10** to **B40** are calculated in response to points **B1** to **B4** comprising an original image with distortion by the x-direction correction. **FIG. 14B** shows the case in which image data of points **b1** to **b4** are further calculated in response to the points **B10** to **B40** by the y-direction correction.

[0124] To be more concrete, the image data of the point **B10** is calculated by effecting the predetermined interpolation calculation on the image data of four lattice points across the point **B1** continuing in the horizontal direction, for example. Similarly, the image data of the respective points **B20** to **B40** are calculated in response to the points **B2** to **B4**, respectively.

[0125] Next, as shown in **FIG. 14B**, with respect to the point **B30**, for example, the image data of the point **b3** is calculated by effecting predetermined interpolation calcula-

tions on image data in four lattice points (points K20 to K23) within a dashed-line across the point B30 continuing in the vertical direction. Similarly, the image data of the respective points b1, b2, b4 are calculated in response to the points B10, B20, B40.

[0126] The above-described one-dimensional interpolation calculation in the horizontal direction is realized by a horizontal processing circuit 40, shown in FIG. 15, included in the data interpolation calculating unit 26. As shown in FIG. 15, the horizontal processing circuit 40 includes four registers 1901 connected in series to an output node of a line memory 1900, four multiplying circuits 1902 for multiplying data outputted from the respective registers 1901 with corresponding interpolation coefficients CHk (k=0 to 3) and an adding circuit 1903 for adding data obtained from the four multiplying circuits 1902.

[0127] The above-described one-dimensional interpolation calculation in the vertical direction is realized by a circuit shown in FIG. 35 which will be described later on, and this circuit will be described in detail later on.

[0128] Next, an outline of operations of the signal processing unit 500 shown in FIG. 13 will be described. Referring back to FIG. 13, first, image data inputted to the horizontal one-dimensional interpolating unit 501 from the data converting unit 400 is supplied to the image memory 601 together with the write control signal by the data writing unit 21 and thereby written in the image memory 601 in response to the write control signal.

[0129] At that time, by supplying the read control signal to the horizontal processing image memory 601, the data acquisition unit 24 acquires image data arrayed in the horizontal direction from the image memory 601 in response to the x-direction correction amount parameter Xm supplied from the image distortion correction parameter decoder 33 as interpolation data.

[0130] Then, the data interpolation calculating unit 26 executes the one-dimensional interpolation calculation of the horizontal direction by using the interpolation coefficient supplied from the interpolation coefficient generating unit 25, and the vertical processing image memory 602 stores therein the calculated results.

[0131] Next, in the vertical one-dimensional interpolating unit 502, the data acquisition unit 29 acquires image data arrayed in the vertical direction from the vertical processing image memory 602 in response to the y-direction correction amount parameter Ym supplied from the image distortion parameter decoder 34 as interpolation data. Then, the data interpolation calculating unit 31 executes the one-dimensional interpolation calculation of the vertical direction by using the interpolation coefficient supplied from the interpolation coefficient generating unit 30, and the output data buffer 32 outputs the calculated result in response to the output synchronizing signal.

[0132] Since the interpolation calculation executed by the horizontal one-dimensional interpolating unit 501 and the vertical one-dimensional interpolating unit 502 is the one-dimensional interpolation calculation as described above, a filter with four taps or a filter with taps of high-order number can be used like cubic interpolation.

[0133] Specifically, since the one-dimensional interpolation calculation can be realized by the simple circuit as described above, calculation which is difficult to be made by a filter with taps of high-order number in the two-dimensional interpolation calculation can be realized easily, thereby making it possible to obtain an image of higher quality. A general pixel number converting circuit is a circuit that may execute one-dimensional interpolation, and hence the existing circuit may be shared in the above-described calculation.

[0134] While the one-dimensional interpolation calculation of the vertical direction is executed after the one-dimensional interpolation calculation of the horizontal direction has been carried out as set forth above, the present invention is not limited thereto, and conversely, the one-dimensional interpolation calculation of the horizontal direction may be executed after the one-dimensional interpolation calculation of the vertical direction has been executed. In this case, the image data outputted from the data converting unit 400 is inputted to the vertical direction one-dimensional interpolating unit 502, wherein it is processed by the vertical direction one-dimensional interpolation calculation and temporarily stored in the horizontal processing image memory 601. Then, the image data stored in the image memory 601 is further supplied to the horizontal direction one-dimensional interpolating unit 501, in which it is processed by the horizontal one-dimensional interpolation calculation and distortion can be completely corrected, thereby being outputted to the outside of the signal processing unit 500.

[0135] The above-described calculation processing is applied not only to data of one system but also to data of every system of color signals (RGB, YUV). Further, when the interpolation calculation is effected on a real moving image, the above-described calculation may be executed on image data in synchronism with the vertical synchronizing signal.

[0136] Most of image pickup apparatus such as a video camera and a digital still camera has so-called optical zoom function and camera-shake correcting function. When optical zoom is made by the above-described optical zoom function, the distortion characteristic of the lens fluctuates in response to the lens position at which the lens is set to the telephoto (zoom-up) side or the wide angle (zoom-down) side. Specifically, in general, when the lens 200 is moved to the wide angle side, barrel-like distortion occurs in the picture. When the lens 200 is moved to the telephoto side, bobbin-like distortion occurs in the picture.

[0137] At that time, unless the picture is not corrected by proper correction vectors corresponding to the optical zoom, then the picture quality is deteriorated. Thus, the correction parameter decoder 1010 is adapted to select optimum correction amount parameters corresponding to the position of the lens.

[0138] Specifically, the correction parameter decoder 1010 receives information indicative of the position of the lens 200 from the control microcomputer 700 and selectively decodes the compressed data Pc supplied from the correction parameter encoder 900 in response to the position information.

[0139] As described above, according to the image processing apparatus 100 shown in FIG. 12, even when the characteristic of the lens 200 is fluctuated, since only the

correction amount parameter decoded in response to the characteristic is used in interpolation calculation, a data amount for use in calculation can be suppressed to the minimum. As a result, it is possible to decrease a manufacturing cost.

[0140] Next, the above-described camera-shake correcting function will be described. In general, as a method of correcting an image with distortion caused by camera-shake, there are known a method of optically correcting the image by controlling the position of the lens and the like as in active prism system or active lens system and a method of electrically correcting the image by effecting predetermined processing on a resultant image signal as in active image area system.

[0141] Since the lens characteristic fluctuates in response to the position of the lens **200** according to the optical correcting method, it is difficult to realize this optical correcting method by the image processing apparatus **100** according to the embodiment of the present invention.

[0142] On the other hand, the above-described electrical correcting method is realized by signal processing in which a part (effective area) of an image is obtained from the whole of the image. At that time, since the image processing target changes in response to the position of the effective area and the like, the correction vectors for use in executing interpolation calculation should be changed in response to the image processing target.

[0143] Accordingly, the correction parameter decoder **1010** further receives information indicative of camera-shake position from the control microcomputer **700** and selectively decodes the compressed data Pc supplied from the correction parameter encoder **900** in response to the position information to thereby realize the camera-shake correction.

[0144] In the image processing apparatus **100** according to this embodiment, when the lens **200** is exchanged, if the correction parameter decoder **1010** selectively decodes the compressed data Pc in response to the new lens **200** or the like, then an image of high quality can easily be obtained after the lens assembly has been exchanged.

[0145] Next, with reference to **FIG. 26** and a flowchart of **FIG. 27**, operations of the horizontal one-dimensional interpolating unit **501** shown in **FIG. 13** will be described in detail. First, the calculation control unit **22** generates a control timing signal in response to the internal synchronizing signal supplied from the synchronizing generating unit **800**. Then, the interpolation phase/input data coordinate calculating unit **23** operates in response to the control timing signal supplied from the calculation control unit **22** to calculate coordinates of the interpolated point on the coordinate system with decimal point when an image inputted into the signal processing unit **500** has no distortion.

[0146] Specifically, referring to **FIG. 16**, and following the start of operation, at a step **S31**, the interpolation phase/input data coordinate calculating unit **23** initializes coordinates (Sx, Sy) on the upper left of an image CI extracted as coordinates (x, y) on an image whose distortion was corrected and which was converted as shown in **FIG. 18A** and supplies a correction parameter request signal Rx to the image distortion correction parameter decoder **33**. On the other hand, at a step **S32**, the image distortion correction parameter decoder **33** calculates a correction amount parameter Xm corresponding to the correction parameter request signal Rx and the coordinates (Sx, Sy) and supplies the calculated correction amount parameter to the data acquisition unit **24** and the interpolation coefficient generating unit **25**.

[0147] The image distortion correction parameter decoder **33** may incorporate therein a ROM (read-only memory), for example, and may store in advance a contrast table between x coordinate and the correction amount parameter Xm in the ROM. Alternatively, the image distortion correction parameter decoder **33** may approximate the correction amount parameter Xm as a certain function of coordinates and may obtain the correction amount parameter Xm by using this function, which will be described in detail later on.

[0148] In the next step **S33**, the data acquisition unit **24** adds correction amount vectors (Xm, O) corresponding to the correction amount parameter Xm supplied thereto from the image distortion parameter decoder **33** to the coordinates (X, Y) supplied from the interpolation phase/input data coordinate calculating unit **23**. Thus, as shown in **FIG. 18B**, there were obtained coordinates (X+Xm, Y) of a point corresponding to the above-described coordinates (X, Y) on the original image OI that is provided before being corrected, i.e., correction vectors.

[0149] Instead of the data acquisition unit **24**, the image distortion correction parameter decoder **33** may calculate the above-described correction vectors in response to x coordinate supplied from the interpolation phase/input data coordinate calculating unit **23** and may supply the correction vectors to the data acquisition unit **24**.

[0150] At that time, it is determined by the data acquisition unit **24** at the decision step **S34** whether or not the integer value of the x coordinate is changed by addition of the correction amount parameter Xm. If the integer value of the x coordinate is changed as represented by a YES at the decision step **S34**, then control goes to the next decision step **S35**. If the integer value of the x coordinate is not changed as represented by a NO at the decision step **S34**, then control goes to a step **S36**.

[0151] It is determined at the decision step **S35** whether or not the integer value of the x coordinate is changed more than 2. If the integer value of the x coordinate is changed more than 2 as represented by a YES at the decision step **S35**, then control goes to a step **S38**. If the integer value of the x coordinate is changed by only 1 as represented by a NO at the decision step **S35**, then control goes to a step **S37**. On the other hand, at the step **S36**, the image memory **601** supplies the same interpolation data as that outputted in the preceding cycle to the data acquisition unit **24** again in response to a hold signal Sh supplied thereto from the data acquisition unit **24**.

[0152] The data acquisition unit **24** generates an address of data that should be readout from the image memory **601** in response to the integer value of x component (X+Xm) of the generated correction vectors and acquires interpolation data corresponding to the address by supplying the read control signal to the image memory **601**.

[0153] While incrementing address from the starting address one by one, the image memory **601** sequentially outputs interpolation data corresponding to the address and

temporarily stops the above-described increment in response to the hold signal Sh from the data acquisition unit **24**.

[0154] The image memory **601** may receive the read start address from the data acquisition unit **24** and may output successive data of a predetermined number in which the read start address is used as the above-described start address.

[0155] Herein, the above-described hold signal Sh and read start address are obtained from the integer component of the correction amount parameter Xm outputted from the image distortion correction parameter decoder **33**.

[0156] On the other hand, the interpolation coefficient generating unit **25** treats a decimal point component of the correction amount parameter Xm supplied from the image distortion correction parameter decoder **33** as the phase of the horizontal interpolation filter and generates an interpolation coefficient in response to the decimal point component. Such operation can be applied to the apparatus when the image **102** inputted to the signal processing unit **10** is formed according to the RGB format. On the other hand, when the image **102** is formed according to the YUV format, the filter phase of the luminance signal Y can be treated similarly to the filter phase of the RGB format. Thus, the interpolation coefficient generating unit **25** can calculate a phase of a color difference signal Cb/Cr by using not only the decimal point component of the correction amount parameter Xm but also the integer component.

[0157] Then, at the step **S37**, the data interpolation calculating unit **26** executes one-dimensional interpolation calculation in response to interpolation data supplied from the data acquisition unit **24** and the above-described interpolation coefficient. Then, control goes to a step **S39**.

[0158] The above-described one-dimensional interpolation calculation uses luminance data Dt of 8 pixels near the correction vectors (X+Xm, Y) in the horizontal direction as interpolation data as shown in **FIG. 18C** to execute 8-tap interpolation calculation that uses the above-described decimal point component as the phase. The result obtained by the interpolation calculation is used as luminance data of the output image, whereby distortion in the horizontal direction can be corrected.

[0159] On the other hand, at a step **S38**, the data acquisition unit **24** supplies a skip signal sk to the interpolation phase/input data calculating unit **24**, the image distortion correction parameter decoder **33** and the data interpolation calculating unit **26** to stop operations of the interpolation phase/input data coordinate calculating unit **23**, the image distortion correction parameter decoder **33** and the data interpolation calculating unit **26**.

[0160] If the x coordinate is changed more than 2 as represented by a YES at the decision step **S35**, then this means that the center coordinate on which the interpolation calculation is effected in actual practice is moved more than two pixels, and hence the output of data to the image memory **602** from the data interpolation calculating unit **26** is interrupted. When the center coordinate on which the interpolation calculation is effected in actual practice is moved more than two pixels, since the decimal point component (interpolation phase) of the correction amount parameter Xm outputted from the image distortion correction parameter decoder **33** is held until the next cycle, operations of the image distortion correction parameter decoder **33** are stopped.

[0161] Then, at a step **S43**, the interpolation phase/input data coordinate calculating unit **23** adds a horizontal direction enlargement and reduction parameter Ha to the x coordinate, and control goes to the step **32**. This enlargement and reduction parameter Ha is determined based upon a ratio between the length of the corrected image and the length of the original image with distortion in the horizontal direction. When the image is enlarged in the horizontal direction after it has been corrected, this enlargement and reduction parameter Ha is selected to be smaller than 1. Conversely, when the image is reduced after it has been corrected, this enlargement and reduction parameter Ha is selected to be larger than 1. When the image is produced at the magnification of ×1, this enlargement and reduction parameter Ha is selected to be 1.

[0162] In a step **S39**, the data interpolation calculating unit **26** stores the resultant image data in the image memory **602** composed of a vertical processing line buffer. Then, it is determined at the next decision step **S40** whether or not the input data coordinate calculating unit **23** outputs image data of one line amount, i.e., output horizontal pixel number HS amount to the image memory **602** based upon the x coordinate of the present time point. If the data of one line amount is outputted as represented by a YES at the decision step **S40**, then control goes to a step **S41**. If on the other hand data of one line amount is not outputted as represented by a NO at the decision step **S40**, then control goes to the step **S43**.

[0163] At the step **S41**, the interpolation phase/input data coordinate calculating unit **23** sets the x coordinate to Sx and adds 1 to the y coordinate. At the next decision step **S42**, it is determined by the interpolation phase/input data coordinate calculating unit **23** based upon the y coordinate whether or not image data of one frame amount, i.e., image data of output vertical line amount is outputted to the image memory **602**. If the image data of the output vertical line amount is outputted to the image memory **602** as represented by a YES at the decision step **S42**, then control is ended. If on the other hand the image data of one frame amount is not outputted to the image memory **602** as represented by a NO at the decision step **602**, then control goes to the step **S43**.

[0164] As described above, the horizontal one-dimensional interpolating unit **501** realizes the horizontal image distortion correcting processing and the horizontal direction enlargement and reduction processing at the same time by effecting the one-dimensional interpolation processing of the horizontal direction on the original image with distortion and saves the resultant image in the vertical processing image memory **602**.

[0165] **FIGS. 19A** to **19I** show specific example in which the image is converted at the magnification of ×1 based upon the above-described horizontal one-dimensional interpolation. **FIGS. 19A** to **19I** show conversions concerning the luminance signal. **FIG. 19A** show interpolation data D0 to D9 inputted to the signal processing unit **500**, **FIGS. 19B and 19F** show correction amount parameter Xm and **FIGS. 19C and 19D** show sampling position and data number of data comprising an image obtained after correction.

[0166] **FIG. 19E** shows x coordinate (xt) supplied from the interpolation phase/input data coordinate calculating unit **23** to the image distortion correction parameter decoder **33**, **FIG. 19G** shows x coordinate (correction parameter) of

correction vectors generated by the data acquisition unit **24**, **FIG. 19H** shows address of interpolation data in the data that is obtained before correction, and **FIG. 19I** shows interpolation phase, respectively.

[0167] As shown in **FIGS. 19A** to **19I**, for example, a correction amount parameter Xm of data in which x coordinate is located at a point of 2.0 in the corrected image is set to 1.25. As a result, the x coordinate of the point corresponding to the above point in the image that is obtained before correction is calculated as 3.25 by adding the correction amount parameter Xm to 2.0. At that time, the integer component (3) of the x coordinate (3.25) shows the address of the data in the image that is obtained before correction, and 0.25 shows the interpolation phase. Accordingly, the luminance signal at the point in which the x coordinate in the corrected image is 2.0 treats a plurality of consecutive data having three approximate x addresses in the image that is not yet corrected and can be obtained by one-dimensional interpolation calculation in which the phase of the horizontal interpolation filter is set to 0.25.

[0168] **FIGS. 20A** to **20N** are, respectively, timing charts showing operation timings in which the image is converted at the magnification of ×1 as shown in **FIGS. 19A** to **19I**. **FIG. 20A** shows an internal synchronizing signal supplied to the calculation control unit **22**, **FIG. 20B** shows a control timing signal generated from the calculation control unit **22**, **FIG. 20C** shows a read control signal supplied from the data acquisition control unit **24** to the image memory **601**, **FIG. 20D** shows interpolation data inputted from the image memory **601** to the data acquisition unit **24**, and **FIG. 20E** shows x coordinate (xt) supplied from the interpolation phase/input data coordinate calculating unit **23** to the image distortion correction parameter decoder **33**, respectively.

[0169] **FIG. 20F** shows a correction amount parameter xm outputted from the image distortion correcting parameter decoder **33**, **FIG. 20G** shows a correction parameter generated from the data acquisition unit **24**, **FIG. 20H** shows address of interpolation data in the image that is not yet corrected, **FIG. 20I** shows an interpolation phase, **FIGS. 20J and 20K** show a skip signal sk and a hold signal sh generated from the data acquisition unit **24**, respectively, **FIG. 20I** shows 2-tap data read out from the image memory **601**, **FIGS. 20J and 20K** show a skip signal sk and a hold signal sh generated from the data acquisition unit **24**, respectively, **FIG. 20L** shows 2-tap data read out from the image memory **601**, **FIG. 20M** shows data outputted from the data interpolation calculating unit **26** to the image memory **602**, and **FIG. 20N** shows an output enable signal that is generated in the inside of the data interpolation calculating unit **26**, respectively. For simplicity of explanation, it is assumed that the interpolation calculation for obtaining one data uses the 2-tap data shown in **FIG. 20L**.

[0170] As shown in **FIG. 20B**, when the control timing signal is activated to high level at a time T1 in response to the internal synchronizing signal, the interpolation phase/input data coordinate calculating unit **23** sequentially supplies the x coordinate (xt), which is incremented from 0.0 by 1.0 each, to the image distortion correction parameter decoder **33** as shown in **FIG. 20E**.

[0171] Thus, as shown in **FIG. 20F**, the image distortion parameter decoder **33** calculates the corresponding correction amount parameter Xm and then the data acquisition unit **24** calculates a correction parameter shown in **FIG. 20G**. As shown in **FIG. 20H**, the data acquisition unit **24** specifies the start address of the interpolation data in the image, which is not yet corrected, from the integer component of the correcting parameter to "0". Then, as shown in **FIGS. 20C and 20D**, the data acquisition unit **24** supplies the above-described specified address "0" to the image memory **601** together with the activated read control signal.

[0172] Thus, as shown in **FIG. 20D**, the image memory **601** sequentially outputs interpolation data to the data acquisition unit **24** from data D0 corresponding to the start address "0".

[0173] As shown in **FIGS. 20G and 20J**, if it is determined by the data acquisition unit **24** at a time T2 that the integer component of the correction parameter increases more than 2, then the data acquisition unit **24** generates the skip signal sk of high level (H) and supplies this skip signal Sk to the interpolation phase/input data coordinate calculating unit **23**, the data interpolation calculating unit **26** and the image distortion correction parameter decoder **33**. As a result, as shown in **FIGS. 20E and 20G**, generating operation of the correction parameter is stopped during one cycle from the time T3, and as shown in **FIGS. 20M and 20N**, the output enable signal is inactivated to low level and hence outputting of data from the data interpolation calculating unit **26** to the image memory **602** is stopped.

[0174] As shown in **FIGS. 20G and 20K**, it is determined by the data acquisition unit **24** at a time T4 that the integer component of the generated correction parameter (8.75) is identical to the integer component of the correction parameter (8.25) of one cycle before, and activates the hold signal Sh to high level at the time T4. Thus, as shown in **FIG. 20L**, at a time T5, the data acquisition unit **24** obtains the same 2-tap interpolation data D8, D9 of the preceding cycle from the image memory **601**.

[0175] **FIGS. 21A** to **21I** show specific examples in which an image is converted in enlargement by the horizontal one-dimensional interpolation similarly to **FIGS. 19A** to **19I**. **FIGS. 22A** to **22M** show operation timings by which an image is converted in enlargement similarly to **FIGS. 20A** to **20N**. In this example of enlargement conversion, as shown in **FIG. 21E**, data of which the data numbers are ranging from 2 to approximately 6 are enlarged in the horizontal direction wherein the enlargement and reduction parameter Ha of the horizontal direction is set to 0.5. **FIG. 21B** shows the correction amount parameter Xm with respect to 10 data of which the data numbers are ranging from 0 to 9, and **FIG. 21F** shows a correction amount parameter Xm at the interpolation point by the enlargement, i.e., at 10 points in which x coordinate lies in a range of from 2.0 to 6.5 at an interval of 0.5.

[0176] In such enlargement conversion, as shown in **FIG. 22G**, since the integer components of the correction parameters are not changed at the times T2, T3, T5, T5, T6, the hold signal Sh is activated during one cycle at each time.

[0177] Operations of the vertical one-dimensional interpolating unit **502** shown in **FIG. 13** will be described in detail with reference to flowcharts of **FIGS. 23 and 24**. First, the calculation control unit **27** generates a control timing signal in response to the internal synchronizing signal supplied from the synchronizing signal generating unit

1600. Then, the interpolation phase/input data coordinate calculating unit **28** operates in response to the control timing signal supplied from the calculation control unit **27** to calculate coordinates of an interpolation point in the coordinate system with decimal points when the picture inputted to the signal processing unit **500** has no distortion.

[0178] Specifically, at a step **S51**, the interpolation phase/input data coordinate calculating unit **29** initializes coordinates (Sx, Sy) on the upper left of an extracted image CI as coordinates (x, y on the image that has been corrected in distortion and converted at the magnification of ×1 as shown in **FIG. 25A** and supplies the correction parameter request signal Ry to the image distortion correction parameter decoder **34**. On the other hand, at a step **S52**, the image distortion correction parameter decoder **34** calculates the correction amount parameter Ym corresponding to the y coordinate in response to the correction parameter request signal Ry supplied thereto and supplies the calculated correction amount parameter Ym to the data acquisition unit **29** and the interpolation coefficient generating unit **30**.

[0179] The image distortion correction parameter decoder **34** may incorporate therein a ROM (read-only memory) and may store in advance a contrast table between the y coordinate and the correction amount parameter ym in the ROM. Alternatively, the image distortion correction parameter decoder **34** may approximate the correction amount parameter Ym as a certain function of the y coordinate and calculate the correction amount parameter Ym by using the above-mentioned function, which will be described in detail later on.

[0180] In the next step **S53**, the data acquisition unit **29** may add the correction amount vectors (O, Ym) corresponding to the correction amount parameter Ym supplied from the image distortion correction parameter decoder **34** to the coordinates (X, Y) supplied from the interpolation phase/input data coordinate calculating unit **29**. Thus, as shown in **FIG. 25B**, coordinates (X, Y+Ym) of a point corresponding to the above-described coordinates (X,Y) in the original image OI that is not yet corrected, i.e., correction vectors are calculated. At that time, the data acquisition unit **29** generates address of data that should be read out from the image memory **602** in response to the integer value of the y component (Y+Ym) of the thus generated correction vector and supplies the same to the image memory **602** together with the memory control signal.

[0181] Instead of the data acquisition unit **29**, the image distortion correction parameter decoder **34** may calculate the above-described correction vector in response to they coordinate supplied from the interpolation phase/input data coordinate calculating unit **28** and may supply the correction vector to the data acquisition unit **29** and the like.

[0182] At a step **S54**, the vertical processing image memory **602** may output a plurality of interpolation data arranged over a plurality of lines in the vertical direction in the coordinate X in response to the supplied address to the data acquisition unit **29** at the same time.

[0183] The image memory **602** may receive the start address that starts reading from the data acquisition unit **29** and may sequentially output interpolation data corresponding to the address by incrementing the address one by one. Alternatively, the image memory **602** may not increment the address but may output consecutive data of a predetermined number from the received start address. The start address is calculated from the integer component of the correction amount parameter Ym outputted from the image distortion correction parameter decoder **34**.

[0184] On the other hand, the interpolation coefficient generating unit **30** treats the decimal component of the correction amount parameter Ym supplied from the image distortion correction parameter decoder **34** as the phase of the vertical interpolation filter to generate an interpolation coefficient in response to the decimal component.

[0185] Then, in a step **S55**, the data interpolation calculating unit **31** executes the one-dimensional interpolation calculation in response to the interpolation data and the interpolation coefficient supplied from the data acquisition unit **29**. The above-described interpolation calculation may not limited to the application of the case where the image **102** inputted to the signal processing unit **500** has the RGB format. Specifically, when the image **102** has the YUV format, if data densities in the vertical direction of the luminance signal and the color difference signals are identical to each other, the filter phase of the luminance signal can be used as the filter phase of the color difference signal. When the above-described data densities are different from each other, the filter phase of the color difference signal can be calculated by using not only the decimal component of the correction amount parameter Ym but also the integer component.

[0186] According to the YUV format, as shown in **FIG. 25C**, luminance data Dt of 8 pixels, for example, in the vertical direction near the correction vector (X, Y+Ym) and the like are used as interpolation data and 8-tap interpolation calculation using the decimal component as the phase is executed. The results obtained by the interpolation calculation are used as the luminance data and the color difference data of the output image, thereby the distortion in the vertical direction being corrected.

[0187] In the next step **S56**, the output data buffer **32** outputs the image data obtained from the interpolation calculation. At the next decision step **S57**, it is determined by the interpolation phase/input data coordinate calculating unit **23** based upon the x coordinate of the present time whether or not image data of one line amount, i.e., image data of output horizontal pixel number HS amount is outputted. If the image data of one line amount is outputted as represented by a YES at the decision step **S57**, then control goes to a step **S58**. If on the other hand the image data of one line amount is not outputted as represented by a NO at the decision step **S57**, then control goes to a step **S60**.

[0188] At the step **S58**, the interpolation phase/input data coordinate calculating unit **28** sets the x coordinate to Sx and adds the enlargement and reduction parameter Va of the vertical direction to the y coordinate. On the other hand, at the step **S60**, the interpolation phase/input data coordinate calculating unit **28** adds the enlargement and reduction parameter Ha of the horizontal direction to the x coordinate, and control goes back to the step **S52**. The above-described enlargement and reduction parameter Va is determined by a ratio between lengths of the vertical direction of the original image with distortion relative to the image that has been corrected. When the corrected image is enlarged in the vertical direction after correction, the above-described

enlargement and reduction parameter Va is selected to be a value smaller than 1. Conversely, when the corrected image is reduced after correction, the above enlargement and reduction parameter Va is selected to be a value larger than 1. When the corrected image is converted at the magnification of ×1, the above enlargement and reduction parameter Va is selected to be 1.

[0189] At the decision step **S59**, it is determined by the interpolation phase/input data coordinate calculating unit **28** based upon the y coordinate whether or not image data of one frame, i.e., image data of vertical line number (vertical pixel number) amount is outputted from the output data buffer **32**. If the image data of one frame is outputted as represented by a YES at the decision step **S59**, then control is ended. If on the other hand the image data of one frame is not outputted as represented by a NO at the decision step **S59**, then control goes to the step **S60**.

[0190] Since the above-described one-dimensional interpolation in the vertical direction is not accompanied with the interpolation of data with respect to the horizontal direction and the enlargement/reduction of the image, in the scanning of the horizontal direction shown in **FIG. 25A**, similar operation is repeated at every cycle. However, when the correction amount parameter Ym is large, a time period necessary for reading interpolation data from each storage place of the image memory **602** increases unavoidably. In such case, the data acquisition unit **29** supplies an activated wait signal WT to the interpolation phase/input data coordinate calculating unit **28** and the image distortion parameter decoder **34** and interrupts operations of the interpolation phase/input data coordinate calculating unit **28** and the image distortion correction parameter decoder **34** during the activation period of the wait signal WT.

[0191] As described above, the vertical one-dimensional interpolating unit **502** can realize the vertical image distortion correction processing and the vertical direction enlargement/reduction processing at the same time by effecting the one-dimensional interpolation calculation of the vertical direction on the original image with the distortion and generates and outputs the image from which the distortion can be removed completely. **FIG. 26** shows a specific example in which an image is converted at the magnification of ×1 by the above-described vertical one-dimensional interpolation. **FIG. 26** is a graph showing the conversion concerning the luminance signal, wherein the horizontal axis represents the x coordinate and the vertical axis represents the corrected y coordinate (Y+Ym).

[0192] In **FIG. 26, 10** points in which y coordinate is 0 and x coordinate falls within a range of from 0.0 to 10.0 represent points on the image obtained after correction, and arrows represent the correction amount parameters Ym up to the points on the original image corresponding to the respective points. Specifically, in the image obtained after correction, for example, the point of the coordinates (1.0, 0) corresponds to the point of coordinates (1.0, 7.1) in the original image obtained before correction. The correction amount parameter is 7.1, and the interpolation phase is its decimal component 0.1.

[0193] The pre-processing apparatus **1500** and the correction parameter decoder **1010** shown in **FIG. 12** will be described below in detail. First, an outline of operations of the pre-processing apparatus **1500** and the correction parameter decoder **1010** will be described with reference to a flowchart of **FIG. 27**.

[0194] Referring to **FIG. 27**, and following start of operation, at a step **S71**, the correction parameter encoder **900** reads correction amount vectors of all pixel points from the correction parameter deriving portion **800**. In the next step **S72**, the correction parameter encoder **900** determines lattice lines which are used to divide the correction amount vectors of all pixel points at every division. A manner of determining the lattice lines will be described in detail later on.

[0195] At a step **S73**, the correction parameter encoder **900** compresses the correction amount vectors of the respective divisions divided by the lattice lines, and supplies the thus compressed correction amount vectors to the correction parameter decoder **1010** and the distortion correction memory **1020** as the compressed data Pc. At a step **S74**, the image pickup element **300** picks up an image. The compression of the correction amount vectors will be described in detail later on.

[0196] At a step **S75**, the data converting unit **400** converts an analog image signal, generated by the above shooting, into a digital image signal. Ata step **S76**, the correction parameter decoder **1010** determines lattices necessary for reading correction amount parameters from the signal processing unit **500**. At a step **S77**, the correction parameter decoder **1010** normalizes coordinates supplied from the signal processing unit **500** in response to the lattices.

[0197] In the next step **S78**, the correction parameter decoder **1010** decodes the compressed data Pc supplied from the correction parameter encoder **900** by using the above lattices, and supplies resultant correction parameters to the signal processing unit **500**. At the next step **S79**, the signal processing unit **500** effects interpolation calculation on the original image by using the correction amount parameters. It is determined at the next decision step **S80** by the control microcomputer **700** whether or not input of original image into the signal processing unit **500** should be ended. If input of the original image to the signal processing unit **500** is ended as represented by a YES at the decision step **S80**, then control of the image processing apparatus **100** is ended. If input of the original image to the signal processing unit **500** is not ended as represented by a NO at the decision step **S80**, then control goes back to the step **S74**.

[0198] **FIG. 28** is a block diagram showing an arrangement of the correction parameter encoder **900** shown in **FIG. 12**. As shown in **FIG. 28**, the lattice dividing unit **911** determines lattice lines used to divide parameters of all points on the picture at every division and supplies distortion correction parameters (distortion correction coordinates) on the lattice points to the distortion correction memory **1020**. The polynomial of degree n coefficient deriving unit **902** expresses all distortion correction coordinates of the respective lattice segments divided by the lattice dividing unit **911** in the form of a function with respect to the lattice segments and approximates the function by a calculated division polynomial of degree n.

[0199] Further, the sample point deriving unit **903** compresses distortion correction parameters from the division polynomial of degree n obtained from the polynomial of degree n coefficient deriving unit **902**. In the thus derived

division polynomial of degree n, internal points which result from dividing both ends of the division polynomial of degree n by n are set to new distortion correction parameters (approximated distortion correction parameters) and supplied to the distortion correction memory **1020**.

[0200] Accordingly, as shown in **FIGS. 29A, 29B** which show the division polynomial of degree **2** as the example, inter division points of h1 (x), h2 (x), h3 (x), h4 (x) have the same correction coordinates and therefore can be shared, thereby making it possible to reduce the number of distortion correction parameters. Specifically, as shown in **FIG. 29C**, considering shared points, middle points between the interdivision points and the lattice segments become the distortion correction parameters.

[0201] Further, **FIG. 30** is a flowchart showing operations of the correction parameter encoder **900**. This flowchart of **FIG. 30** is a flowchart obtained by modifying the flowchart (**FIG. 8**) which shows the operations of the previously-proposed apparatus. In **FIG. 30**, elements and parts identical to those of **FIG. 8** are denoted by identical reference numerals.

[0202] Referring to **FIG. 30**, and following the start of operation, at the step **S11**, distortion correction coordinates corresponding to all pictures on the target image are read out. In the next step **S12**, a picture is divided into lattices in accordance with the lattice dividing method. At the step **S13**, correction data for decoding distortion correction coordinates in the points of lattice points which are interdivision points of lattice lines are transferred to the distortion correction memory **1020**. Further, at the step **S14**, the lattice segment encircled by lattice points is selected.

[0203] Then, at the step **S15**, a discrete function is made by representing distortion correction coordinates of all points on the selected lattice segment with the y axis and by representing distances with x axis and the discrete function is approximated by the division polynomial of degree n. Further, at the step **S16**, the effective range of the approximated division polynomial of degree n is divided by n and respective x values are calculated. At the step **S17**, a value of y of the approximated division polynomial of degree n corresponding to the x coordinate calculated at the step **S16** is calculated.

[0204] Further, at the step **S18**, a value of n−1 point except both ends of the effective range calculated at the step S17 is transferred to the distortion correction memory **1020** as distortion correction parameters for decoding distortion correction coordinates. If deriving of distortion correction parameters concerning all lattice segments is not ended as represented by a NO at the decision step **S19**, then control goes back to the step **S14**. If on the other hand deriving of distortion correction parameters concerning all lattice segments is ended as represented by a YES at the decision step **S19**, then control is ended. Encoding is executed by the above-mentioned method.

[0205] Operations of the correction parameter encoder **900** will be described below with reference to the case of the division polynomial of degree **2**. Specifically, the polynomial of degree n deriving unit **902** receives necessary distortion correction coordinates from the correction parameter deriving unit **800** based upon information of lattice position obtained from the lattice dividing unit **911**. In order to decode data by using the division polynomial of degree 2, the polynomial of degree n deriving unit **902** should select the optimum point in the division polynomial of degree 2.

[0206] A certain lattice segment is used as a target like the previously-proposed apparatus as shown in **FIGS. 7A** to **7D**. In **FIGS. 7A** to **7D**, positions of both ends and distortion correction coordinates are set to (x0, h(x0)), (x2, h(x2)). At that time, (x1, h(x1)) are set to all pixels in the lattice segment, and the coefficients of a, b, c are calculated from the following equations:

$$a*x0^2+b*x0+c=v0$$

$$a*x1^2+b*x1+c=v1$$

$$a*x2^2+b*x2+c=v2$$

[0207] Accordingly, errors of distortion correction coordinates at respective points are calculated by the target segment and the division polynomial of degree 2 that was obtained as described above. Here, a point (x1, h(x1)) having minimum error becomes a point that should be calculated. The division polynomial of degree 2 is created from a, b, c that are obtained from the three points. A point on the target y axis is a point 1 and a point that is to be calculated by bidivision is a point of (x2−x0)/2.

[0208] Specifically, calculating the distortion correction parameters of the above-described point by the approximate expression, we have:

$$h(x1')=a*[(x2-x(0)/2)]^2+b*[(x2-x0)/2]+c$$

[0209] The above-described processing is effected on all lattice segments. In this manner, the processing in the correction parameter encoder **900** shown in **FIG. 28** is carried out.

[0210] Further, details of the correction parameter decoder **1010** will be described with reference to **FIG. 31**. Specifically, the correction parameter decoder **1010** is a block to decode distortion correction coordinates of respective points of picture from distortion correction parameters obtained from the correction parameter encoder **910** in accordance with the request from the signal processing unit **500**.

[0211] As shown in **FIG. 31**, the correction parameter decoder **1010** is supplied with lattice information indicative of divided positions of respective x, y directions from the correction parameter encoder **910**. The inputted lattice information is stored in the lattice information buffer **1001**. Then, when the correction parameter decoder **1010** receives a request of coordinates (xt, yt) that should be corrected in distortion from the signal processing unit **500**, the lattice determining unit **1002** compares a lattice containing target coordinates (xt, yt) with lattice position information of the lattice buffer **1001** and calculates the target lattice.

[0212] The correction parameter decoder **1010** generates address in which distortion correction parameters on the four lattice segments surrounding the calculated lattice are stored and supplies a read request signal to the distortion correction memory **1020**. At the same time, the lattice determining unit **1002** supplies the thus determined lattice position to the normalizing unit **1003**. The normalizing unit **1003** calculates relative coordinates (xt', yt') used by the four lines surrounding the lattice from the target coordinates (xt, yt), the lattice position and the lattice information.

[0213] Thus, the function calculating unit **1004** reconstructs the division polynomial of degree n based upon

distortion information of resultant each n+1 point. A function converting unit **1005** converts coefficients of function received from the distortion correction memory **1020** into a function format that is used inplane interpolation. Further, aplane interpolating unit **1006** creates a plane function by using coefficients of a plane function obtained from the function converting unit **1005**. The plane interpolating unit **1006** obtains respective coordinates from the normalizing unit **1003**, calculates desired correction coordinates and supplies a calculated result to the signal processing unit **500**.

[0214] In this manner, distortion correction coordinates of respective points of a picture are decoded by the distortion correction parameters. Further, **FIG. 32** is a flowchart showing operations of the correction parameter decoder **1010**. This flowchart shown in **FIG. 32** is a modification of the flowchart (**FIG. 10**) which shows the operations of the previously-proposed apparatus. In **FIG. 32**, elements and parts identical to those of **FIG. 10** are denoted by identical reference numerals.

[0215] Referring to **FIG. 32**, and following the start of operation, at the step **S21**, lattice information is read as the initialization. Then, the signal processing apparatus is placed in the standby state (WAIT) until a distortion correction request signal is issued at the step **S22**. When it is requested to decode the distortion correction parameters at the step **S22**, the distortion correction parameter decoder **1010** receives coordinates of a target point from the signal processing unit **500**. Further, at the step **S23**, the distortion correction parameter decoder **1010** determines the lattice that contains the coordinates of the target point.

[0216] At the step **S24**, the distortion correction parameter decoder **1010** calculates relative coordinates in each lattice segment of the target point. At the step **S25**, the distortion correction parameter decoder **1010** selects one line from four lines surrounding a lattice as a lattice and reads distortion correction parameters of n+1 point. Further, at the step **S26**, the distortion correction parameter decoder **1010** generates the division polynomial of degree n from the thus read n+1 distortion correction parameters. Specifically, the distortion correction parameter decoder **1010** selects one line from four lattice lines encircled as the lattice and reads the distortion correction parameters (coefficients) of the division polynomial of degree n.

[0217] Further, if the processing concerning the four lattice segments is not finished as represented by a NO at the decision step **S27**, then control goes back to the step **S25**. If on the other hand the processing concerning the four lattice segments is finished as represented by a YES at the decision step **S27**, then control goes to a step **S28**, whereat a plane function made by the four division polynomials of degree n is derived. At the next step **S29**, the distortion correction coordinates of the target point are derived by using the plane function, and the correction parameter decoder **1010** is placed in the standby state (WAIT) until the next request signal is issued. The distortion correction parameters are decoded by the above-mentioned method.

[0218] An example of the case of the division polynomial of degree **2** will be described below with reference to **FIGS. 33A** to **33C** and **FIG. 34**. As shown on the right-hand portion in FIG. **33A**, the lattice position corresponding to address (xt, yt) obtained from the signal processing unit **500** is calculated. Specifically, with respect to the division polynomial of degree 2, distortion correction parameters of three points are read out from respective lattice lines. However, since the lattice points can be made common as described in the right-hand side notes of **FIGS. 33B and 33C**, in actual practice, parameters of 8 points [4+(n−1)*4:n=4] are read out.

[0219] Further, **FIG. 33B** shows relationships between positions of three points in each line of four lattice lines and distortion correction parameters. Since coordinate x1' becomes a bisected middle point, division polynomials of degree 2 and distortion correction parameters are expressed by the following equations:

$$a*x0^2+b*x0+c=h(x0)$$

$$a*x2^2+b*x2+c=h(x2)$$

$$a*[(x2-x0)/2]^2+b*[(x2-x0)/2]+c=h(x1)$$

[0220] Accordingly, the division polynomial of degree 2 is reproduced by calculating the above-mentioned coefficients a, b, c.

[0221] Specifically, normalizing the above equations with reference to x0, the above-described equations are modified as:

[0222] x0=0×

[0223] 2=lattice width

[0224] c=h(x0)

[0225] a*x2^2+b*x2+c=h(x2)

[0226] a*[x2/2]^2+b*[x2/2]+c=h(x1)'

[0227] Thus, as shown in **FIG. 33C**, we have the division polynomial of degree 2 expressed as:

[0228] a=[{2*h(x2)−4*h(x1)'+2*h(x0)}/x2^2]

[0229] b=[{−h(x2)+4*h(x1)'−3*h(x0)}/x2]

[0230] c=h(x0)

[0231] Since x2 represents the width of the lattice, reciprocal number and square of reciprocal number can be held as lattice information.

[0232] Further, the function converting block **1005** calculates functions of four lines f(x), g(x), m(y), n(y) of respective lattice lines of the calculated lattice. The coefficients a, b, c of four lines are obtained by the above-described calculations.

[0233] While distortion correction coordinates of the target point are calculated by using the four lines of the lattice, herein the coefficients of the respective functions are modified as:

[0234] f(x): afx, bfx, cfx

[0235] g(x): agx, bgx, cgx

[0236] m(y): amy, bmy, cmy

[0237] n(y): any, bny, cny

[0238] That is, we have:

[0239] F(x)=f'(x)=2*afx*x^2+(bfx−afx)*x+cfx

[0240] G(x)=g'(x)=2*agx*x^2+(bgx−agx)*x+cgx

[0241] M(y)=m'(y)=2*amy*y^2+(bmy−amy)*y+cmy

[0242] N(y)=n'(y)=2*any*y^2+(bny−any)*y+cny

[0243] The normalizing block **1003** converts x_t, y_t as:

[0244] xt'=xt−x0

[0245] yt'=yt−y0

[0246] Then, the normalizing block **1003** substitutes the converted xt, yt into the above-described functions. Then, the plane interpolating block **1005** calculate the distortion correction coordinates of the target point based upon the newly-calculated four functions and xt', yt'.

[0247] Specifically, a distortion correction coordinate Vtarget of the target point is calculated by the following equation:

$$Vtarget=(1/2)*\{(1-yt')*F(xt')+yt'*G(xt')+(1-xt')*N(yt')+xt'*M(yt')\}$$

[0248] In this manner, the correction parameter decoder **1010** shown in **FIG. 31** carries out the processing. This processing operation has been described so far with reference to **FIG. 34**.

[0249] Further, **FIG. 35** is a block diagram showing arrangements of the image memory **602**, the data acquisition unit **29** and the data interpolation calculating unit **31** shown in **FIG. 13**. **FIG. 35** shows the arrangement in which the image processing apparatus **100** generates image data of each pixel by interpolation calculation using image data of 16 pixels of (4×4) taps.

[0250] As shown in **FIG. 35**, the image memory **602** includes a selector **67** and five memories of the number larger than the number of vertical taps by one, i.e., an A memory **71**, a B memory **72**, a C memory **73**, a D memory **74** and an E memory **75**. The data acquisition unit **29** includes a control unit **80**, an A buffer **81**, a B buffer **82**, a C buffer **83**, a D buffer **84**, an E buffer **85**, a cycle dividing unit **560** and selectors **96** to **99**. The cycle dividing unit **560** includes the selectors **91** to **95**.

[0251] The data acquisition unit **29** includes the five buffers (A buffer **81** to E buffer **85**) of the number larger than the number of the vertical taps by one, the five corresponding selectors **91** to **95** and the four selectors **96** to **99** of the number corresponding to the number of the vertical taps.

[0252] The data interpolation calculating unit **31** includes four registers **901**, a multiplying circuit **902** and an adding circuit **43**.

[0253] As shown in **FIG. 35**, the selector **67** is connected to the data interpolation calculating unit **26** and the control unit **80**, and the A memory **71**, the B memory **72**, the C memory **73**, the D memory **74** and the E memory **75** are connected to the selector **67**.

[0254] The control unit **80** is connected to the image distortion correction parameter decoder **34**, the A buffer **81** is connected to the A memory **71**, and the B buffer **82** is connected to the B memory **72**. Similarly, the C buffer **83** is connected to the C memory **73**, the D buffer **84** is connected to the D memory **74** and the E buffer **85** is connected to the E memory **75**.

[0255] The selector **91** is connected to the A buffer **81**, the selector **92** is connected to the B buffer **82**, and the selector **93** is connected to the C buffer **83**. In a like manner, the selector **94** is connected to the D buffer **84**, and the selector **95** is connected to the E buffer **85**. The selectors **96** to **99** are connected to the five selectors **91** to **95**, respectively. The selectors **91** to **99** are controlled by the control unit **80**, respectively.

[0256] Registers **901** are respectively connected to the selectors **96** to **99**, and multiplying circuits **902** are connected to the registers **901**, respectively. Then, the four multiplying circuits **902** are connected to an adding circuit **43**.

[0257] As described above, since the data interpolation calculating unit **26** writes data, which has been corrected in the horizontal direction, in the image memory **602** and at the same time, the data acquisition unit **29** effects the interpolation processing of the vertical direction on the data obtained from the image memory **602**, image distortion can be corrected without causing delay of frame as a processing wait time.

[0258] Operations of the image memory **602**, the data acquisition unit **29** and the data interpolation calculating unit **31** shown in **FIG. 35** will be described below in detail. First, the data that has been interpolated in the horizontal direction is supplied from the data interpolation calculating unit **26** to the selector **67** sequentially, and this data is distributed and stored in the five memories of the A memory **71** to the E memory **75** by the selector **67** which is controlled by the control unit **80**.

[0259] The data stored in the A memory **71** is supplied through the A buffer **81** to the selector **91**, and the data stored in the B memory **72** is supplied through the B buffer **82** to the selector **92**. Similarly, the data stored in the C memory **73** is supplied through the C buffer **83** to the selector **93**, the data stored in the D memory **74** is supplied through the D buffer **84** to the selector **94**, and the data stored in the E memory is supplied through the E buffer **85** to the selector **95**.

[0260] The selectors **91** to **95** included in the cycle dividing unit **560** divide data read out from the A buffer **81** to the E buffer **85** at the unit of two pixels, for example, under control of the control unit **80** and supply data of one pixel to the selectors **96** to **99** at every cycle.

[0261] The selectors **96** to **99** selectively output data supplied from the selectors **91** to **95** to the registers **901** under control of the control unit **80**. Thus, four data of the number corresponding to the number of taps necessary for the vertical direction interpolation processing are selectively supplied to the data interpolation calculating unit **31**.

[0262] The respective multiplying circuits **902** calculate products of the data stored in the registers **901** and interpolation coefficients C0 to C3 and the four products are added by the adding circuit **43** and thereby the vertical direction interpolation calculation is carried out, the calculated result being supplied to the output data buffer **32**.

[0263] Operations of the image processing apparatus **100** according to the embodiment of the present invention will be described with reference to **FIGS. 36A** to **36D**. **FIGS. 36A** to **36D** show image data of one frame amount.

[0264] As shown in **FIG. 36A**, when image data is inputted to the signal processing unit **500** at a time T1, the horizontal one-dimensional interpolating unit **501** effects the horizontal direction interpolation processing on the image data at a time T2 as shown in **FIG. 36B**. Then, as shown in

FIG. 36C, the image that has been interpolated in the horizontal direction is sequentially written in the A memory 71 to the E memory 75 included in the image memory 602 at times following the time T2.

[0265] When vertical processing data is read out from the image memory 602 to the data acquisition unit 29 at an odd-number cycle, for example, and data that has been processed in the horizontal direction is written in the image memory 602 from the data interpolation calculating unit 26 at an even-number cycle, the distortion correction processing at the 2-cycle period can be executed.

[0266] At that time, as shown in FIG. 37, from a time T3 in which data Dmx of the number of lines corresponding to the vertical direction maximum distortion amount in a horizontal line maximum distortion curve 104 in the image 102 is stored in the image memory 602, the interpolation processing in the vertical direction of each line is executed sequentially. Accordingly, the delay time in the interpolation calculation is selected to be a duration ranging from the time T1 to the time T3 and the time in which the horizontal direction interpolation processing is effected on the data of one frame amount (frame delay) need not be used as a wait time, whereby image distortion can be corrected in a real-time fashion.

[0267] On the whole, the image memory 602 has a memory capacity large enough to store data of the number which results from adding the number of lines corresponding to the maximum distortion amount in the vertical direction and the number of vertical processing taps (e.g. four taps) and data of the number of pixels in the horizontal direction of the image inputted to the signal processing unit 500 in the horizontal direction. The five memories of the A memory 71 to the E memory 75 shown in FIG. 35 are the same in memory capacity, for example, and the port width of each memory is selected to be 32 bits, for example.

[0268] FIG. 38 shows a method for storing data at an area 102P of the image 102 in the image memory 602. Reference letters "A" to "E" in FIG. 38 represent the A memory 71 to the E memory 75 shown in FIG. 35. When the port width of each memory is 32 bits and data of one pixel amount is 16 bits containing a Y signal (luminance information) and a C signal (color difference signal) as described above, the selector 67 sequentially stores the data in the A memory 71 to the E memory 75 at the unit of data of 2 pixel amounts.

[0269] Specifically, as shown in FIG. 38, the selector 67 stores data of 0th line 0 to 23rd pixel in the A memory 71, and stores data of first line 0 to 23rd pixel in the B memory 72. Similarly, the selector 67 stores data of second line 0 to 23rd pixel in the C memory 73, stores data of third line 0 to 23rd pixel in the D memory 74, and stores data of fourth line 0 to 23rd pixel in the E memory 75. The selector 67 will sequentially store data of each line in the A memory 71 to the E memory 75 at every line in a similar manner.

[0270] The reason that the data acquisition unit 29 needs the buffers of the number larger than the number of the vertical taps will be described below. When the image 102 with distortion is examined locally, as shown by patterns 1 to 3 of FIGS. 39A to 39C, image data can be prevented from being moved in the vertical direction more than two pixels between two pixels adjacent in the horizontal direction.

[0271] Specifically, the image data is not moved in the vertical direction at all between the pixels adjacent in the horizontal direction as shown by the pattern 1 in FIG. 39A, the image data is moved in the vertical direction by one pixel amount as shown by the patterns 2 and 3 in FIGS. 39B and 39C, but the image data can be prevented from being moved in the vertical direction more than two pixels between the pixels adjacent in the horizontal direction as shown in FIGS. 40A and 40B.

[0272] In the vertical 4-tap processing, as shown in FIG. 41, filtering processing is executed by using data of four pixels containing three marginal pixels Ip adjacent to the center pixel Ic in the vertical direction.

[0273] At that time, as shown in FIG. 42, each of the five memories of the A memory 71 to the E memory 75 contained in the image memory 602 has the 32-bit port, for example. In this case, 16-bit image data is outputted from each port by two pixel amounts in one access.

[0274] Specifically, as shown in FIG. 42, by one access, image data Ia0, Ia1, each formed of 16 bits, are read out from the A memory 71 at the unit of 2 pixels, image data Ib0, Ib1, each formed of 16 bits, are read out from the B memory 72 at the unit of 2 pixels, and Ic0, Ic1, each formed of 16 bits, are read out from the C memory 73 at the unit of 2 pixels. Similarly, image data Id0, Id1, each formed of 16 bits, are read out from the D memory 74 at the unit of 2 pixels and image data Ic0, Ic1, each formed of 16 bits, are read out from the E memory 75 at the unit of 2 pixels.

[0275] In this manner, if the image data of the adjacent two pixels are read out in the vertical direction by the data amount larger than the number of the taps, even when the change between the adjacent pixels is identical to any one of the patterns 1 to 3 shown in FIGS. 39A to 39C, the same processing is executed in the same column. Specifically, as shown hatched in FIG. 42, image data of the adjacent two pixels in the horizontal direction are respectively generated by executing filtering processing that intends to process image data in the four pixels arranged in the vertical direction from a pixel located above the center pixel Ic to the second pixel located below the center pixel Ic in each column, respectively.

[0276] Before the filtering processing, it is determined by the control unit 80 which of the patterns 1 to 3 is identical to the change between the adjacent pixels.

[0277] More specifically, the control unit 80 receives the y coordinates of the two center pixels Ic in the adjacent two columns in the horizontal direction from the image distortion parameter decoder 34 and controls the selectors 96 to 99 in response to a difference between they coordinates, whereby image data shown hatched in FIG. 42 are selectively supplied to the data interpolation calculating unit 31 as the filtering processing targets.

[0278] While the 4-tap filtering processing has been described so far by way of example, the image processing method according to the embodiment of the present invention is not limited to the above 4-tap filtering processing, and it is needless to say that the image processing method according to the present invention can be applied to filtering processing with other taps than the 4 taps if the image memory 602, the data acquisition unit 29 and the data interpolation calculating unit 32 may have the arrangements corresponding to the number of taps and the cycle in which data is to be inputted to and outputted from the image memory 602 may be changed.

[0279] Further, the present invention can be applied to an image pickup apparatus and a display apparatus to which this image processing method has been applied. In the display apparatus, the present invention can be applied to mis-convergence correction and the like sufficiently.

[0280] As described above, according to the image processing method and the image processing apparatus of this embodiment and the image pickup apparatus and the display apparatus to which the image processing method according to this invention can be applied, since one-dimensional interpolation calculations of horizontal and vertical directions are effected on the picked-up image with the optical distortion and the correction vectors are used efficiently, not only still image but also moving image which needs real-time processing can be corrected in distortion by the simple arrangement, and an image of high quality without distortion can be obtained with ease.

[0281] According to the image processing method and the image processing apparatus of the embodiment of the present invention and the image pickup method and the display apparatus to which the image processing method according to the present invention can be applied, since distortion of the image can be corrected in a real-time fashion by the signal processing, freedom in designing lenses can increase, and miniaturization of a lens and reduction of a cost of a lens can be realized with ease.

[0282] Further, according to the image processing method and the image processing apparatus of the embodiment of the present invention and the image pickup apparatus and the display apparatus to which the image processing method according to the present invention can be applied, memory capacities of required memories can be reduced. According to the present invention, assuming that the picture is divided in the x direction by m and also divided in the y direction by n, then memory capacity reduction effect of 3n*m+n+m−1 can be achieved.

[0283] Specifically, assuming that the picture is divided by polynomial of degree k, divided in the x direction by m and is also divided in the y direction by n, then as shown in **FIG. 11**, we can have the divided lattice line n*(m+1)+m*(n+1). In this case, according to the present invention, the number of required distortion correction parameters can be reduced from the related-art (k+1) {n*(m+1)+m*(n+1)} to the inventive (n+1)*(m+1)+(k-1) {n*(m+1)+m*(n+1)}, and hence memory capacity reduction effect of 3n*m+n+m−1 can be achieved.

[0284] Having described a preferred embodiment of the invention with reference to the accompanying drawings, it is to be understood that the invention is not limited to that precise embodiment and that various changes and modifications could be effected therein by one skilled in the art without departing from the spirit or scope of the invention as defined in the appended claims.

What is claimed is:

1. An image processing method realized by using:

input means for inputting an image;

signal processing means for effecting signal processing on said image;

parameter deriving means for deriving distortion correction data;

lattice dividing means for dividing a picture with lattices;

parameter compressing means for compressing data necessary for calculation by using lattice positions determined by said lattice dividing means, positions at which said lattices are crossing each other and data obtained from said parameter deriving means;

parameter holding means for holding said compressed necessary data;

parameter decoding means for expanding compressed data at every division and using said expanded data to correct distortion;

control means for controlling said signal processing and decoding operation; and

output means for outputting or saving an image.

2. An image processing method according to claim 1, wherein said lattice dividing means divides equally a parameter to determine position at which data is compressed with lattices.

3. An image processing method according to claim 1, wherein said lattice dividing means divides unequally a parameter to determine position at which data is compressed with lattices by a width of power of 2.

4. An image processing method according to claim 1, wherein said lattice dividing means obtains an optimum point to minimize an error and the number of divided lattices by calculation in order to determine position at which data is compressed.

5. An image processing method according to claim 1, wherein said lattice dividing means divides equally a parameter with lattices in order to determine position at which data is compressed, said parameter compressing means holds an internally dividing point n−1, which results from dividing both ends of a lattice and its lattice segment by n by using the lattice position determined by said lattice dividing means, said lattice crossing position and data obtained from said parameter deriving means, as data necessary for calculation, and said parameter decoding means reproduces polynomial of degree n from a point n−1 between both ends of division at every division and expands said compressed data for use in correcting distortion.

6. An image processing method according to claim 1, wherein said lattice dividing means divides unequally a parameter to determine position at which data is compressed with lattices by a width of power of 2 and said parameter compressing means holds an internally dividing point n−1, which results from dividing both ends of a lattice and its lattice segment by n by using the lattice position determined by said lattice dividing means, said lattice crossing position and data obtained from said parameter deriving means, as data necessary for calculation, and said parameter decoding means reproduces polynomial of degree n from a point n−1 between both ends of division at every division and expands said compressed data for use in correcting distortion.

7. An image processing method according to claim 1, wherein said lattice dividing means obtains an optimum point to minimize an error and the number of divided lattices by calculation in order to determine position at which data is compressed, said parameter compressing means holds an internally dividing point n−1, which results from dividing

both ends of a lattice and its lattice segment by n by using the lattice position determined by said lattice dividing means, said lattice crossing position and data obtained from said parameter deriving means, as data necessary for calculation, and said parameter decoding means reproduces polynomial of degree n from a point n−1 between both ends of division at every division and expands said compressed data for use in correcting distortion.

8. An image processing apparatus comprising:

input means for inputting an image;

signal processing means for effecting signal processing on said image;

parameter deriving means for deriving distortion correction data;

lattice dividing means for dividing a picture with lattices;

parameter compressing means for compressing data necessary for calculation by using lattice positions determined by said lattice dividing means, positions at which said lattices are crossing each other and data obtained from said parameter deriving means;

parameter holding means for holding said compressed necessary data;

parameter decoding means for expanding compressed data at every division and using said expanded data to correct distortion;

control means for controlling said signal processing and decoding operation; and

output means for outputting or saving an image.

9. An image processing apparatus according to claim 8, wherein said lattice dividing means divides equally a parameter to determine position at which data is compressed with lattices.

10. An image processing apparatus according to claim 8, wherein said lattice dividing means divides unequally a parameter to determine position at which data is compressed with lattices by a width of power of 2.

11. An image processing apparatus according to claim 8, wherein said lattice dividing means obtains an optimum point to minimize an error and the number of divided lattices by calculation in order to determine position at which data is compressed.

12. An image processing apparatus according to claim 8, wherein said lattice dividing means divides equally a parameter with lattices in order to determine position at which data is compressed, said parameter compressing means holds an internally dividing point n−1, which results from dividing both ends of a lattice and its lattice segment by n by using the lattice position determined by said lattice dividing means, said lattice crossing position and data obtained from said parameter deriving means, as data necessary for calculation, and said parameter decoding means reproduces polynomial of degree n from a point n−1 between both ends of division at every division and expands said compressed data for use in correcting distortion.

13. An image processing apparatus according to claim 8, wherein said lattice dividing means divides unequally a parameter to determine position at which data is compressed with lattices by a width of power of 2 and said parameter compressing means holds an internally dividing point n−1, which results from dividing both ends of a lattice and its lattice segment by n by using the lattice position determined by said lattice dividing means, said lattice crossing position and data obtained from said parameter deriving means, as data necessary for calculation, and said parameter decoding means reproduces polynomial of degree n from a point n−1 between both ends of division at every division and expands said compressed data for use in correcting distortion.

14. An image processing apparatus according to claim 8, wherein said lattice dividing means obtains an optimum point to minimize an error and the number of divided lattices by calculation in order to determine position at which data is compressed, said parameter compressing means holds an internally dividing point n−1, which results from dividing both ends of a lattice and its lattice segment by n by using the lattice position determined by said lattice dividing means, said lattice crossing position and data obtained from said parameter deriving means, as data necessary for calculation, and said parameter decoding means reproduces polynomial of degree n from a point n−1 between both ends of division at every division and expands said compressed data for use in correcting distortion.

15. An image pickup apparatus suitable for the application of an image processing method realized by using:

input means for inputting an image;

signal processing means for effecting signal processing on said image;

parameter deriving means for deriving distortion correction data;

lattice dividing means for dividing a picture with lattices;

parameter compressing means for compressing data necessary for calculation by using lattice positions determined by said lattice dividing means, positions at which said lattices are crossing each other and data obtained from said parameter deriving means;

parameter holding means for holding said compressed necessary data;

parameter decoding means for expanding compressed data at every division and using said expanded data to correct distortion;

control means for controlling said signal processing and decoding operation; and

output means for outputting or saving an image.

16. An image pickup apparatus suitable for the application of an image processing method according to claim 15, wherein said lattice dividing means divides equally a parameter to determine position at which data is compressed with lattices.

17. An image pickup apparatus suitable for the application of an image processing method according to claim 15, wherein said lattice dividing means divides unequally a parameter to determine position at which data is compressed with lattices by a width of power of 2.

18. An image pickup apparatus suitable for the application of an image processing method according to claim 15, wherein said lattice dividing means obtains an optimum point to minimize an error and the number of divided lattices by calculation in order to determine position at which data is compressed.

19. An image pickup apparatus suitable for the application of an image processing method according to claim 15,

wherein said lattice dividing means divides equally a parameter with lattices in order to determine position at which data is compressed, said parameter compressing means holds an internally dividing point n−1, which results from dividing both ends of a lattice and its lattice segment by n by using the lattice position determined by said lattice dividing means, said lattice crossing position and data obtained from said parameter deriving means, as data necessary for calculation, and said parameter decoding means reproduces polynomial of degree n from a point n−1 between both ends of division at every division and expands said compressed data for use in correcting distortion.

20. An image pickup apparatus suitable for the application of an image processing method according to claim 15, wherein said lattice dividing means divides unequally a parameter to determine position at which data is compressed with lattices by a width of power of 2 and said parameter compressing means holds an internally dividing point n−1, which results from dividing both ends of a lattice and its lattice segment by n by using the lattice position determined by said lattice dividing means, said lattice crossing position and data obtained from said parameter deriving means, as data necessary for calculation, and said parameter decoding means reproduces polynomial of degree n from a point n−1 between both ends of division at every division and expands said compressed data for use in correcting distortion.

21. An image pickup apparatus suitable for the application of an image processing method according to claim 15, wherein said lattice dividing means obtains an optimum point to minimize an error and the number of divided lattices by calculation in order to determine position at which data is compressed, said parameter compressing means holds an internally dividing point n−1, which results from dividing both ends of a lattice and its lattice segment by n by using the lattice position determined by said lattice dividing means, said lattice crossing position and data obtained from said parameter deriving means, as data necessary for calculation, and said parameter decoding means reproduces polynomial of degree n from a point n−1 between both ends of division at every division and expands said compressed data for use in correcting distortion.

22. A display apparatus suitable for the application of an image processing method realized by using:

input means for inputting an image;

signal processing means for effecting signal processing on said image;

parameter deriving means for deriving distortion correction data;

lattice dividing means for dividing a picture with lattices;

parameter compressing means for compressing data necessary for calculation by using lattice positions determined by said lattice dividing means, positions at which said lattices are crossing each other and data obtained from said parameter deriving means;

parameter holding means for holding said compressed necessary data;

parameter decoding means for expanding compressed data at every division and using said expanded data to correct distortion;

control means for controlling said signal processing and decoding operation; and

display means for displaying an image.

23. A display apparatus suitable for the application of an image processing method according to claim 22, wherein said lattice dividing means divides equally a parameter to determine position at which data is compressed with lattices.

24. A display apparatus suitable for the application of an image processing method according to claim 22, wherein said lattice dividing means divides unequally a parameter to determine position at which data is compressed with lattices by a width of power of 2.

25. A display apparatus suitable for the application of an image processing method according to claim 22, wherein said lattice dividing means obtains an optimum point to minimize an error and the number of divided lattices by calculation in order to determine position at which data is compressed.

26. A display apparatus suitable for the application of an image processing method according to claim 22, wherein said lattice dividing means divides equally a parameter with lattices in order to determine position at which data is compressed, said parameter compressing means holds an internally dividing point n−1, which results from dividing both ends of a lattice and its lattice segment by n by using the lattice position determined by said lattice dividing means, said lattice crossing position and data obtained from said parameter deriving means, as data necessary for calculation, and said parameter decoding means reproduces polynomial of degree n from a point n−1 between both ends of division at every division and expands said compressed data for use in correcting distortion.

27. A display apparatus suitable for the application of an image processing apparatus according to claim 22, wherein said lattice dividing means divides unequally a parameter to determine position at which data is compressed with lattices by a width of power of 2 and said parameter compressing means holds an internally dividing point n-1, which results from dividing both ends of a lattice and its lattice segment by n by using the lattice position determined by said lattice dividing means, said lattice crossing position and data obtained from said parameter deriving means, as data necessary for calculation, and said parameter decoding means reproduces polynomial of degree n from a point n−1 between both ends of division at every division and expands said compressed data for use in correcting distortion.

28. A display apparatus suitable for the application of an image processing method according to claim 22, wherein said lattice dividing means obtains an optimum point to minimize an error and the number of divided lattices by calculation in order to determine position at which data is compressed, said parameter compressing means holds an internally dividing point n−1, which results from dividing both ends of a lattice and its lattice segment by n by using the lattice position determined by said lattice dividing means, said lattice crossing position and data obtained from said parameter deriving means, as data necessary for calculation, and said parameter decoding means reproduces polynomial of degree n from a point n−1 between both ends of division at every division and expands said compressed data for use in correcting distortion.

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(54) IMAGE CAPTURING APPARATUS

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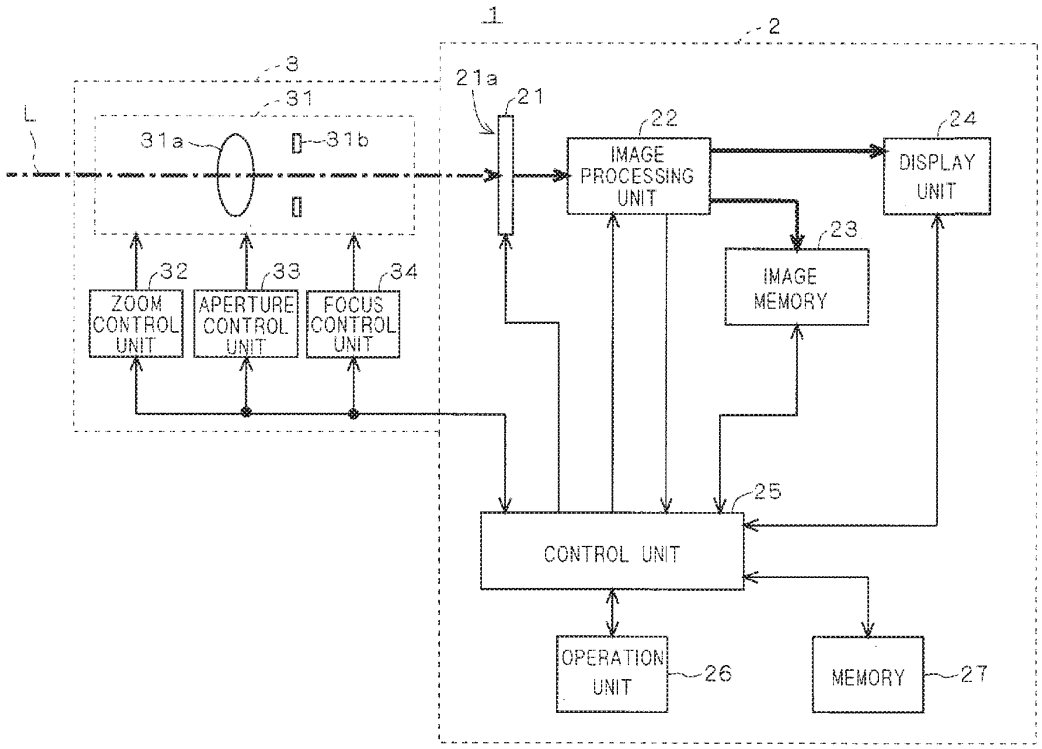
Publication Classification

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(52) U.S. Cl. 348/272

(57) ABSTRACT

An object of the present invention is to realize an image processing technique of making chromatic aberration correction excellently function and capable of efficiently correcting a chromatic aberration and to reduce storage capacity of parameters used for the chromatic aberration correction. It is constructed so that an image processing unit concurrently performs a chromatic aberration correcting process of correcting a chromatic aberration by an image capturing optical system and a color interpolating process of interpolating a dropout color component pixel by pixel on an image signal obtained from an image capturing device. On the basis of position information of a pixel to be processed obtained from the image processing unit, a control unit determines an image filter to be applied to the pixel. For example, an image filter is generated by combining a filter for chromatic aberration correction and a filter for color interpolating process. The image filter is applied, filter computation is performed on the image signal, and the chromatic aberration correcting process and the color interpolating process are concurrently performed.



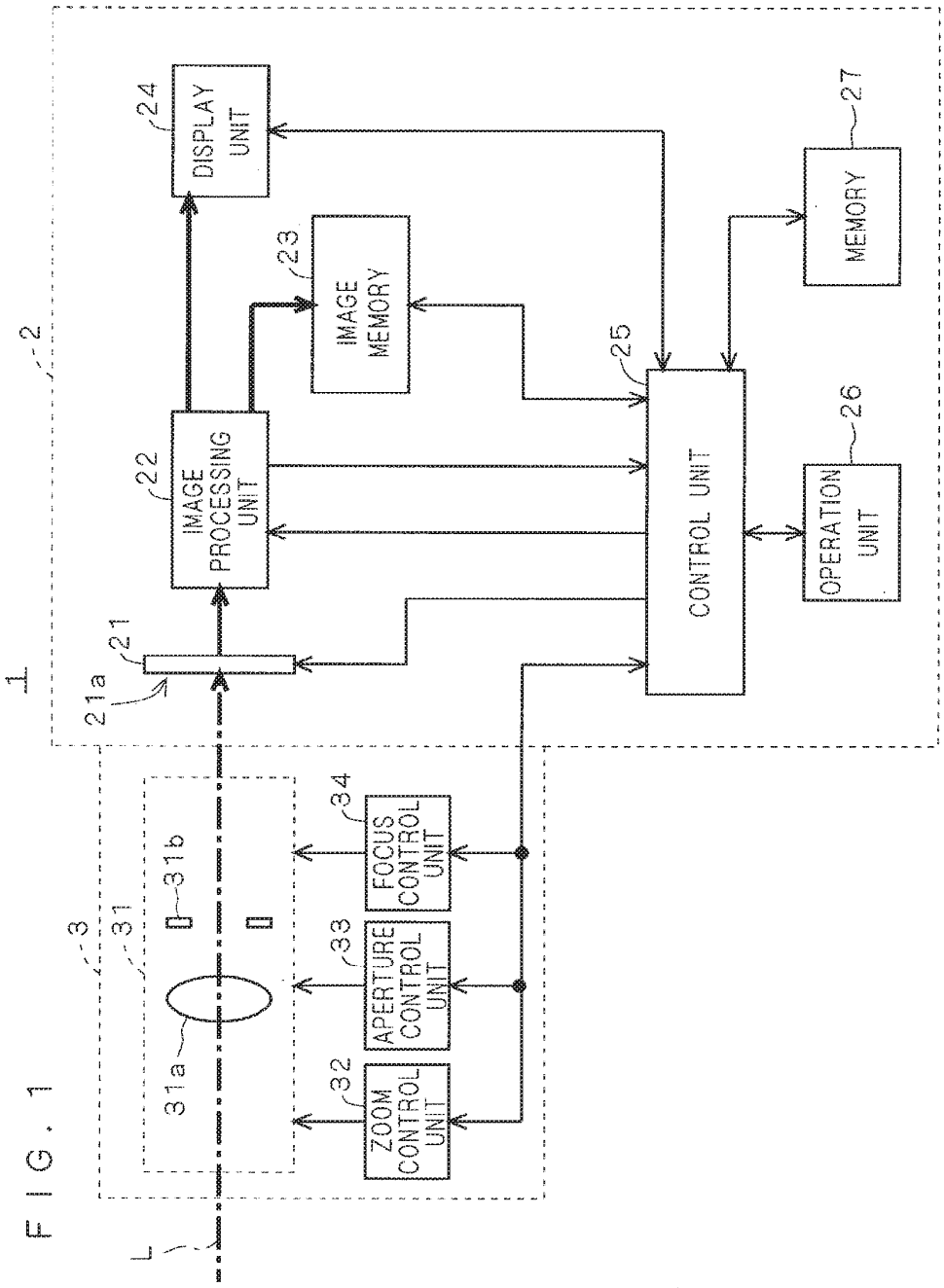
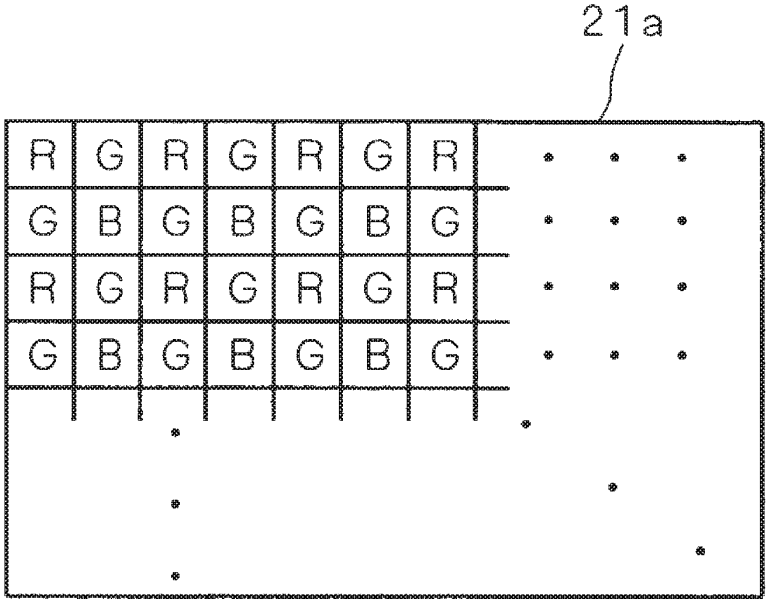

1
2
3
21
21a
22
IMAGE PROCESSING UNIT
23
IMAGE MEMORY
24
DISPLAY UNIT
25
CONTROL UNIT
26
OPERATION UNIT
27
MEMORY
31
31a
31b
32
ZOOM CONTROL UNIT
33
APERTURE CONTROL UNIT
34
FOCUS CONTROL UNIT
L

FIG. 1

FIG. 2



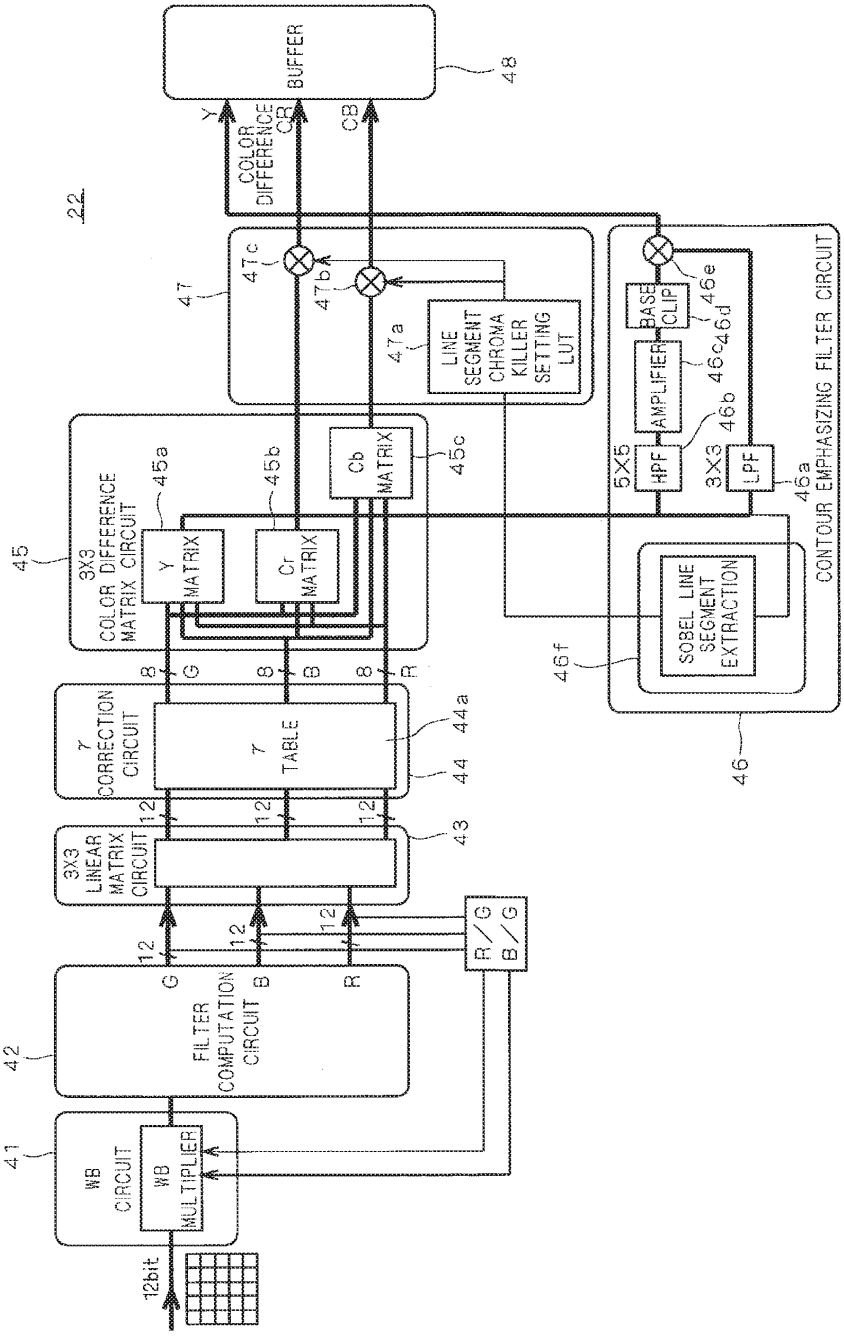


FIG. 3

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FIG. 4

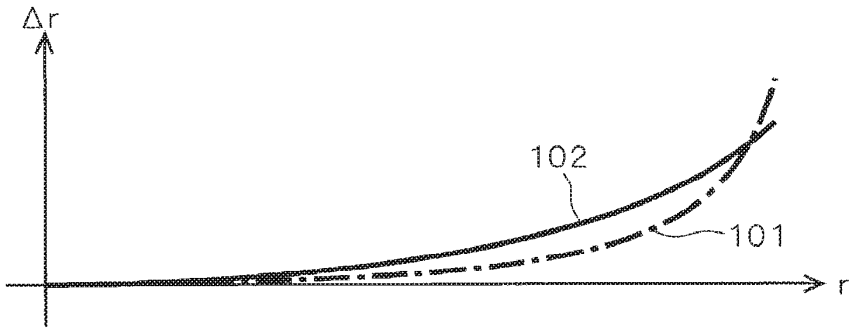


FIG. 5

201

1	2	1
2	4	2
1	2	1

FIG. 6

202

0	0	0	1	1
0	0	0	1	1
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

FIG. 7

203

0	0	0	1	3	3	1
0	0	0	3	9	9	3
0	0	0	3	9	9	3
0	0	0	1	3	3	1
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

FIG. 8

IMAGE CAPTURING CONDITIONS			COEFFICIENTS OF APPROXIMATION FUNCTION			
FOCAL LENGTH	PHOTOGRAPHING DISTANCE	f-NUMBER	a	b	c	d
5～10mm	2～5m	F2	1.234	0.123	2.345	0
		F4	2.345	0.234	3.456	0.001
		F8	3.456	0.345	4.567	0.002
	5～10m	F2	1.357	0.135	0.246	0.003
		⋮	⋮	⋮	⋮	⋮
	10m～	F2	3.579	0.357	0.468	0.004
		⋮	⋮	⋮	⋮	⋮
10～30mm	2～5m	F2	2.345	0.234	0.357	0.005
		⋮	⋮	⋮	⋮	⋮

FIG. 9

IMAGE CAPTURING CONDITIONS			COEFFICIENTS OF APPROXIMATION FUNCTION			
FOCAL LENGTH	PHOTOGRAPHING DISTANCE	f-NUMBER	a	b	c	d
5～10mm	2～5m	F2	-1.234	-0.123	-2.345	0
		F4	-2.345	-0.234	-3.456	-0.001
		F8	-3.456	-0.345	-4.567	-0.002
	5～10m	F2	-1.357	-0.135	-0.246	-0.003
		⋮	⋮	⋮	⋮	⋮
	10m～	F2	-3.579	-0.357	-0.468	-0.004
		⋮	⋮	⋮	⋮	⋮
10～30mm	2～5m	F2	-2.345	-0.234	-0.357	-0.005
		⋮	⋮	⋮	⋮	⋮

FIG. 10

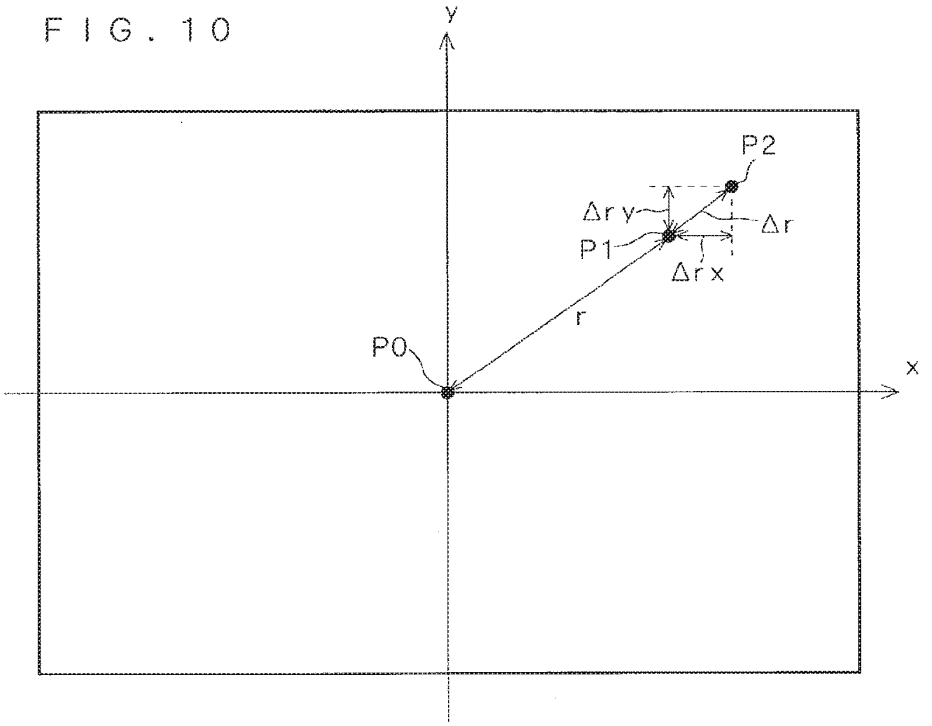


FIG. 11

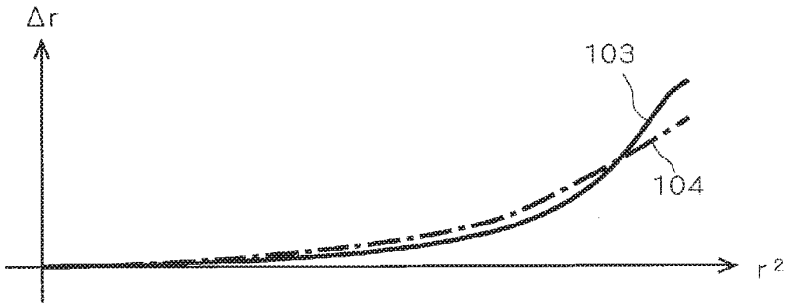


FIG. 12

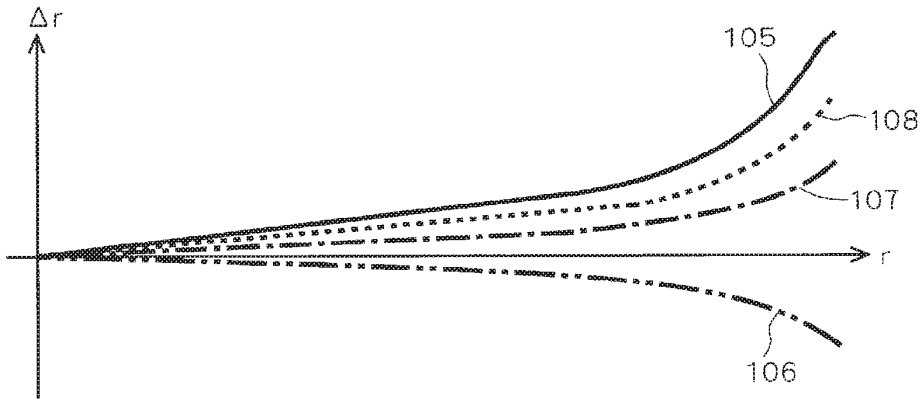


FIG. 13

0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
1	3	3	1	0	0	0
3	9	9	3	0	0	0
3	9	9	3	0	0	0
1	3	3	1	0	0	0

FIG. 14

301

COORDINATES OF POSITION OF IMAGE TO BE PROCESSED		MOVEMENT AMOUNT BY CHROMATIC ABERRATION	
x	y	Δrx	Δry
⋮	⋮	⋮	⋮
1324	256	1.33	0.88
1324	257	1.32	0.87
1324	258	1.32	0.86
⋮	⋮	⋮	⋮

FIG. 15

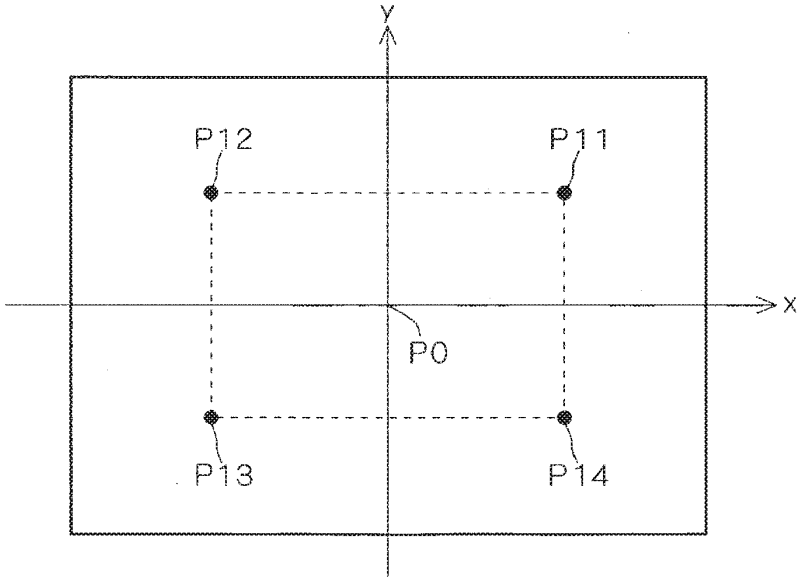


FIG. 16B

204

1	3	3	1	0	0	0
3	9	9	3	0	0	0
3	9	9	3	0	0	0
1	3	3	1	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

FIG. 16A

203

0	0	0	1	3	3	1
0	0	0	3	9	9	3
0	0	0	3	9	9	3
0	0	0	1	3	3	1
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

FIG. 16C

205

0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
1	3	3	1	0	0	0
3	9	9	3	0	0	0
3	9	9	3	0	0	0
1	3	3	1	0	0	0

FIG. 16D

206

0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	1	3	3	1
0	0	0	3	9	9	3
0	0	0	3	9	9	3
0	0	0	1	3	3	1

FIG. 17

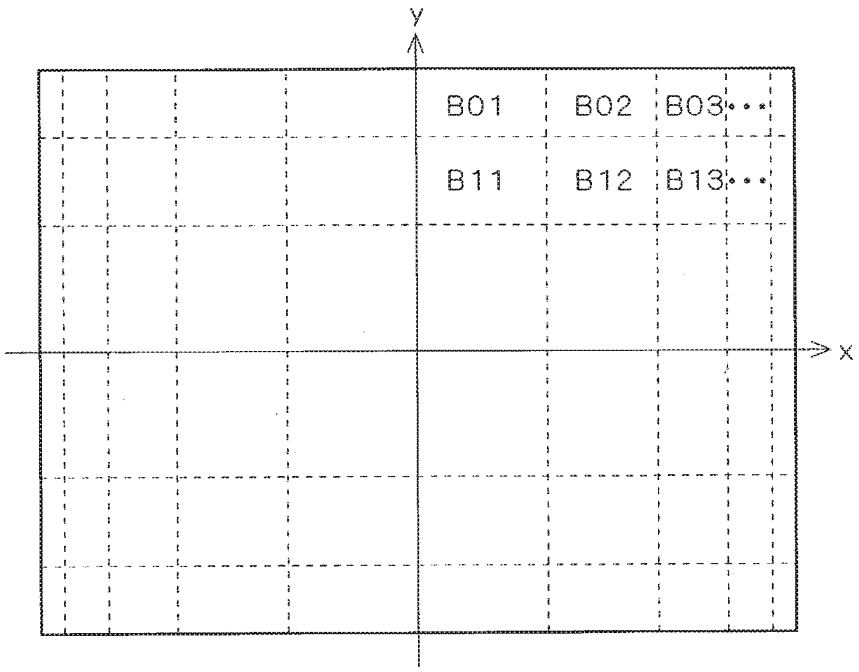


FIG. 18

302

NUMBER OF CORRECTION BLOCK	MOVEMENT AMOUNT BY CHROMATIC ABERRATION	
	Δ r x	Δ r y
B01	0.00	0.42
B02	0.13	0.47
B03	0.56	0.56
B04	0.82	0.76
⋮	⋮	⋮

FIG. 19

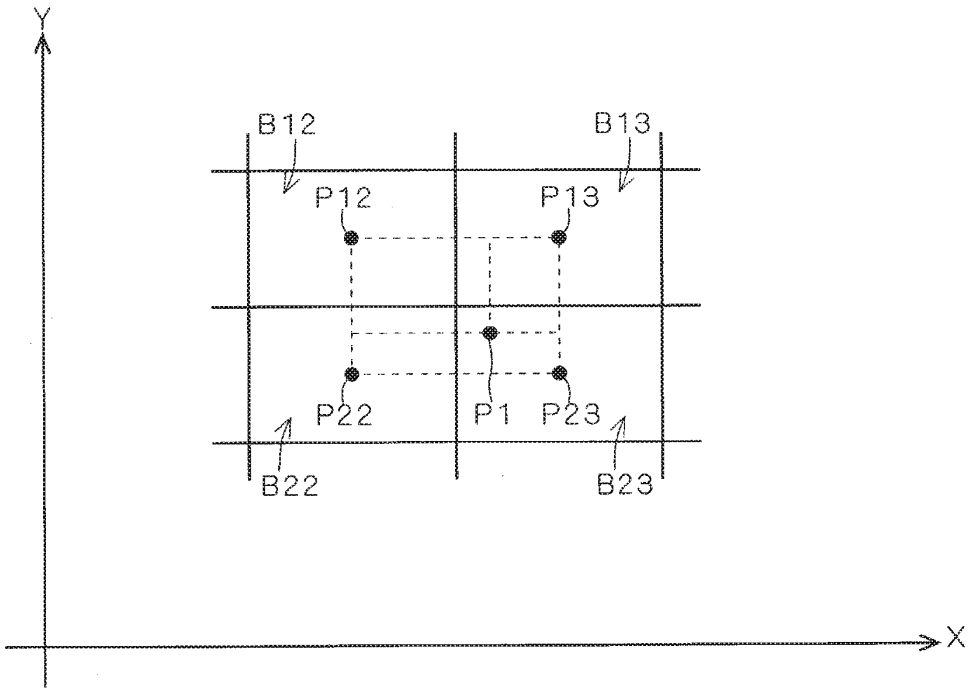


FIG. 20A

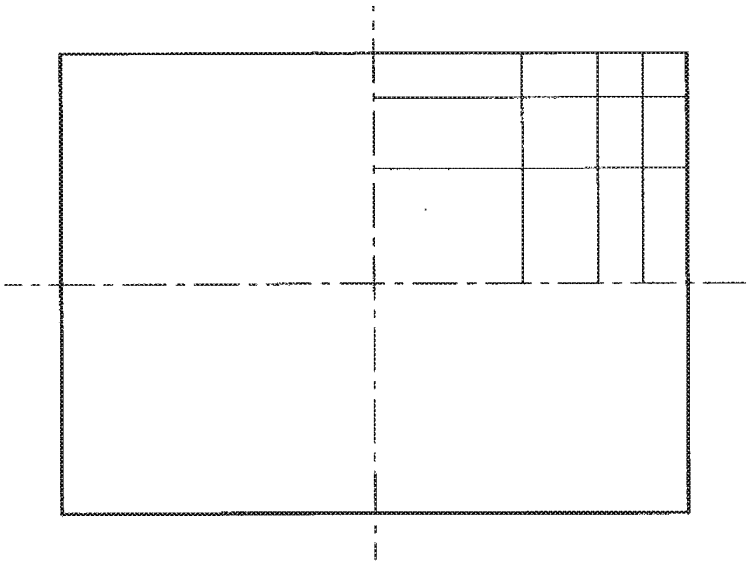
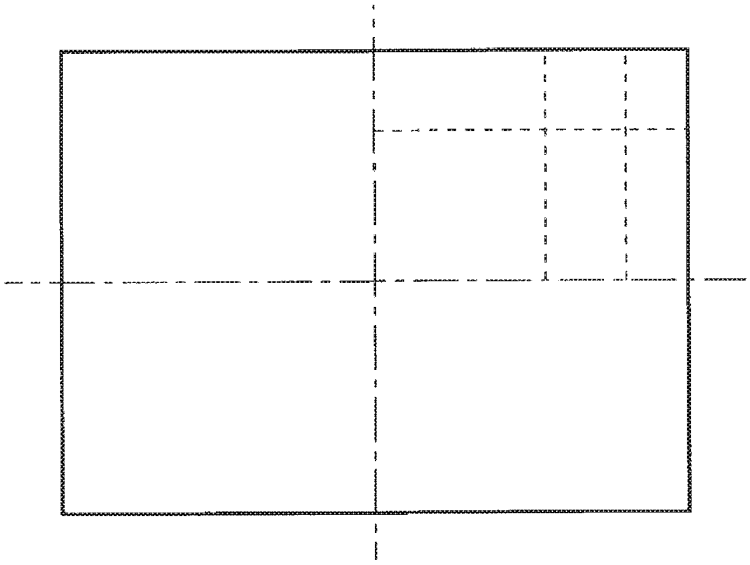


FIG. 20B



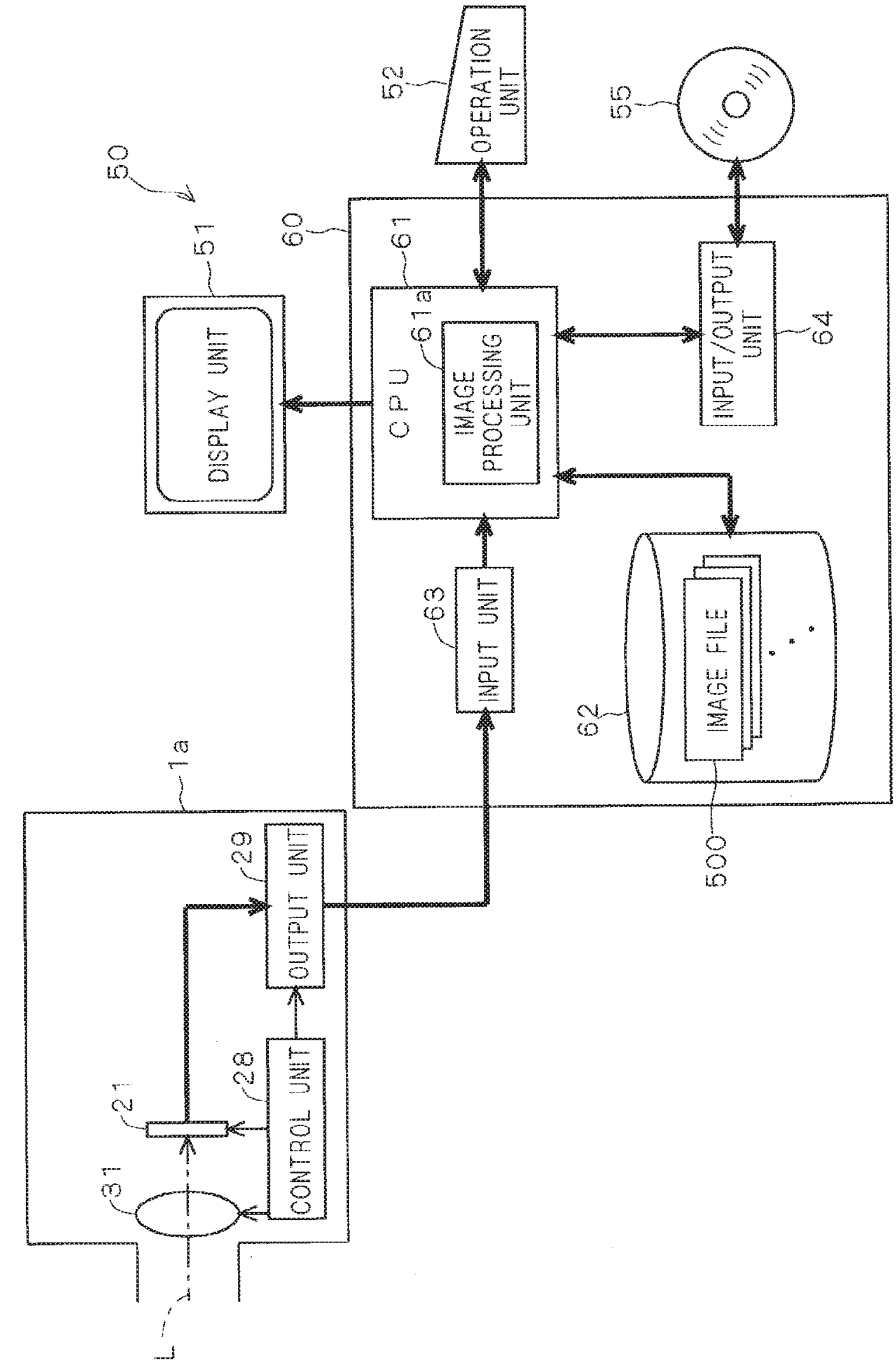

50
51
DISPLAY UNIT
52
OPERATION UNIT
55
60
61
61a
CPU
IMAGE PROCESSING UNIT
INPUT/OUTPUT UNIT
64
63
INPUT UNIT
62
IMAGE FILE
500
1a
29
OUTPUT UNIT
28
CONTROL UNIT
21
31
L

FIG. 21

FIG. 22

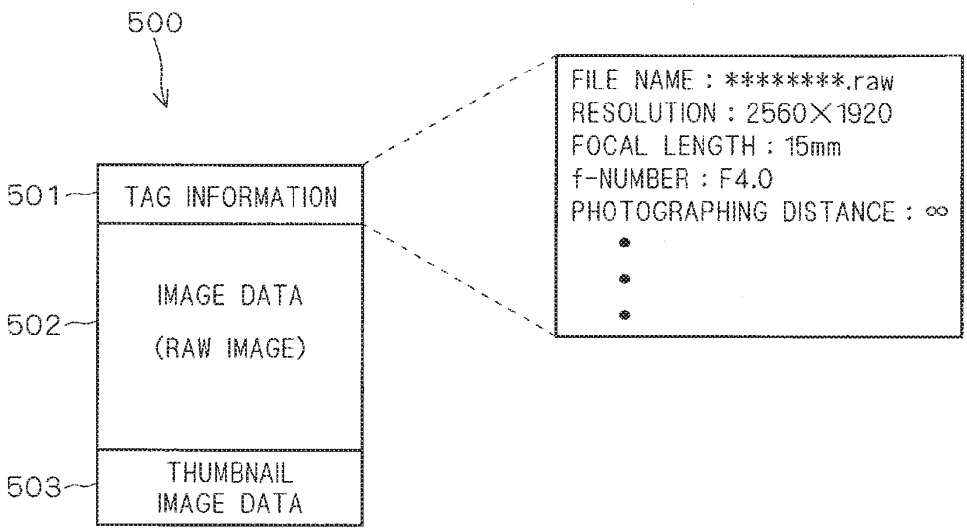
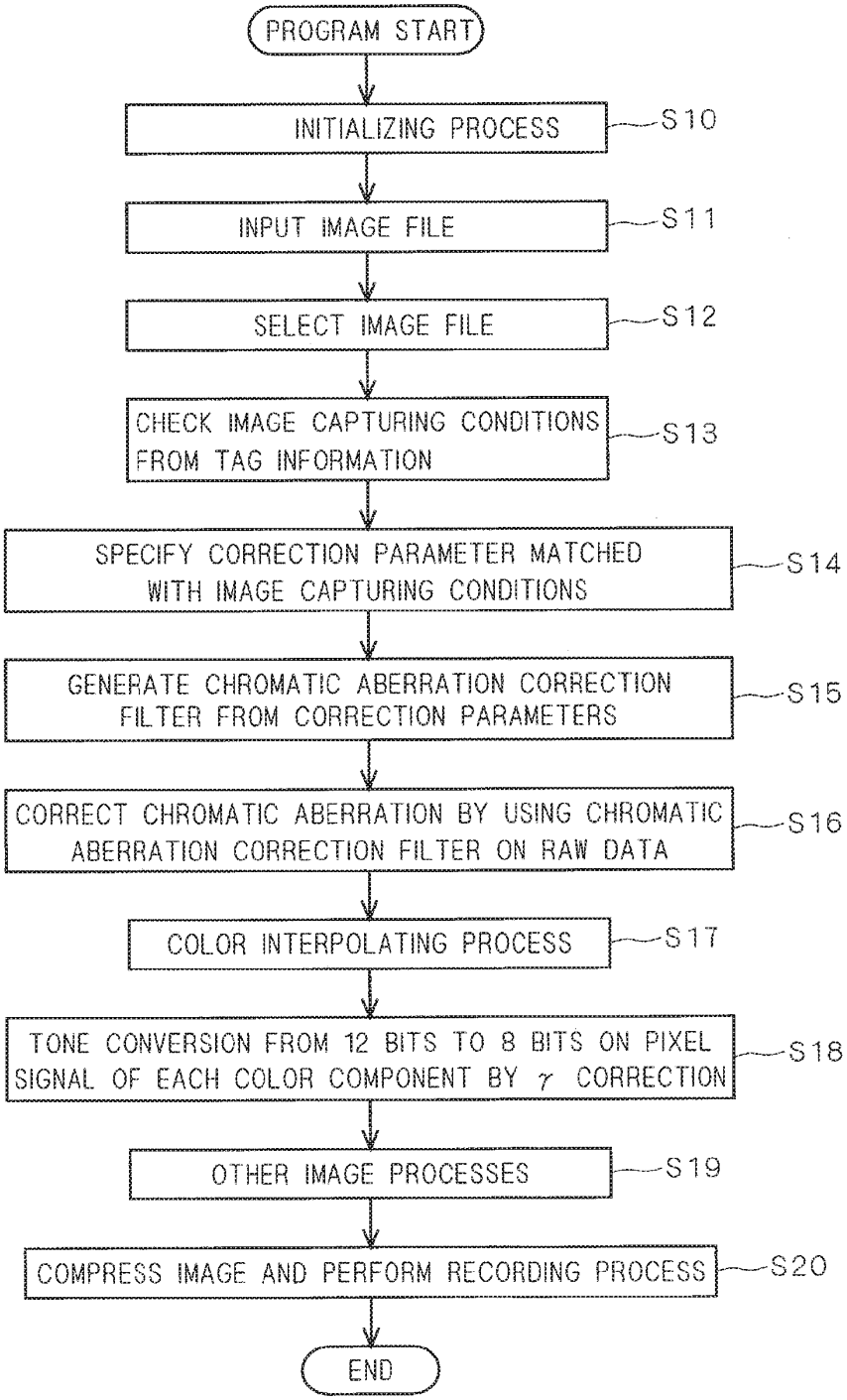

500
501
TAG INFORMATION
502
IMAGE DATA
(RAW IMAGE)
503
THUMBNAIL
IMAGE DATA
FILE NAME : ********.raw
RESOLUTION : 2560×1920
FOCAL LENGTH : 15mm
f-NUMBER : F4.0
PHOTOGRAPHING DISTANCE : ∞

FIG. 23


PROGRAM START
INITIALIZING PROCESS
S10
INPUT IMAGE FILE
S11
SELECT IMAGE FILE
S12
CHECK IMAGE CAPTURING CONDITIONS FROM TAG INFORMATION
S13
SPECIFY CORRECTION PARAMETER MATCHED WITH IMAGE CAPTURING CONDITIONS
S14
GENERATE CHROMATIC ABERRATION CORRECTION FILTER FROM CORRECTION PARAMETERS
S15
CORRECT CHROMATIC ABERRATION BY USING CHROMATIC ABERRATION CORRECTION FILTER ON RAW DATA
S16
COLOR INTERPOLATING PROCESS
S17
TONE CONVERSION FROM 12 BITS TO 8 BITS ON PIXEL SIGNAL OF EACH COLOR COMPONENT BY γ CORRECTION
S18
OTHER IMAGE PROCESSES
S19
COMPRESS IMAGE AND PERFORM RECORDING PROCESS
S20
END

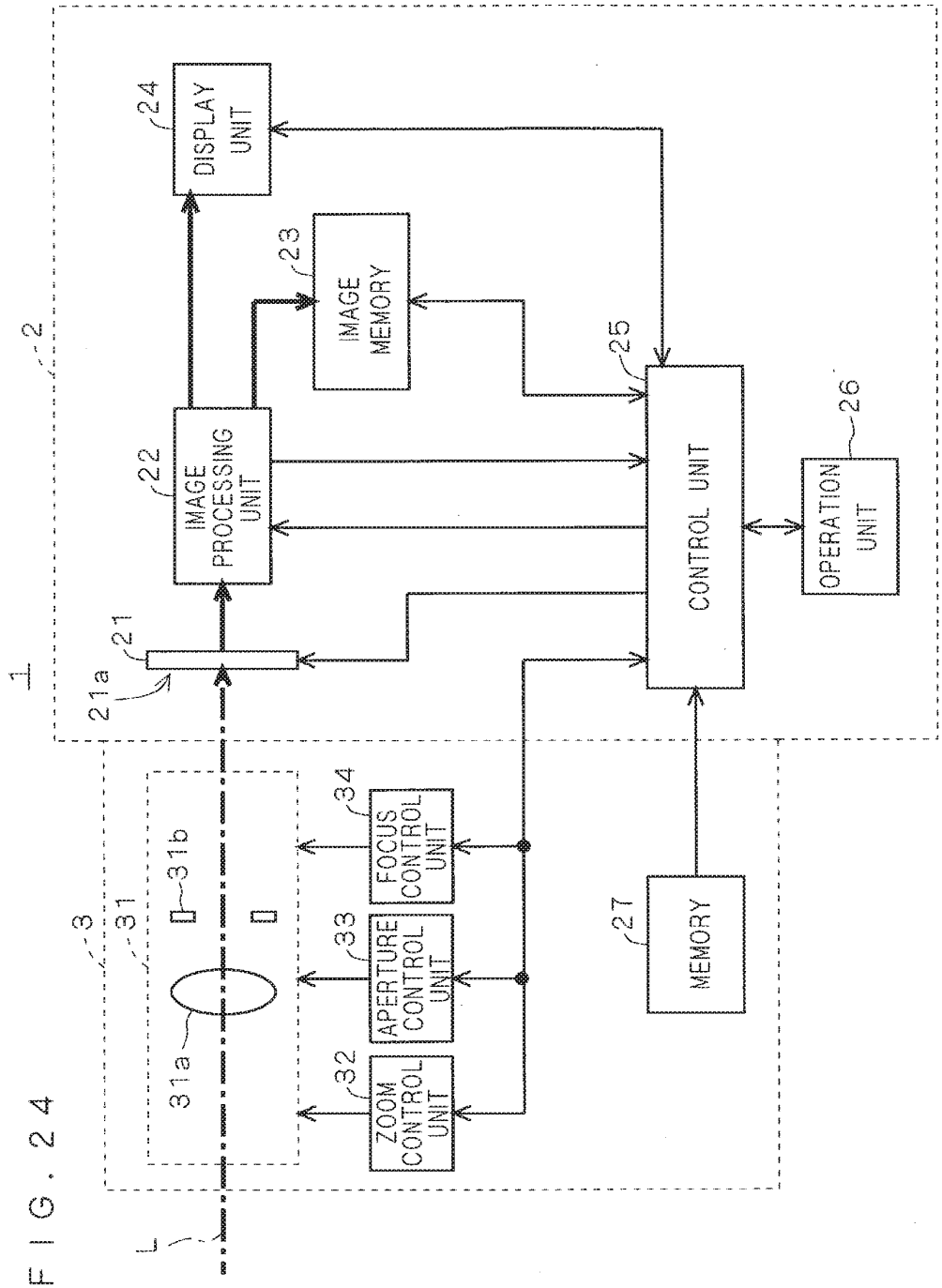

1
2
3
21
21a
22
IMAGE PROCESSING UNIT
23
IMAGE MEMORY
24
DISPLAY UNIT
25
CONTROL UNIT
26
OPERATION UNIT
27
MEMORY
31
31a
31b
32
ZOOM CONTROL UNIT
33
APERTURE CONTROL UNIT
34
FOCUS CONTROL UNIT
L

FIG. 24

IMAGE CAPTURING APPARATUS

[0001] This application is based on application No. 2003-028306 filed in Japan, the contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to an image processing technique in an image capturing apparatus, an image processing apparatus or the like, and more particularly to a technique of correcting a chromatic aberration caused by an image capturing optical system on an image signal obtained by photoelectrically converting a light image entered via the image capturing optical system.

[0004] 2. Description of the Background Art

[0005] In an image capturing apparatus such as a digital camera, a light image from the subject is led to an image capturing device such as a CCD via an image capturing optical system (taking lens).

[0006] In recent years, as reduction in the size of an image capturing device and increase in pixel resolution advance, aberration correction conditions requested for an image capturing optical system are becoming severer from the viewpoint of designing. In addition, miniaturization is demanded also for the image capturing optical system and designing of the optical system is becoming severer.

[0007] A particularly obtrusive aberration among the aberrations of the image capturing optical system is a magnification chromatic aberration (hereinafter, also simply referred to as chromatic aberration). Examples of known techniques of correcting a magnification chromatic aberration by image processing include a technique of correcting a magnification chromatic aberration by storing outputted image signals for each of color components of R (red), G (green) and B (blue) into a memory and moving and synthesizing the image signal on a pixel unit basis in accordance with the state of zooming and focusing of a taking lens (for example, Japanese Patent Application Laid-Open No. 5-3568 (1993) (hereinafter, referred to as Patent Literature 1)), and a technique of constructing an image capturing device by four CCDs and correcting a magnification chromatic aberration in accordance with the position of each CCD (for example, Japanese Patent Application Laid-Open No. 6-350904 (1994) (hereinafter, referred to as Patent Literature 2).

[0008] As disclosed in Japanese Patent Application Laid-Open No. 2002-209224 (hereinafter, referred to as Patent Literature 3), when a single-chip color image capturing device such as a CCD is used as an image capturing device, only a charge corresponding to one of primary color components of the three primary colors is accumulated in each pixel. Consequently, in order to obtain signals of color components of all of R, G and B with respect to each pixel, a color interpolating process (pixel interpolating process) has to be performed.

[0009] Even any of the techniques of Patent Literatures 1 and 2 is used, the following problem occurs. Specifically, in any of the techniques of Patent Literatures 1 and 2, a chromatic aberration correcting process is performed after a color interpolating process. After a color interpolating process is performed on an image including a chromatic aberration, the chromatic aberration correcting process is performed. It is therefore difficult to make the chromatic aberration correction properly and sufficiently function. As a result, although the chromatic aberration correcting process is performed also in the conventional techniques, a problem such that a chromatic aberration is still conspicuous in a reproduced image occurs.

[0010] Conventionally, it is not considered to reduce a storage amount at the time of storing parameters and the like used at the time of correcting a chromatic aberration. When the pixel density of an image capturing device is conspicuously increasing as in recent years, the capacity necessary to store parameters and the like becomes enormous. It hinders reduction in the size of an apparatus and also causes a problem such as an increase in cost.

SUMMARY OF THE INVENTION

[0011] The present invention is directed to an image capturing apparatus.

[0012] According to an aspect of the present invention, an image capturing apparatus comprises: an image capturing optical system; a color image sensor for converting a light image obtained by said image capturing optical system to an image signal having a color component which varies according to a pixel; and an image processor for concurrently performing a chromatic aberration correcting process of correcting a chromatic aberration of said image capturing optical system and a color interpolating process of interpolating a dropout color component pixel by pixel on an image signal generated by said color image sensor.

[0013] With the configuration, chromatic aberration correction can be made excellently function and high-precision chromatic aberration correction can be performed. Since the chromatic aberration correcting process and the color interpolating process are concurrently performed, processing efficiency is improved.

[0014] According to another aspect of the present invention, an image capturing apparatus comprises: an image capturing optical system; a color image sensor for converting a light image obtained by said image capturing optical system into an image signal having a color component which varies according to a pixel; a divider for dividing an image signal generated by the color image sensor into a plurality of blocks; a memory for storing a parameter for chromatic aberration correction applied to each block divided by the divider; and an image processor for correcting a chromatic aberration caused by said image capturing optical system by the block on the basis of the parameter stored in said memory on an image signal generated by said color image sensor.

[0015] Consequently, the number of parameters to be stored in a memory may be the number corresponding to the number of blocks. Therefore, it becomes unnecessary to store parameters of all of pixels, so that an amount of information stored in the memory can be excellently reduced.

[0016] According to still another aspect of the present invention, an image capturing apparatus comprises: an image capturing optical system; a color image sensor for converting a light image obtained by said image capturing

optical system into an image signal of a color component which varies according to a pixel; a memory for storing a parameter for approximating a chromatic aberration caused by said image capturing optical system; and an image processor for performing a chromatic aberration correcting process on an image signal generated by said color image sensor by performing computation with an approximation function by using the parameter stored in said memory.

[0017] With this configuration, since a deviation amount can be estimated by using an approximation function, while maintaining correction precision in a predetermined range, the storage capacity of parameters can be reduced as compared with the case of storing an accurate deviation amount for each pixel.

[0018] Further, the present invention is also directed to an image processing apparatus for performing an image process on an image signal which is generated on the basis of a light image received via an image capturing optical system and has a color component which varies according to a pixel, and a program product in which a program of allowing a computer to perform a predetermined process on an image signal which is generated on the basis of a light image received via an image capturing optical system and has a color component which varies according to a pixel.

[0019] As described above, an object of the present invention is to realize an image processing technique of making chromatic aberration correction excellently function and capable of efficiently correcting a chromatic aberration, and to provide a technique of reducing storage capacity of parameters used for the chromatic aberration correction.

[0020] These and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] **FIG. 1** is a block diagram showing a schematic configuration of an image capturing apparatus;

[0022] **FIG. 2** is a diagram showing a light-receiving face of an image capturing device;

[0023] **FIG. 3** is a block diagram showing an example of the detailed configuration of an image processing unit;

[0024] **FIG. 4** is a diagram showing a magnification chromatic aberration of an image capturing optical system under an image capturing condition;

[0025] **FIG. 5** is a diagram showing an example of an image filter applied to a color interpolating process;

[0026] **FIG. 6** is a diagram showing an example of an image filter applied to a chromatic aberration correcting process;

[0027] **FIG. 7** is a diagram showing an example of an image filter for concurrently performing the color interpolating process and the chromatic aberration correcting process;

[0028] **FIG. 8** is a diagram showing an example of the relationship between image capturing conditions and coefficients of an approximation function stored with respect to an R component;

[0029] **FIG. 9** is a diagram showing an example of the relationship between image capturing conditions and coefficients of an approximation function stored with respect to a B component;

[0030] **FIG. 10** is a diagram showing an image plane of an image obtained from the image capturing device;

[0031] **FIG. 11** is a diagram showing an example of a chromatic aberration characteristic in the case where the square of distance is an argument;

[0032] **FIG. 12** is a diagram showing a chromatic aberration characteristic by the image capturing optical system;

[0033] **FIG. 13** is a diagram showing an example of a filter of a B component obtained from the filter of **FIG. 7**;

[0034] **FIG. 14** is a diagram showing an example of a lookup table stored in a memory;

[0035] **FIG. 15** is a diagram showing an image plane;

[0036] **FIGS. 16A** to **16D** are diagrams for describing conversion of filter coefficients;

[0037] **FIG. 17** is a diagram showing an example of dividing an image plane of an image obtained from the image capturing device into blocks;

[0038] **FIG. 18** is a diagram showing an example of a lookup table stored in a memory;

[0039] **FIG. 19** is a diagram for describing concept of weighted average;

[0040] **FIGS. 20A and 20B** are diagrams showing an example of dividing an image plane into blocks differently with respect to R and B components;

[0041] **FIG. 21** is a diagram showing the configuration of an image processing system;

[0042] **FIG. 22** is a diagram showing an example of an image file;

[0043] **FIG. 23** is a flowchart showing a processing sequence in a computer; and

[0044] **FIG. 24** is a block diagram showing a schematic configuration of an image capturing apparatus in which a memory is provided on a lens unit side.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0045] Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the drawings.

1. First Preferred Embodiment

[0046] A first preferred embodiment will be described. In the present preferred embodiment, an example of a configuration for excellently performing chromatic aberration correction in an image capturing apparatus such as a digital camera will be described.

[0047] **FIG. 1** is a block diagram showing a schematic configuration of an image capturing apparatus **1**. As shown in **FIG. 1**, the image capturing apparatus **1** has a body **2** and a lens unit **3**. The lens unit **3** is constructed so that it can be separated from the body **2**.

[0048] The lens unit **3** has an image capturing optical system **31**, a zoom control unit **32**, an aperture control unit **33** and a focus control unit **34**. The image capturing optical system **31** has a lens **31***a* and an aperture member **31***b* disposed on an optical axis L to lead a light image of a subject to the body **2**. The zoom control unit **32** changes a focal length by driving the image capturing optical system **31**, thereby changing a magnification. The aperture control unit **33** adjusts the opening diameter of the aperture member **31***b* included in the image capturing optical system **31**. The focus control unit **34** drives the image capturing optical system **31** so that a proper focus state is realized in accordance with the distance between the subject and the image capturing apparatus. Each of the zoom control unit **32**, aperture control unit **33**, and focus control unit **34** drives and controls the image capturing optical system **31** on the basis of a control signal supplied from a control unit **25** of the body **2**.

[0049] The body **2** includes an image capturing device **21**, an image processing unit **22**, an image memory **23**, a display unit **24**, the control unit **25**, an operation unit **26** and a memory **27**.

[0050] The image capturing device **21** takes the form of, for example, a single-chip CCD image sensor and has a structure in which a plurality of pixels are disposed two-dimensionally on a light-receiving face **21***a* perpendicular to the optical axis L. The image capturing device **21** is disposed so that the center of the light-receiving face **21***a* coincides with the center of the optical axis L. **FIG. 2** is a diagram showing the light-receiving face of the image capturing device **21**. As shown in **FIG. 2**, a color filter array of a so-called Bayer matrix is disposed on the light-receiving face of the image capturing device **21**. Each pixel receives light of the color component of any one of the three primary colors of R, G and B. Consequently, charges according to a light amount of the color component received are accumulated in each pixel. In the image capturing device **21**, a color component which varies according to a pixel out of the three primary colors of R, G and B is detected pixel by pixel and pixel signals are generated. Color image signals of one frame are generated by a collection of a plurality of the pixel signals. The image capturing device **21** has, therefore, the function of photoelectrically converting a light image entering via the image capturing optical system **31** into image signals of different color components pixel by pixel. The image signal obtained is converted to, for example, a 12-bit digital signal by a not-shown A/D converter, and the digital signal is outputted to the image processing unit **22**.

[0051] In the image signal outputted to the image processing unit **22**, each pixel has information of the color component of any of the three primary colors of R, G and B. The image signal is an image signal including a chromatic aberration caused by the image capturing optical system **31**.

[0052] Generally, the chromatic aberration caused by the image capturing optical system **31** increases with distance from the center of the optical axis L in the light-receiving face of the image capturing device **21**. **FIG. 4** is a diagram showing a magnification chromatic aberration under certain image capturing conditions of the image capturing optical system **31**. It shows the relationship between a distance "r" from the center of an image (center of the optical axis L) and a deviation amount (Δr) of an image formation position of light of an R component from an image formation position of light of a G component. A chromatic aberration **101** of the R component light is obtained by optical simulation or actual measurement as a deviation in the radial direction from the center of the optical axis as a reference on an image of the R component light from the G component. The chromatic aberration **101** increases with distance from the center of the optical axis L. In other words, even when light is from the same position of the subject, the image formation position of the G component and that of the R component do not coincide with each other and the deviation amount increases toward the peripheral portion of the image.

[0053] The above is similarly applied to light of the B component. Generally, when the G component is used as a reference, the aberration of light of the B component appears on the side opposite to the aberration of light of the R component (that is, $-\Delta r$ side in **FIG. 4**). In a manner similar to the R component, the aberration of the B component light increases with distance from the center of the optical axis L.

[0054] Therefore, the image processing unit **22** is constructed so as to correct the chromatic aberration which is caused by the image capturing optical system **31**. As will be described later, the image processing unit **22** is constructed so as to perform not only the chromatic aberration correcting process but also other various image processes.

[0055] An image signal subjected to the image process in the image processing unit **22** is outputted to at least one of the image memory **23** and the display unit **24**. The image memory **23** is a recording medium such as a semiconductor memory for recording image signals. The image memory **23** may be constructed like a memory card so as to be removable from the image capturing apparatus **1**. The display unit **24** is a display device provided on the rear face side or the like of the body **2** and is, for example, a liquid crystal display.

[0056] The operation unit **26** is operation members such as a switch and a button provided for the user to enter operation instructions for the image capturing apparatus **1**. An operation instructed to the operation unit **26** is converted to an electric signal and the electric signal is supplied to the control unit **25**.

[0057] The control unit **25** is a function realized when a CPU provided in the body **2** executes a predetermined program. The control unit **25** controls various members provided for the body **2** and also controls the state of the image capturing optical system **31** by transmitting control signals to the zoom control unit **32**, aperture control unit **33** and focus control unit **34** provided for the lens unit **3**. For example, when the user operates the operation unit **26** to change the magnification, the control unit **25** transmits a control signal of changing the focal length of the zoom control unit **32** on the basis of the operation amount. Consequently, the control unit **25** can identify the state of the image capturing optical system at the time of photographing (hereinafter, referred to as the image capturing condition).

[0058] The control unit **25** determines an image filter (hereinafter, simply referred to as a filter) applied when the color interpolating process and chromatic aberration correcting process are performed in the image processing unit **22** and supplies the filter to the image processing unit **22**. In order to determine the filter, the memory **27** is provided in

the body **2**. In the memory **27**, various parameters based on the optical characteristics of the image capturing optical system **31** and the image capturing conditions at the time of photographing are stored. Therefore, the control unit **25** is constructed to determine a filter by referring to information stored in the memory **27**.

[0059] The image processing unit **22** performs filter computation by using the filter supplied from the control unit **25** at the time of performing the color interpolating process and chromatic aberration correcting process on an image signal obtained from the image capturing device **21**.

[0060] **FIG. 3** is a block diagram showing an example of the detailed configuration of the image processing unit **22**. In the image processing unit **22**, an image signal obtained from the image capturing device **21** is inputted to a WB (white balance) circuit **41** where level conversion of R, G and B is performed, thereby adjusting white balance.

[0061] After the adjustment of white balance, the image signal is inputted to a filter computation circuit **42**. By filter computation using a filter, a color interpolating process and also a chromatic aberration correcting process for correcting a chromatic aberration caused by the image capturing optical system **31** are performed on each pixel.

[0062] Since each pixel has information of the primary color component of only one of R, G and B, the color interpolating process estimates information of the other primary color components dropped in each pixel on the basis of values of peripheral pixels. By the color interpolating process, information of 12 bits of each of R, G and B is given to each pixel.

[0063] Generally, in the color interpolating process, a filter **201** having filter coefficients as shown in **FIG. 5** is applied. By performing the filter computation while selecting a filter coefficient from the filter **201** in accordance with a color component to be interpolated of the pixel to be processed, the information of the dropped color components of the pixel can be obtained by being estimated from color components of the peripheral pixels. Filter coefficient can be set in various well-known ways. By way of example, the details of setting of filter coefficients of the filter **201** and the filter action are disclosed in the Japanese Patent Application Laid-Open No. 2000-287219.

[0064] The chromatic aberration correcting process is a process for correcting a chromatic aberration caused by the image capturing optical system **31** and is to correct a deviation between the image formation position of the G component and that of each of the R and B components, which is conspicuous particularly in an image peripheral portion.

[0065] Generally, in the chromatic aberration correcting process, an asymmetric filter **202** in which filter coefficients are distributed in an unbalanced manner as shown in **FIG. 6** is applied. The filter **202** has a filter structure for correcting a chromatic aberration of the case where the image formation position of the R component is deviated to the right upper direction by 1.5 pixels from the G component. Information of the R component regarding a pixel to be processed (pixel in the center of the filter) can be estimated from four pixels positioned in the right upper direction. In other words, the filter **202** has the function of moving a pixel signal of which image formation position was moved by a chromatic aberration to the center of the image. The filter **202** is a filter capable of correcting a chromatic aberration by moving a pixel signal. The details of setting of filter coefficients of the filter **202** and the filter action are disclosed in Japanese Patent Application Laid-Open No. 5-3568 (1993) (Patent Literature 1). Such a filter **202** is obtained for each of the R and B components.

[0066] In the filter computation circuit **42**, filter computation is performed by using a filter **203** as shown in **FIG. 7** obtained by combining the filter **201** of **FIG. 5** and the filter **202** of **FIG. 6** by convolution computation or the like in order to simultaneously perform the color interpolating process and the chromatic aberration correcting process. The filter applied in the filter computation circuit **42** is changed for each pixel on the basis of an instruction from the control unit **25**. Consequently, the filter computing circuit **42** is constructed so as to transmit position information of a pixel to be processed is notified to the control unit **25**. On the basis of the position information, the control unit **25** determines a filter (filter obtained by combining the filter for color correcting process and the filter for correcting chromatic aberration) adapted to the process on the pixel with respect to each of the R component and the B component, and supplies the filter to the filter computing circuit **42**. A method of determining a filter applied in the filter computing circuit **42** in the control unit **25** will be described later.

[0067] After the color interpolating process and chromatic aberration correcting process are performed in the filter computing circuit **42**, each of pixel signals (R, G and B) is subjected to a predetermined correcting process in a linear matrix circuit **43** and, the resultant is inputted to a γ correction circuit **44**. In the γ correction circuit **44**, the pixel signals (R, G and B) are corrected in accordance with reproduction characteristics of a display with a γ correction table (RGB gamma LUT) **44***a*. Further, a 12-bit signal of each pixel is compressed to an 8-bit signal in the γ correction circuit **44**.

[0068] Then, the pixel signal (R, G and B) compressed to 8 bits is inputted to a color difference matrix circuit **45**. The color difference matrix circuit **45** has a Y matrix **45***a*, a Cr matrix **45***b* and a Cb matrix **45***c* matrixes for conversion, and a color space having the primary color components of R, G and B is converted into a color space having a luminance component (Y) and color difference components (Cr and Cb).

[0069] The luminance signal Y outputted from the color difference matrix circuit **45** is inputted to a contour emphasizing filter circuit **46**. In the contour emphasizing filter circuit **46**, the luminance signal Y is split to three signals. One of the three split luminance signals Y passes through an HPF (High-Pass Filter) **46***b*, one of them passes through an LPF (Low-Pass Filter) **46***a*, and the other is inputted to a line segment extracting circuit **46***f*.

[0070] From the luminance signal Y passed through the HPF **46***b*, a high frequency component is detected. The detected high frequency component is inputted to an amplifier **46***c* where it is amplified. Further, in a base clip **46***d*, only a high frequency component of a predetermined value or larger is detected and outputted.

[0071] In an adder **46***e*, the high frequency component of the predetermined value or larger outputted from the base

clip **46***d* is added to the luminance signal Y passed through the LPF **46***a*, thereby performing contour emphasis on the luminance signal Y, and the resultant signal is outputted.

[0072] In the line segment extracting circuit **46***f*, by using a Sobel line segment extraction filter, a line segment component is extracted from the luminance signal Y. The luminance signal Y inputted to the line segment extracting circuit **46***f* is stored in a buffer (not shown). On the basis of the luminance signal Y stored in the buffer, a line segment extracting process of a pixel to be processed is performed. For example, the line segment extraction filter is expressed by a matrix form of three rows and three columns, and the line segment extracting process is performed by using the luminance signal Y of the target pixel and the luminance signals Y of eight pixels adjacent to the target pixel. Therefore, at least the luminance signals Y of nine pixels have to be stored in the buffer. With respect to each of the luminance signals Y of nine pixels in the three rows and three columns, by performing a pattern matching with the line segment extraction filter, whether the target pixel is a line segment component or not is determined. If the target pixel is a line segment component, the detection level of the line segment component is detected. As concrete processes in the line segment extracting circuit **46***f*, for example, the processes described in Japanese Patent Application Laid-Open No. 2002-209224 (Patent Literature 3) can be applied.

[0073] After the line segment extracting circuit **46***f* extracts the line segment component, position information of the pixel determined as a line segment component and the detection level of the line segment component in the pixel are inputted to a line segment chroma killer circuit **47**.

[0074] The line segment chroma killer circuit **47** performs a suppressing process of a color difference signal (in the following description, electric signals of color difference components are properly expressed as color difference signals Cr and Cb) for the color difference components Cr and Cb on the basis of the detection level of an inputted line segment component. Specifically, the line segment chroma killer circuit **47** obtains the degree of suppression of the color difference signals Cr and Cb by referring to a line segment chroma killer setting lookup table (line segment chroma killer setting LUT) **47***a* on the basis of the detection level of an inputted line segment component, and performs a process of suppressing the color difference signals Cr and Cb according to the degree of suppression by multipliers **47***b* and **47***c*. As concrete processes in the line segment chroma killer circuit **47**, for example, processes disclosed in Japanese Patent Application Laid-Open No. 2002-209224 (Patent Literature 3) can be applied. In the line segment chroma killer circuit **47**, the degree of suppression control is changed according to the detection level of the line segment component, and an image process is performed so that an output image does not become unnatural.

[0075] An image signal constructed by the luminance signal Y subjected to the contour emphasizing process and the color difference signals Cr and Cb subjected to the suppression control, which is outputted by the process is temporarily stored in a buffer **48**. As shown in **FIG. 1**, at the time of displaying an image, an image signal is outputted from the buffer **48** to the display unit **24**. At the time of recording an image, an image signal is outputted from the buffer **48** to the image memory **23**. For example, when an image is displayed, the image signal stored in the buffer **48** is converted to a predetermined video signal, and the video signal is outputted. When an image is recorded, a predetermined compressing process such as JPEG encoding is performed on the image signal stored in the buffer **48**, and the compressed image signal is outputted.

[0076] A process of specifying a filter in the control unit **25** will now be concretely described.

[0077] As shown in **FIG. 4**, in the case where the image capturing optical system **31** is under an image capturing condition, the chromatic aberration **101** of the R component with respect to the G component can be preliminarily specified according to the characteristics of the image capturing optical system **31** by optical simulation or actual measurement. An approximation function **102** for approximating the actual chromatic aberration **101** of the R component in the case where the image capturing optical system **31** is under the certain image capturing conditions is preset in the control unit **25** (see **FIG. 4**). For example, in the case of approximating the approximation function **102** by a cubic function, when the distance from the center of an image (position coinciding with the center of the optical axis L) is set as "r" and a deviation amount between the R component and the G component in the distance "r" is set as f(r), the approximation function **102** can be expressed as follows.

$$f(r)=ar^3+br^2+cr+d \qquad \text{Equation 1}$$

[0078] In equation 1, a, b, c and d are coefficients of approximation function and are values determined by the image capturing conditions of the image capturing optical system **31**. The coefficients a, b, c, and d are prestored in the memory **27** for each of different image capturing conditions.

[0079] **FIG. 8** is a diagram showing an example of the relation between the image capturing conditions and the coefficients a, b, c and d stored in the memory **27**. As shown in **FIG. 8**, the coefficients a, b, c and d of the approximation function **102** vary according to the image capturing conditions specified by the focal length, photographing distance and f-number. When the image capturing conditions are determined, each of the coefficients a, b, c and d is specified accordingly. When the position of a pixel to be processed differs, the relation as shown in **FIG. 8** also becomes different. Consequently, the relationship between the image capturing conditions and the approximation function **102** is stored for each pixel in the memory **27**.

[0080] The B component is processed in a manner similar to the R component. Specifically, light of the B component is deviated in the direction opposite to the direction of deviation of the R component when the G component is used as a reference. Consequently, with respect to the B component, the relation between the image capturing conditions and the approximation function is stored in signs opposite to those in the case of the R component into the memory **27** as shown in **FIG. 9**.

[0081] **FIG. 10** is a diagram showing an image plane of an image obtained from the image capturing device **21** and shows a case where the center of the image coincides with the center of the optical axis L. As shown in **FIG. 10**, when the center **P0** of an image is set as a reference (0, 0), the X-axis is determined in the horizontal direction and the Y-axis is determined in the vertical direction. When the pixel to be processed is P1, the control unit **25** obtains position

information (X, Y) of the present pixel P1 to be processed from the filter computation circuit **42**, and computes the distance "r" between the center P0 of the image and the pixel P1 to be processed. That is, the distance "r" is obtained by computing the following equation.

$$r=\sqrt{(X^2+Y^2)} \quad \text{Equation 2}$$

[0082] The control unit **25** reads out the coefficients a, b, c and d according to the image capturing conditions from the memory **27** and executes computation by substituting the distance "r" for Equation 1, thereby obtaining the deviation amount Δr=f(r). It is known that by executing such computation, as shown in **FIG. 10**, light of the R component in the pixel P1 to be processed is moved to a pixel position P2 by a chromatic aberration.

[0083] When movement components parallel to the X-axis and Y-axis are obtained on the basis of the movement amount Δr to the pixel position P2, a movement component Δrx parallel to the X-axis can be expressed as follows.

$$\Delta rx=\Delta r\cdot X/r \quad \text{Equation 3}$$

[0084] A movement component Δry parallel to the Y-axis can be expressed as follows.

$$\Delta ry=\Delta r\cdot Y/r \quad \text{Equation 4}$$

[0085] X in the right side of Equation 3 denotes an X coordinate of the pixel P1 to be processed and Y in the right side of Equation 4 denotes a Y coordinate of the pixel P1 to be processed.

[0086] Therefore, from the positional information (X, Y) of the pixel P1 to be processed, the deviation amount Δr of the image formation position due to chromatic aberration is obtained and, further, the X component (Δrx) and the Y component (Δry) of the deviation amount Δr can be derived. At the time of obtaining a signal value of the R component of the pixel P1 to be processed, by referring to information of the pixel P2 in a position deviated from the position (X, Y) of the pixel P1 to be processed by Δrx in the X direction and Δry in the Y direction, a chromatic aberration can be corrected properly.

[0087] The filter **202** shown in **FIG. 6** shows a case where each of the deviation amounts due to the chromatic aberration in the X-axis and the Y-axis is 1.5 pixels by the computation as described above. Specifically, since a pixel having proper information does not exist in the position moved from the pixel P1 to be processed in both of the X direction and the Y direction each by 1.5 pixels in the image plane, the filter of **FIG. 6** is constructed to generate information of the pixel P1 to be processed from information of four pixels positioned around the pixel P1 to be processed.

[0088] That is, generally, the control unit **25** determines a filter for correcting chromatic aberration so as to generate information of the pixel P1 to be processed by referring to information of pixels in a deviated position in accordance with the deviation amounts in the X and Y directions.

[0089] Further, the control unit **25** executes convolution computation or the like on the basis of the filter **201** for processing color interpolation process (see, for example, **FIG. 5**) prestored in the memory **27** and the filter **202** for correcting chromatic aberration determined as described above (see, for example, **FIG. 6**), thereby generating the filter **203** (see, for example, **FIG. 7**) for simultaneously executing the color interpolating process and the chromatic aberration correcting process. The filter **203** is outputted to the filter computing circuit **42** in the image processing unit **22**.

[0090] At the time of outputting the filters for obtaining signal values of the R and B components with respect to the pixel P1 to be processed, to the filter computation circuit **42**, the control unit **25** obtains the filter derived by combining the filter for color interpolating process with respect to each of the R and B components and the filter for correcting chromatic aberrations with respect to the R and B components. With respect to the G component, it is regarded in the present preferred embodiment that no chromatic aberration occurs. Consequently, the filter for color interpolating process with respect to the G component is output as it is to the filter computing circuit **42**.

[0091] The filter computation circuit **42** performs filter computation by applying the filters supplied from the control unit **25**. Particularly, at the time of obtaining signal values of the R component and the B component of the pixel P1 to be processed, the color interpolating process and the chromatic aberration correcting process are concurrently performed.

[0092] Although the case where the approximation function **102** is expressed by a cubic function using the distance "r" as an argument has been described above, alternately, the approximation function **102** may be expressed by a cubic function using the square (r^2) of distance as an argument. **FIG. 11** is a diagram showing an example of an aberration characteristic in the case where a distance r^2 is an argument. Even when the distance r^2 is an argument as shown in **FIG. 11, a** chromatic aberration **104** of the R component becomes almost the same form as that of the chromatic aberration **101** in **FIG. 4**. As shown in **FIG. 11**, an approximation function **103** is defined by setting the square (r^2) of the distance as an argument. For example, the approximation function is specified as follows.

$$f(r)=a(r^2)^3+b(r^2)^2+c(r^2)+d \quad \text{Equation 5}$$

[0093] In this case, at the time of obtaining an argument from position information (X, Y) of the pixel P1 to be processed, it becomes unnecessary to perform root computation as shown in Equation 2 and an argument can be obtained efficiently.

[0094] As described above, in the image capturing apparatus **1** of the present preferred embodiment, the chromatic aberration correcting process of correcting chromatic aberration caused by the image capturing optical system **31** and the color interpolating process of interpolating a dropout color component of each pixel are concurrently performed on image signals obtained from the image capturing device **21**. Thus, chromatic aberration correction can be made function at high precision. That is, when the color interpolating process is performed prior to the chromatic aberration correction as in the conventional technique, an influence of chromatic aberration is exerted on peripheral pixels, so that excellent chromatic aberration correction cannot be performed. However, by performing the color interpolating process and the chromatic aberration correction concurrently, such a problem does not occur and the chromatic aberration correction can be made excellently. Since the chromatic aberration is corrected by the image process, the image capturing optical system **31** is not burdened with

severe design conditions and the flexibility in designing of the image capturing optical system **31** is improved.

[0095] The image capturing apparatus **1** of the present preferred embodiment is constructed so that each of the pixels in the image capturing device **21** detects one of the color components of the three primary colors of R, G and B. The image processing unit **22** performs, as the chromatic aberration correcting process, different filter computations for at least two color components of the three primary colors, thereby performing the process of moving pixel signals of at least two color components to the center of an image. Specifically, by performing the filter computation with a filter adapted to each of the R and B components, a chromatic aberration in the case of using the G component as a reference is corrected. Consequently, without making design of a high order for the image capturing optical system **31**, a chromatic aberration can be excellently corrected by the conventionally known image processing computation referred to as filter computation. Thus, a chromatic aberration can be corrected relatively easily.

[0096] The image processing unit **22** of the image capturing apparatus **1** is constructed to perform the filter computation with, as a filter applied for filter computation, a filter having coefficients obtained by combining filter coefficients for performing the color interpolating process and filter coefficients for moving a pixel signal (that is, filter coefficients for performing the chromatic aberration correcting process). Therefore, the color interpolating process and the chromatic aberration correcting process can be performed concurrently.

[0097] The image capturing apparatus **1** of the present preferred embodiment stores a plurality of filters for correcting chromatic aberrations caused by the image capturing optical system **31** in the memory **27**, applies an approximation function according to the position of a pixel to be processed to thereby specify a filter applied to chromatic aberration correction from the plurality of filters stored in the memory **27**, and performs chromatic aberration correction on an image obtained from the image capturing device **21** by using the specified filter. Consequently, it is unnecessary to execute complicated calculation for movement in order to correct a chromatic aberration, and a chromatic aberration can be corrected by relatively easy filter computation.

[0098] The image capturing apparatus **1** of the present preferred embodiment stores a parameter for approximating a chromatic aberration caused by the image capturing optical system **31** into the memory **27**, obtains a parameter from the memory **27** in accordance with the position of a pixel to be processed and the image capturing conditions at the time of photographing of the image capturing optical system **31**, executes computation with the approximation function **102**, thereby estimating a deviation amount of the chromatic aberration of the image capturing optical system **31**. The chromatic aberration correction on an image obtained from the image capturing device **21** is carried out in accordance with the estimated deviation amount. Therefore, since the chromatic aberration is specified by the approximation function **102**, as compared with the case of registering all of patterns of the chromatic aberrations caused by the image capturing optical system **31** in the memory **27**, the amount of information to be stored in the memory **27** can be reduced and, accordingly, the storage capacity of the memory **27** can be reduced. As a result, reduction in the cost and size of the image capturing apparatus **1** can be realized.

[0099] Since the approximation function **102** is an approximation function using the distance "r" from the center of an image of a pixel to be processed as an argument, the amount of parameters stored in the memory **27** can be reduced. For example, in the case of storing parameters for each of the position coordinates (X, Y) of the pixel P1 to be processed, parameters have to be specified with respect to all of coordinates in the image plane. By using the distance "r" from the center of an image as an argument as in the present preferred embodiment, the same parameter can be applied to pixels in equal distances from the center of an image, so that the storage capacity of the memory **27** can be reduced.

[0100] By expressing the approximation function **102** by an approximation function of which argument is the square of the distance "r" from the center of an image of a pixel to be processed, computation efficiency is improved, and chromatic aberration correction can be performed efficiently.

[0101] Further, the image capturing apparatus **1** of the present preferred embodiment can change parameters for performing chromatic aberration correction in accordance with image capturing conditions so that proper chromatic aberration correction can be conducted even in the case where the image capturing conditions (focal length, photographing distance, f-number and the like) of the image capturing optical system **31** are changed.

[0102] Although the case where the control unit **25** obtains a filter applied in the image processing unit **22** has been described in the present preferred embodiment, the above-described filter determining function of the control unit **25** may be realized by the image processing unit **22**.

2. Second Preferred Embodiment

[0103] A second preferred embodiment will now be described. The configuration of the image capturing apparatus **1** of the second preferred embodiment is similar to that in the first preferred embodiment.

[0104] In the first preferred embodiment, the case where the control unit **25** executes computation based on the approximation function on each of the R and B components has been described. However, since the wavelength of the B component and that of the R component have a reverse relation, when the G component is set as a reference, the chromatic aberration which occurs in the B component often appears on the side opposite to the chromatic aberration which occurs in the R component. In the present preferred embodiment, therefore, the case of obtaining the parameter of the B component from the parameter of the R component without separately storing the parameter of the B component will be described.

[0105] **FIG. 12** is a diagram showing a chromatic aberration characteristic caused by the image capturing optical system **31**. A chromatic aberration **105** of the R component appears on the side opposite to a chromatic aberration **106** of the B component. The chromatic aberration **106** of the B component becomes a chromatic aberration **107** when the diagram is folded around the r-axis as a center. In the present preferred embodiment, an approximation function **108** obtained by a weighted average between the chromatic

aberrations **105** and **107**, as an approximation function which can be applied to both the R and B components is approximated with a cubic function. The degree of weighted average is preset so that, for example, the ratio of the chromatic aberration **105** of the R component becomes 0.5 to 1 in consideration of a coloring characteristic and the like of the image capturing optical system **31**. The coefficients (the parameters of a, b, c and d) of the approximation function **108** which is set in such a manner are stored in the memory **27**. With such a configuration, it becomes unnecessary to store independent parameters of the R and B components in the memory **27**, so that the storage capacity of the memory **27** can be reduced.

[0106] When the control unit **25** obtains a filter to be outputted to the filter computing circuit **42** with respect to the R component, the parameters stored in the memory **27** are obtained and computation based on the approximation function **108** is executed, thereby determining a chromatic aberration (deviation amount) with respect to the pixel P1 to be processed, and the filter **203** for output (see **FIG. 7**) is determined on the basis of the deviation amount.

[0107] In the case where the pixel P1 to be processed is the same by applying the same approximation function **108** to both of the R and B components, a chromatic aberration (deviation amount) obtained by computation based on the approximation function **108** becomes the same value. Consequently, when the filter **203** for output as shown in **FIG. 7** is obtained with respect to the R component, if a filter having filter coefficients symmetrical with respect to the position of the pixel P1 to be processed (that is, the filter center position) as a reference is generated as the filter **203** of **FIG. 7**, the control unit **25** can obtain the filter for output which can be applied to the B component.

[0108] **FIG. 13** is a diagram showing an example of the filter of the B component obtained from the filter of **FIG. 7**. As shown in **FIG. 13**, when the filter **203** for output as shown in **FIG. 7** is obtained with respect to the R component, by moving filter coefficients symmetrically with respect to the filter center position as a reference, the filter **204** for output shown in **FIG. 13** can be obtained.

[0109] Therefore, the image capturing apparatus **1** of the present preferred embodiment specifies an approximation function which can be applied to the chromatic aberrations of both the R and B components, generates a filter applied to a filter computation by executing computation based on the approximation function **108** with respect to either the R or B component, and moves the filter coefficient with respect to the other component symmetrically without performing the computation based on the approximation function, thereby generating a filter applied to the filter computation. Therefore, it is unnecessary to store parameters for generating filters in the memory **27** with respect to the other color component, so that the storage capacity of the memory **27** can be reduced. By executing the computation on one of the color components, for the other color component, a final filter can be generated without performing complicated computation. Thus, computation efficiency for generating filters can be improved.

3. Third Preferred Embodiment

[0110] A third preferred embodiment will now be described. The configuration of the image capturing apparatus **1** in the third preferred embodiment is also similar to that in the first preferred embodiment.

[0111] In the first and second preferred embodiments, a deviation amount of a chromatic aberration is obtained by performing computation with an approximation function by using the distance "r" from the image canter of the pixel P1 to be processed as an argument, and the filter applied to the filter computing circuit **42** is obtained on the basis of the deviation amount. However, the approximation function is obtained by optical characteristics of the image capturing optical system **31**, so that the approximation function can be preliminarily applied to each of pixels positions in an image plane and computation can be executed. In the third preferred embodiment, therefore, a case of prestoring a deviation amount obtained by applying an approximation function to each of the pixel positions in an image plane in a lookup table in the memory **27** in order to improve computation efficiency will be described.

[0112] The argument "r" in Equation 1 can be unconditionally obtained from the pixel position (X, Y) as in Equation 2. Since each of the coefficients a, b, c and d in Equation 1 is predetermined by the image capturing conditions of the image capturing optical system **31**, deviation amounts Δrx and Δry in the X and Y directions derived by applying the approximation function are preliminarily computed, and the relation is stored in the memory **27**.

[0113] **FIG. 14** is a diagram showing an example of a lookup table **301** stored in the memory **27**. As shown in **FIG. 14**, when the position coordinates (X, Y) of a pixel to be processed are designated from an input address, the lookup table **301** is constructed so as to output movement amounts (deviation amounts) Δrx and Δry due to chromatic aberrations corresponding to the pixel position.

[0114] By setting the lookup table **301** as shown in **FIG. 14** for each image capturing condition, a movement amount due to a chromatic aberration under a specific image capturing condition can be promptly obtained without performing a computing process. By setting the lookup table **301** with respect to each of the R and B components, the movement amount due to a chromatic aberration under a specific image capturing condition can be promptly obtained without performing a computing process with respect to each of the R and B components.

[0115] As a result, time required to determine a filter to be finally outputted to the filter computation circuit **42** is shortened, so that efficient filter computation is executed.

[0116] In this case, by setting the image center coinciding with the center of the optical axis L as the coordinate origin, the amount of information to be stored in the memory **27** can be reduced. **FIG. 15** is a diagram showing an image plane. As shown in **FIG. 15**, an XY coordinate system in which the image center P0 coincides with the center of the optical axis L and which specifies a pixel position by using the image center P0 as the origin is set.

[0117] Attention is paid to a pixel P11 included in a first quadrant in the coordinate system, and it is assumed that the coordinate position of the pixel P11 is (X1, Y1). The pixel position of a pixel P12 symmetrical to the pixel P11 with respect to the Y-axis is (−X1, Y1), the pixel position of a pixel P13 symmetrical to the pixel P12 with respect to the X-axis is (−X1, −Y1), and the pixel position of a pixel P14

symmetrical to the pixel P13 with respect to the Y-axis (the pixel is also symmetrical to the pixel P11 with respect to the X-axis) is (X1, −Y1). The four pixels P11, P12, P13 and P14 are in the equidistance from the pixel center P0. The absolute value of the deviation amount in the X direction and that in the Y direction in the case where the pixels are pixels to be processed are equal to each other.

[0118] Specifically, when the deviation amount in the pixel P11 is (Δrx1, Δry1), the deviation amount in the pixel P12 is (−Δrx1, Δry1), and the deviation amount in the pixel P13 is (−Δrx1, −Δry1), and the deviation amount in the pixel P14 is (Δrx1, −Δry1).

[0119] Therefore, as the lookup table **301** to be stored in the memory **27**, for example, it is preferable to divide an image plane into four quadrants by using the image center as a reference and store only parameters related to the first quadrant. In the case where a pixel to be processed is included in the first quadrant, the deviation amounts in the X and Y directions can be immediately obtained by referring to the lookup table **301**. In the case where a pixel to be processed is positioned in any of the second to fourth quadrants in an image plane, by referring to the lookup table **301** on the basis of absolute values of coordinate values of the pixel to be processed, deviation amounts in the X and Y directions are obtained. By assigning a sign according to the coordinate position of the pixel to be processed to the deviation amount obtained, a proper deviation amount can be obtained.

[0120] In the present preferred embodiment, it is therefore preferable to store only parameters in the case where a pixel to be processed is included in the first quadrant of an image plane. When the pixel to be processed is included in a region other than the first quadrant, a proper parameter is obtained by using the parameter stored in the memory **27** and the sign is inverted in consideration of symmetry of the coordinates by using the parameters stored in the memory **27**. With such a configuration, the amount of information to be stored in the memory **27** becomes ¼ of that of information with respect to the whole image plane. Thus, it can contribute to reduction in the storage capacity.

[0121] Although the case of storing the relationship between the pixel position and the deviation amount as a lookup table into the memory **27** has been described in the present preferred embodiment, the present invention is not limited to the case. For example, it is also possible to store a filter for chromatic aberration correction as a lookup table in the memory **27** in correspondence with each of the deviation amounts in the X and Y directions. In this case, the control unit **25** can determine the filter for chromatic aberration correction only by reading a filter for chromatic aberration correction from the memory **27** on the basis of the deviation amount in each of the X and Y directions and the efficiency of the computing process required to determine a filter can be increased.

[0122] As obvious from Equation 1, after the image capturing conditions are determined, the deviation amounts in the X and Y directions are unconditionally determined from a pixel position. Consequently, it is possible to preliminarily obtain the deviation amounts and store the filter for chromatic aberration correction as a lookup table in correspondence with the image capturing conditions and the pixel position into the memory **27**.

[0123] With respect to each of the R and B components, a preliminarily obtained filter for output (filter obtained by combining the filter for color interpolating process and the filter for chromatic aberration correction) in correspondence with the image capturing condition and the pixel position may be stored as a lookup table into the memory **27**. In this case, it is unnecessary to execute complicated computation to determine a filter for output in the control unit **25** and a filter for output can be obtained most efficiently.

[0124] In those cases as well, only filters applied for filter computation and applied to image components included in the first quadrant obtained by using the image center as a reference are stored in the memory **27**. When a pixel to be processed is included in the first quadrant, a filter applied to the filter computation is immediately obtained by referring to the memory **27**. On the other hand, when a pixel to be processed is not included in the first quadrant, by obtaining a filter stored in the memory **27** and performing conversion of a filter coefficient, a filter applied to the filter computation can be obtained.

[0125] The filter coefficient conversion will be described by referring to **FIGS. 16A** to **16D**. It is assumed that, by referring to the memory **27** with respect to the pixel P11 (see **FIG. 15**) included in the first quadrant of an image plane, the filter **203** as shown in **FIG. 16A** is obtained. In this case, the filter **203** is outputted as it is to the filter computing circuit **42**. On the other hand, in the case of generating a filter for the pixel P12 (see **FIG. 15**) included in the second quadrant of the image plane, by referring to the memory **27**, the filter **203** as shown in **FIG. 16A** is obtained. Consequently, the filter coefficient is moved symmetrically on the basis of the symmetry of the coordinates of the first and second quadrants, the filter coefficient is converted, thereby generating the filter **204** as shown in **FIG. 16B**. The control unit **25** is also constructed so as to output the filter **204** to the filter computing circuit **42**. The case where a pixel exists in the third or fourth quadrant is similar to the above (for example, the pixels P13 and P14 in **FIG. 15**). By performing symmetrical movement of filter coefficients on the basis of symmetry of coordinates on the filter **203** obtained from the memory **27**, filters **205** and **206** as shown in **FIGS. 16C and 16D** are generated and outputted to the filter computing circuit **42**.

[0126] Since such conversion of a filter coefficient can be relatively easily performed, while suppressing time required to generate a filter, the storage capacity of the memory **27** can be effectively reduced.

[0127] In the present preferred embodiment as well, as described in the second preferred embodiment, it is also possible to store parameters of either the R or B component in the memory **27** and, for the other component, to generate a proper filter by converting the parameter obtained from the memory **27** (for example, symmetrical movement of a filter coefficient). As an example, filters in the case where the pixel to be processed is positioned in the first quadrant will be described. Only filters applied to the R component are stored in the memory **27** and a filter applied to the B component and a filter applied to the R component in the case where a pixel to be processed is positioned in the other area may be generated by converting the filter coefficient for the filter stored in the memory **27**. With such a configuration, the storage capacity of the memory **27** can be reduced.

Concretely, as compared with the case of storing parameters in the whole image area with respect to both the R and B components into the memory **27**, the storage capacity can be reduced to ⅛.

[0128] As described above, in the image capturing apparatus **1** of the present preferred embodiment, with respect to filters applied to the filter computation, a filter applied to an image component included in the first quadrant when the image center is a reference is stored in the memory **27**. In the case where a pixel signal to be processed is not included in the first quadrant, the filter stored in the memory **27** is converted, thereby obtaining a filter applied to filter computation. Consequently, it becomes sufficient to store information in which the pixel position and a filter are associated with each other with respect to only the region which is ¼ of an image plane into the memory **27**. Thus, the storage capacity of the memory **27** can be reduced.

[0129] In the present preferred embodiment, with respect to filters applied to filter computation, in the case of storing only filters applied to a specific color in the three primary colors of R, G and B in the memory **27** and performing the process for a color component other than the specific color, by converting a filter stored in the memory **27**, a filter adapted to the color component is obtained. Therefore, as compared with the case of storing proper filters for the R and B components of the two colors out of the three primary colors of R, G and B, the storage capacity of the memory **27** can be effectively reduced.

[0130] In the present preferred embodiment as well, the filter applied to filter computation has to be changed according to the image capturing conditions of the image capturing optical system **31**. For this purpose, a lookup table is prepared for each of image capturing conditions.

4. Fourth Preferred Embodiment

[0131] A fourth preferred embodiment will now be described. In the fourth preferred embodiment as well, the configuration of the image capturing apparatus **1** is similar to that described in the first preferred embodiment.

[0132] In the fourth preferred embodiment, a method of reducing the storage capacity of the memory **27** more than the third preferred embodiment will be described. **FIG. 17** is a diagram showing an image plane of an image obtained from the image capturing device **21**. In the fourth preferred embodiment, as shown in **FIG. 17**, a plurality of blocks **B01**, **B02**, **B03**, . . . are specified for an image obtained from the image capturing device, and chromatic aberrations (deviation amounts) of pixels signals included in blocks are stored in the memory **27** on the block unit basis.

[0133] The control unit **25** obtains position information of the pixel P1 to be processed from the filter computing circuit **42**, determines a block in which the pixel P1 to be processed is included from the plurality of blocks, and obtains a deviation amount determined for the block from the memory **27**.

[0134] **FIG. 18** is a diagram showing an example of a lookup table **302** stored in the memory **27** in the present preferred embodiment. As shown in **FIG. 18**, the lookup table **302** is constructed so that when the number of a block including the pixel to be processed is designated by an input address, the movement amounts (deviation amounts) Δrx and Δry caused by chromatic aberrations corresponding to the block number are outputted.

[0135] By setting the lookup table **302** as shown in **FIG. 18** for each of the image capturing conditions, the movement amount caused by a chromatic aberration under a specific image capturing condition can be promptly obtained. By setting the lookup table **302** for each of the R and B components, the movement amount caused by the chromatic aberration under the specific image capturing condition with respect to each of the R and B components can be promptly obtained without executing the computing process.

[0136] Although similar chromatic aberration corrections are applied on the block unit basis in the present preferred embodiment, it is also possible to apply similar chromatic aberration corrections within the same block to a degree that the chromatic aberration is inconspicuous. At the time of dividing an image plane into blocks, it is sufficient to make a division setting so that an actual deviation amount in each block lies within a predetermined range.

[0137] By dividing the image plane into a plurality of blocks and setting parameters stored in the memory **27** on the block unit basis, the amount of information to be stored in the memory **27** can be largely reduced, and the present invention can be excellently adapted to increase in the number of pixels of the image capturing device **21**.

[0138] Since the chromatic aberration increases with distance "r" from the image center (center of the optical axis L), at the time of specifying each block, it is desirable that a block of a relatively large size be specified in a center portion of the image and the size of block decreases toward the periphery of the image as shown in **FIG. 17**. By employing such a block configuration, chromatic aberration correction can be made excellently function also in the peripheral portion of an image where the chromatic aberration conspicuously appears. In the center portion of an image where the chromatic aberration is inconspicuous, a large area to which the same parameter is applied can be assured. Thus, an amount of information to be stored in the memory **27** can be efficiently reduced.

[0139] The control unit **25** obtains the deviation amount with respect to the pixel P1 to be processed from the memory **27**, determines a filter for chromatic aberration correction on the basis of the deviation amount, and combines the determined filter with a filter for color interpolating process, thereby obtaining a filter for output. The filter for output is outputted to the filter computing circuit **42** where the filter computation is performed, and the color interpolating process and the chromatic aberration correcting process are concurrently carried out. In the filter computing circuit **42**, the process of correcting the chromatic aberration which occurs in the image capturing optical system **31** is performed as a similar process on the block unit basis.

[0140] In the case where the process is performed on the block unit basis, mismatching of parameters occurs in the border of blocks, and there is the possibility that discontinuity of images is visually conspicuous in the border of the blocks. Consequently, it is more preferable to generate a parameter to be applied to filter computation by performing weighted averaging according to a pixel position by using not only the parameter of a block to be processed but also the parameters of peripheral blocks.

[0141] **FIG. 19** is a diagram for describing the concept of weighted averaging. As shown in **FIG. 19**, for a block B12, the chromatic aberration (deviation amount) of a representative pixel P12 is stored in the memory **27**. For blocks B13, B22 and B23, chromatic aberrations (deviation amounts) of representative pixels P13, P22 and P23 are stored in the memory **27**, respectively. In this case, if the pixel P1 to be processed is positioned in the block B23 (see **FIG. 19**), the pixel P1 to be processed is surrounded by four representative pixels P12, P13, P22 and P23. Consequently, at the time of obtaining a deviation amount of the pixel P1 to be processed, only the deviation amount stored in the block B23 is not used. The deviation amounts stored with respect to the four blocks B12, B13, B22 and B23 positioned near the pixel P1 to be processed are read from the memory **27** and weighted averaging is performed in consideration of the positional relations between the pixel P1 to be processed and the representative pixels P12, P13, P22 and p23, thereby obtaining the chromatic aberration (deviation amount) in the pixel P1 to be processed. For the setting of weighting, for example, the technique disclosed in Japanese Patent Application Laid-Open No. 5-3568 (1993) (Patent Literature 1) can be applied.

[0142] As described above, by constructing the image capturing apparatus **1** to obtain a parameter for the pixel P1 to be processed by performing weighted averaging with the parameters stored in adjacent blocks, discontinuity in the border of blocks can be eliminated. Without deteriorating the picture quality, excellent chromatic aberration correction can be made.

[0143] Although the case where the parameter stored in the memory **27** is a chromatic aberration (deviation amount) caused by the image capturing optical system **31** has been described. However, the parameter stored in the memory **27** is not limited to the chromatic aberration but may be the filter for chromatic aberration correction applied to each block or the filter for output to be outputted to the filter computing circuit **42**.

[0144] As described above, the image capturing apparatus **1** in the present preferred embodiment is constructed so that a plurality of blocks are specified for an image plane of an image obtained from the image capturing device **21**, and the parameter for chromatic aberration correction applied to each block is stored in the memory **27**. For an image signal obtained from the image capturing device **21** at the time of photographing, the parameter is read from the memory **27**, and the process of correcting the chromatic aberration which is caused by the image capturing optical system **31** is performed on a block unit basis. Thus, chromatic aberration correction can be excellently performed while reducing the storage capacity of the memory **27**.

[0145] Since blocks specified for the image plane of an image obtained from the image capturing device **21** are set so that the size decreases with distance from the center of an image, a chromatic aberration in the peripheral portion of an image can be excellently corrected while reducing the storage capacity of the memory **27**.

[0146] At the time of performing the process of correcting a chromatic aberration on the block unit basis, a parameter to be applied to a peripheral block is read in accordance with the position of a pixel to be processed, a weighted parameter is obtained, and the process of correcting a chromatic aberration is performed by using the weighted parameter. Thus, images can be prevented from being discontinued at the border of blocks.

[0147] Division of an image plane into blocks may be set for, for example, each of the R and B components. **FIGS. 20A and 20B** are diagrams showing an example of performing different block dividing operations for the R and B components. **FIG. 20A** shows block division for correcting a chromatic aberration on an image of B components, and **FIG. 20B** shows block division for correcting a chromatic aberration on an image of R components. **FIGS. 20A and 20B** show that a chromatic aberration appears on the image of the B components larger than that on the image of the R components. The image plane of the B component is divided into the larger number of blocks as compared with block division of the R component. As described above, the blocks specified for the image plane obtained from the image capturing device **21** may be specified differently with respect to color components on each of which chromatic aberration correction is made. In this case, the chromatic aberration which varies according to a color component can be excellently corrected. Correction precision can be increased and, moreover, the storage capacity of the memory **27** can be reduced.

[0148] In the present preferred embodiment, the filter applied to the filter computation has to be changed according to the image capturing conditions of the image capturing optical system **31**. Consequently, it is preferable to set block division and the parameter to be stored in the memory **27** be set for each image capturing condition.

[0149] At the time of storing parameters of each area divided in blocks into the memory **27**, as described in the third preferred embodiment, only the part of the first quadrant of the image plane is stored in the memory **27**. If a pixel to be processed is positioned in other areas, a parameter applied to the first quadrant is read to perform a converting process according to the position of the pixel to be processed, thereby generating a parameter applied to the pixel to be processed.

5. Fifth Preferred Embodiment

[0150] A fifth preferred embodiment will now be described. In the first to fourth preferred embodiments, the case where the image process is performed in the image capturing apparatus and the color interpolating process and the chromatic aberration correcting process are performed in the image process was described. In the fifth preferred embodiment, an example of the configuration in the case where an image signal obtained by the image capturing device **21** is outputted from the image capturing apparatus **1** as it is to external devices and the color interpolating process and the chromatic aberration correcting process are performed in external devices will be described.

[0151] **FIG. 21** is a diagram showing the configuration of an image processing system according to the fifth preferred embodiment. The system is constructed so that data communication can be performed between an image capturing apparatus **1***a* and a computer **50** in a wired or wireless communication form. The image capturing apparatus 1a receives light from the subject entering via the image capturing optical system **31** by the image capturing device **21** and generates a color image signal of the subject. The

image capturing optical system **31** and the image capturing device **21** are similar to those described in the first preferred embodiment.

[0152] A control unit **28** controls the image capturing optical system **31** and the image capturing device **21** and controls the image capturing operation in a centralized manner. Consequently, the control unit **28** can grasp the image capturing condition of the image capturing optical system **31**.

[0153] An image signal generated by photoelectric conversion in the image capturing device **21** is converted into, for example, a 12-bit digital signal and the digital signal is supplied to an output unit **29**. Therefore, the image signal (image data) supplied from the image capturing device **21** to the output unit **29** is a signal obtained by digitizing the signal as it is, which is outputted from the image capturing device **21** and is so-called RAW data (RAW image data). The output unit **29** generates an image file on the basis of the image signal obtained from the image capturing device **21**.

[0154] **FIG. 22** is a diagram showing an example of an image file generated by the output unit **29**. As shown in **FIG. 22**, an image file **500** includes tag information **501**, image data **502** and thumbnail image data **503**. The tag information **501** includes information regarding image capturing conditions obtained from the control unit **28** by the output unit **29**. Specifically, the information such as resolution at the time of photographing of the image capturing device **21**, and focal length, an f-number and photographing distance at the time of photographing of the image capturing optical system **31** is included as the tag information **501** in the image file **500**. The image data **502** is an image signal (that is RAW data) inputted from the image capturing device **21**. The thumbnail image data **503** is generated by the output unit **29** on the basis of the RAW data. In the present preferred embodiment, the thumbnail image data **503** is not necessarily included in the image file **500**.

[0155] The output unit **29** is constructed to transmit the image file **500** as shown in **FIG. 22** to the computer **50**.

[0156] The computer **50** is constructed by a body **60**, a display unit **51** and an operation unit **52**. The display unit **51** is a display device such as a CRT or a liquid crystal display. The operation unit **52** is a device for inputting operations, such as a keyboard or a mouse.

[0157] The body **60** is constructed by a CPU **61**, a storing unit **62**, an input unit **63** and an input/output unit **64**. The input/output unit **64** can access the recording medium **55** such as a CD-ROM to read/record information from/to the recording medium **55**. Consequently, the CPU **61** can obtain a program (including an image processing program) stored in the recording medium **55** via the input/output unit **64** and execute the program.

[0158] By executing a predetermined image processing program by the CPU **61**, the function of performing the chromatic aberration correcting process in the computer **50** described in the foregoing preferred embodiments is realized. That is, the CPU **61** functions as an image processing unit **61***a*.

[0159] The CPU **61** receives an image file from the image capturing apparatus **1***a* via the input unit **63** and temporarily stores the image file into the storing unit **62** such as a magnetic disk drive.

[0160] The image processing unit **61***a* functions and an image file as an object of an image process is read out from the plurality of image files **500** stored in the storing unit **62**. While referring to tag information included in the image files **500**, the chromatic aberration correcting process, color interpolating process, and the like are performed on image data (RAW data), thereby generating image data of each of the color components of R, G and B.

[0161] Specifically, the image processing unit **61***a* determines an image center (the center position of the light axis L) from resolution included in the tag information, and sets an image plane of the RAW image. The image processing unit **61***a* obtains a chromatic aberration caused by the image capturing optical system from the image capturing conditions (focal length, f-number and photographing distance) of the image capturing optical system **31** and determines a chromatic aberration correcting filter for correcting the chromatic aberration. By performing a filter computing process on the RAW image data by using the filter for chromatic aberration correction, chromatic-aberration-corrected image data is generated.

[0162] An image subjected to chromatic aberration correction is displayed on the display unit **51** or stored in the storing unit **62**. Alternately, the image may be outputted from the computer **50** to an external device.

[0163] **FIG. 23** is a flowchart showing a processing sequence in the computer **50** constructed as described above. When the CPU **61** starts an image processing program in the computer **50**, a process of initializing the components is performed (step S10). After the initializing process is finished, the computer **50** inputs an image file from the image capturing apparatus **1***a* (step S11). In the case of performing an image process on an image file already stored in the storing unit **62**, it is unnecessary to input an image file at this stage.

[0164] The CPU **61** displays an image file selection screen on the display unit **51** and extracts an image file to be processed from the storing unit **62** on the basis of a selecting operation of the user (step S12). The CPU **61** checks image capturing conditions from the tag information included in the image file (step S13) and specifies a parameter for correcting a chromatic aberration on the basis of the image capturing conditions (step S14). It is assumed that information indicative of optical characteristics of an image capturing optical system as the image capturing apparatus **1***a* connected to the computer **50** is preliminarily registered in the storing unit **62**.

[0165] The filter for chromatic aberration correction is generated on the basis of the parameters obtained in step S13 (step S15), a filter computation is performed on the RAW data with the filter for chromatic aberration correction, thereby correcting the chromatic aberration (step S16).

[0166] After correcting the chromatic aberration, the CPU **61** performs a color interpolating process (step S17). The color interpolating process is performed by the filter computation to which, for example, the filter **201** shown in **FIG. 5** is applied. That is, in the present preferred embodiment, the chromatic aberration correcting process is performed prior to the color interpolating process on RAW data. Consequently, the chromatic aberration correcting process can be made function excellently, and high-precision chro-

matic aberration correction can be performed. In the present preferred embodiment as well, the chromatic aberration correcting process and the color interpolating process can be performed concurrently as described in the foregoing preferred embodiments.

[0167] By performing the chromatic aberration correcting process and the color interpolating process, an image signal (image data) including information of the color component of each of R, G and B in each pixel is generated. γ correction is performed on the image data to decrease the number of bits of the pixel signal of each color component from 12 bits to 8 bits (step **S18**). By the γ correction, in addition to general γ correction, a tone decreasing process is simultaneously performed.

[0168] Other image processes such as a color space converting process and a line segment extracting process are performed (step **S19**). Further, image compression is carried out and a process of recording a resultant image to the storing unit **62** is performed (step **S20**).

[0169] The computer **50** functions as an image processing apparatus as described above and is constructed so as to perform the chromatic aberration correcting process of correcting a chromatic aberration caused by the image capturing optical system **31** on an image signal entered from the image capturing apparatus **1***a* prior to the color interpolating process for interpolating a dropout color component pixel by pixel. Therefore, chromatic aberration correction can be made at high precision.

[0170] At the time of inputting an image signal, the image capturing condition information at the time of capturing the image is also inputted, and parameters applied to the chromatic aberration correcting process are determined on the basis of the image capturing condition information. Consequently, the optical conditions of an image as an object of the image process can be grasped, and proper chromatic aberration correction can be performed so as to be adapted to the optical conditions at the time of image capturing.

6. Modifications

[0171] Although the preferred embodiments of the present invention have been described above, the present invention is not limited to the above.

[0172] For example, the case where the image center is disposed so as to coincide with the center position of the optical axis L of the image capturing optical system **31** has been described in each of the foregoing preferred embodiment. However, when the image center and the center position of the optical axis L do not coincide with each other, a parameter such as a deviation amount may be specified on the basis of the center position of the optical axis L.

[0173] In the case where the lens unit **3** is exchangeable in the image capturing apparatus **1** of **FIG. 1**, when the memory **27** is disposed in the body **2**, the parameter for chromatic aberration correction has to be stored in the memory **27** for each lens unit. Consequently, as shown in **FIG. 24**, the memory **27** may be disposed on the lens unit **3** side. In **FIG. 24**, the same reference numerals as those in **FIG. 1** are assigned to the same members.

[0174] While the invention has been shown and described in detail, the foregoing description is in all aspects illustrative and not restrictive. It is therefore understood that numerous modifications and variations can be devised without departing from the scope of the invention.

What is claimed is:

1. An image capturing apparatus comprising:

an image capturing optical system;

a color image sensor for converting a light image obtained by said image capturing optical system to an image signal having a color component which varies according to a pixel; and

an image processor for concurrently performing a chromatic aberration correcting process of correcting a chromatic aberration of said image capturing optical system and a color interpolating process of interpolating a dropout color component pixel by pixel on an image signal generated by said color image sensor.

2. The image capturing apparatus according to claim 1, wherein

said color image sensor generates color image signals of three primary colors, and

said image processor performs a chromatic aberration correcting process by moving image signals of at least two colors out of said color image signals of three primary colors by different amounts with respect to an optical axis.

3. The image capturing apparatus according to claim 2, wherein

said image processor performs filter computation of coefficients which vary according to colors.

4. The image capturing apparatus according to claim 3, wherein

said image processor employs, as a filter applied to said filter computation, a filter having filter coefficients for performing said color interpolating process and filter coefficients for moving an image signal with respect to the optical axis.

5. The image capturing apparatus according to claim 2, further comprising

a memory for storing a filter applied to a specific pixel, wherein

said image processor performs a chromatic aberration correcting process on a pixel in a position symmetrical to said specific pixel with respect to the optical axis by converting the filter stored in said memory.

6. The image capturing apparatus according to claim 2, further comprising

a memory for storing a filter applied to a specific color out of said three primary colors, wherein

said image processor performs a chromatic aberration correcting process on colors other than said specific color by converting the filter stored in said memory.

7. The image capturing apparatus according to claim 1, wherein

said image processor performs a process which varies according to an image capturing condition as said chromatic aberration correcting process.

8. An image capturing apparatus comprising:

an image capturing optical system;

a color image sensor for converting a light image obtained by said image capturing optical system into an image signal having a color component which varies according to a pixel;

a divider for dividing an image signal generated by said color image sensor into a plurality of blocks;

a memory for storing a parameter for chromatic aberration correction applied to each block divided by said divider; and

an image processor for correcting a chromatic aberration caused by said image capturing optical system by the block on the basis of the parameter stored in said memory on an image signal generated by said color image sensor.

9. The image capturing apparatus according to claim 8, wherein

said block specified to an image signal becomes finer with distance from an optical axis of said image capturing optical system.

10. The image capturing apparatus according to claim 8, wherein

said image processor performs chromatic aberration correction by using parameters applied to peripheral blocks onto an image signal to be processed.

11. The image capturing apparatus according to claim 8, wherein

said block specified to an image signal is specified so as to be varied according to a color component generated by said color image sensor.

12. The image capturing apparatus according to claim 8, wherein

said parameter is a deviation amount of a chromatic aberration.

13. The image capturing apparatus according to claim 8, wherein

said image processor also performs a color interpolating process of interpolating a dropout color component pixel by pixel.

14. The image capturing apparatus according to claim 8, wherein

said image processor performs a chromatic aberration correcting process which varies according to an image capturing condition.

15. An image capturing apparatus comprising:

an image capturing optical system;

a color image sensor for converting a light image obtained by said image capturing optical system into an image signal of a color component which varies according to a pixel;

a memory for storing a parameter for approximating a chromatic aberration caused by said image capturing optical system; and

an image processor for performing a chromatic aberration correcting process on an image signal generated by said color image sensor by performing computation with an approximation function by using the parameter stored in said memory.

16. The image capturing apparatus according to claim 15, wherein

said approximation function is a function corresponding to position of a pixel of which chromatic aberration is to be corrected and a function of which argument is a distance from an optical axis of said image capturing optical system.

17. The image capturing apparatus according to claim 15, wherein

said approximation function is a function corresponding to position of a pixel of which chromatic aberration is to be corrected and a function of which argument is the square of a distance from an optical axis of said image capturing optical system.

18. The image capturing apparatus according to claim 15, wherein

said image processor performs a chromatic aberration correcting process of generating a filter according to a deviation amount of a chromatic aberration obtained by performing computation with said approximation function and performing filter computation based on said filter.

19. The image capturing apparatus according to claim 15, wherein

said image processor further performs a color interpolating process of interpolating a dropout color component pixel by pixel.

20. The image capturing apparatus according to claim 15, wherein

said image processor performs a chromatic aberration correcting process which varies according to an image capturing condition.

21. An image processing apparatus for performing an image process on an image signal which is generated on the basis of a light image received via an image capturing optical system and has a color component which varies according to a pixel, comprising:

an input unit for inputting said image signal; and

an image processor for concurrently performing a chromatic aberration correcting process of correcting a chromatic aberration of said image capturing optical system and a color interpolating process of interpolating a dropout color component pixel by pixel on said image signal inputted to said input unit.

22. A program product in which a program of allowing a computer to perform a process on an image signal which is generated on the basis of a light image received via an image capturing optical system and has a color component which varies according to a pixel, the process comprising the steps of:

inputting said image signal; and

concurrently performing a chromatic aberration correcting process of correcting a chromatic aberration of said image capturing optical system and a color interpolating process of interpolating a dropout color component pixel by pixel on said inputted image signal.

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(54) **IMAGING ARRANGEMENTS AND METHODS THEREFOR**

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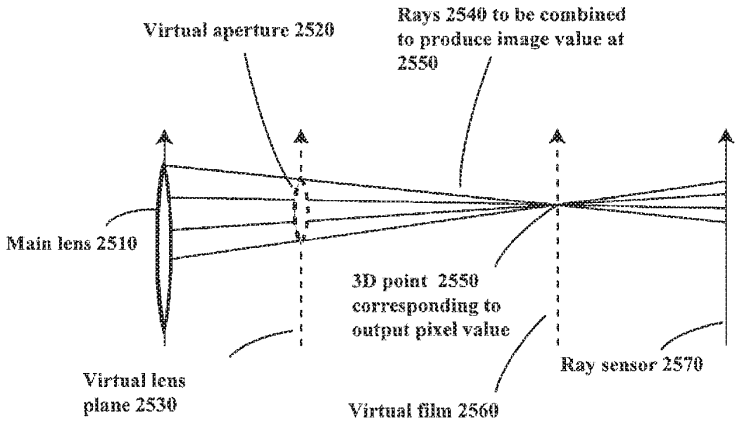
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(57) **ABSTRACT**

Image data is processed to facilitate focusing and/or optical correction. According to an example embodiment of the present invention, an imaging arrangement collects light data corresponding to light passing through a particular focal plane. The light data is collected using an approach that facilitates the determination of the direction from which various portions of the light incident upon a portion of the focal plane emanate from. Using this directional information in connection with value of the light as detected by photosensors, an image represented by the light is selectively focused and/or corrected.

14 Claims, 35 Drawing Sheets



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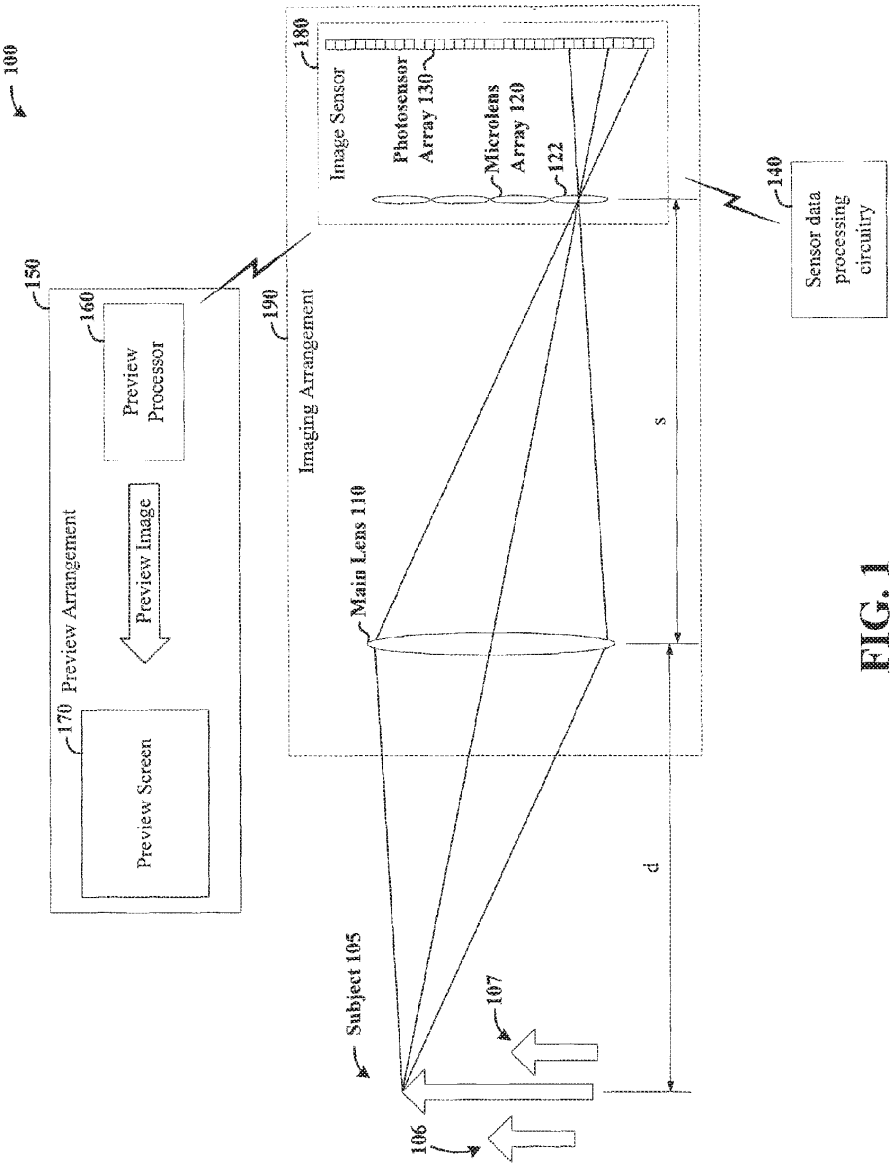


FIG. 1

EX1002 - Page 507

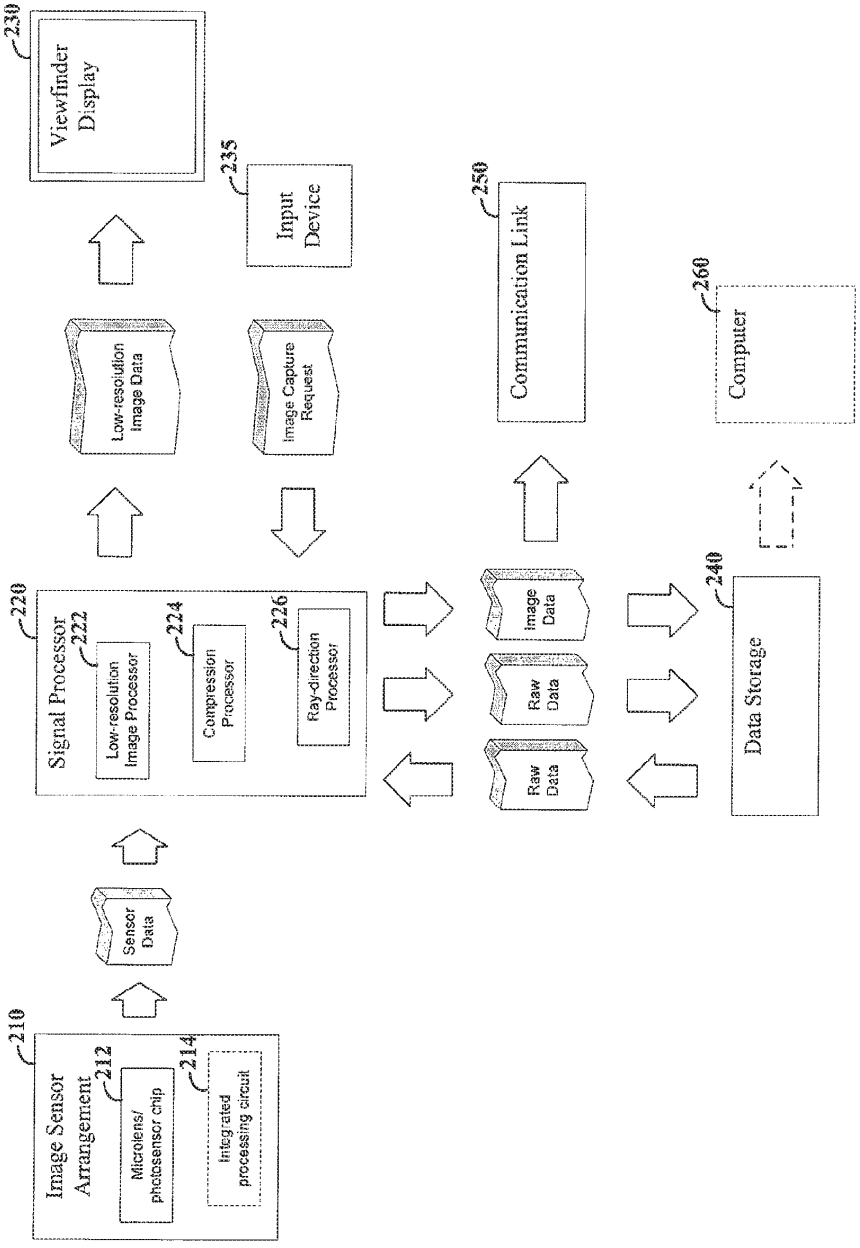


FIG. 2

EX1002 - Page 508

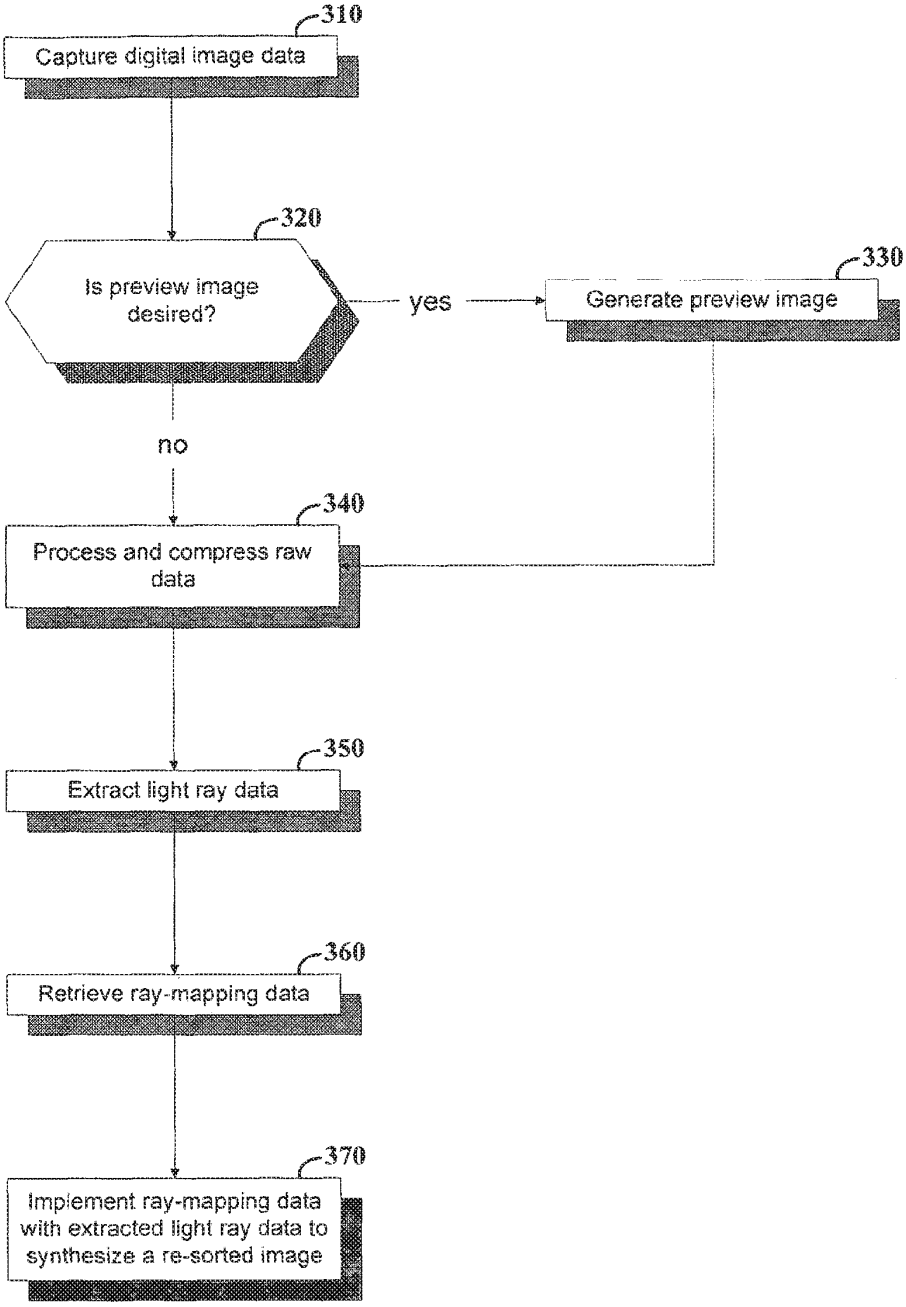

310
Capture digital image data
320
Is preview image desired?
yes
330
Generate preview image
no
340
Process and compress raw data
350
Extract light ray data
360
Retrieve ray-mapping data
370
Implement ray-mapping data with extracted light ray data to synthesize a re-sorted image

FIG. 3

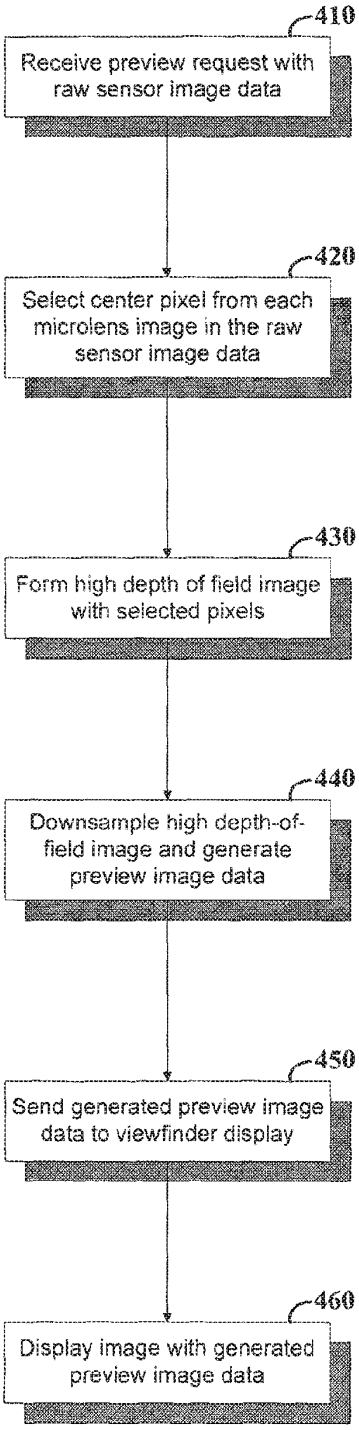

410
Receive preview request with raw sensor image data
420
Select center pixel from each microlens image in the raw sensor image data
430
Form high depth of field image with selected pixels
440
Downsample high depth-of-field image and generate preview image data
450
Send generated preview image data to viewfinder display
460
Display image with generated preview image data

FIG. 4

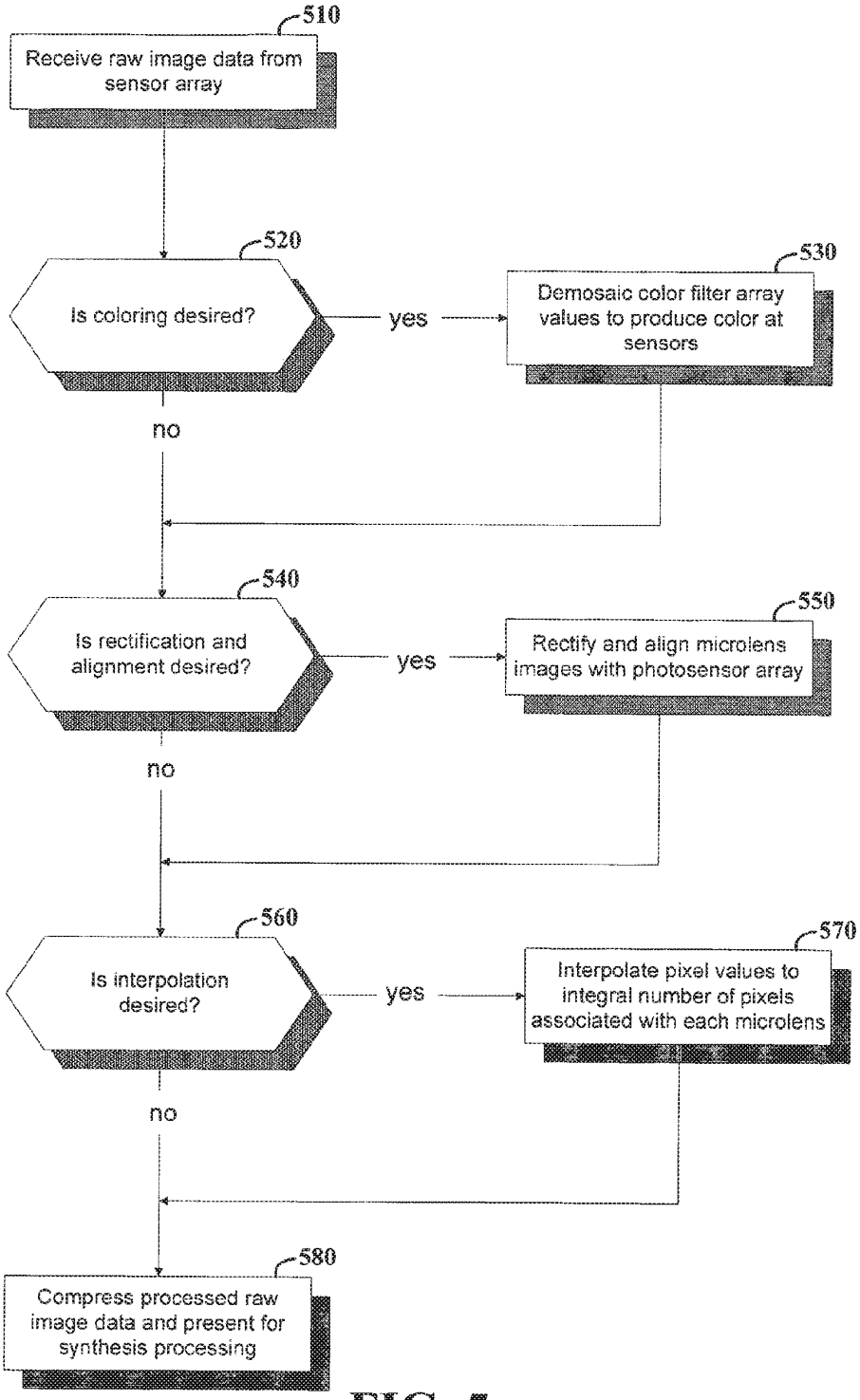

510
Receive raw image data from sensor array
520
Is coloring desired?
yes
530
Demosaic color filter array values to produce color at sensors
no
540
Is rectification and alignment desired?
yes
550
Rectify and align microlens images with photosensor array
no
560
Is interpolation desired?
yes
570
Interpolate pixel values to integral number of pixels associated with each microlens
no
580
Compress processed raw image data and present for synthesis processing

FIG. 5

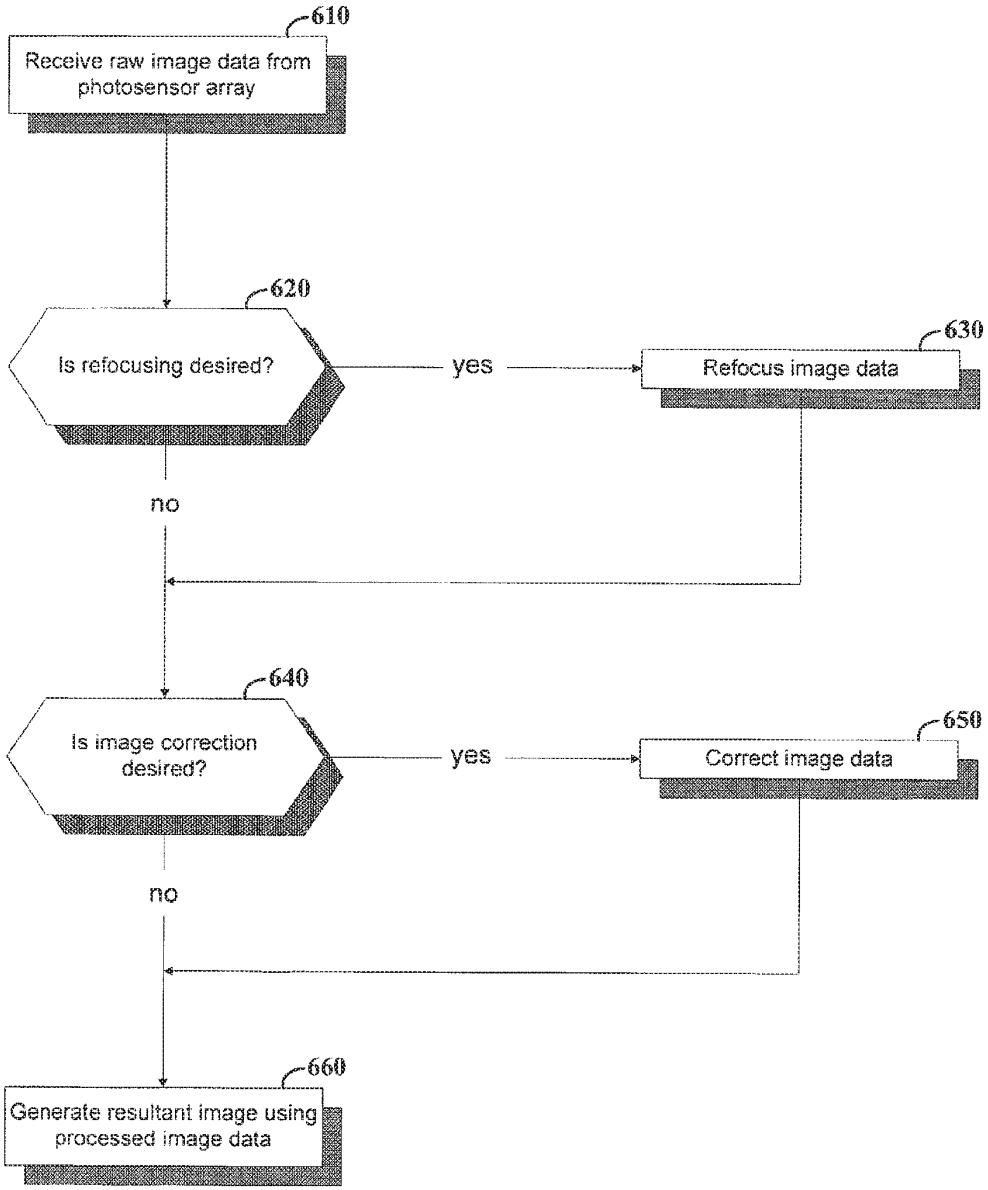
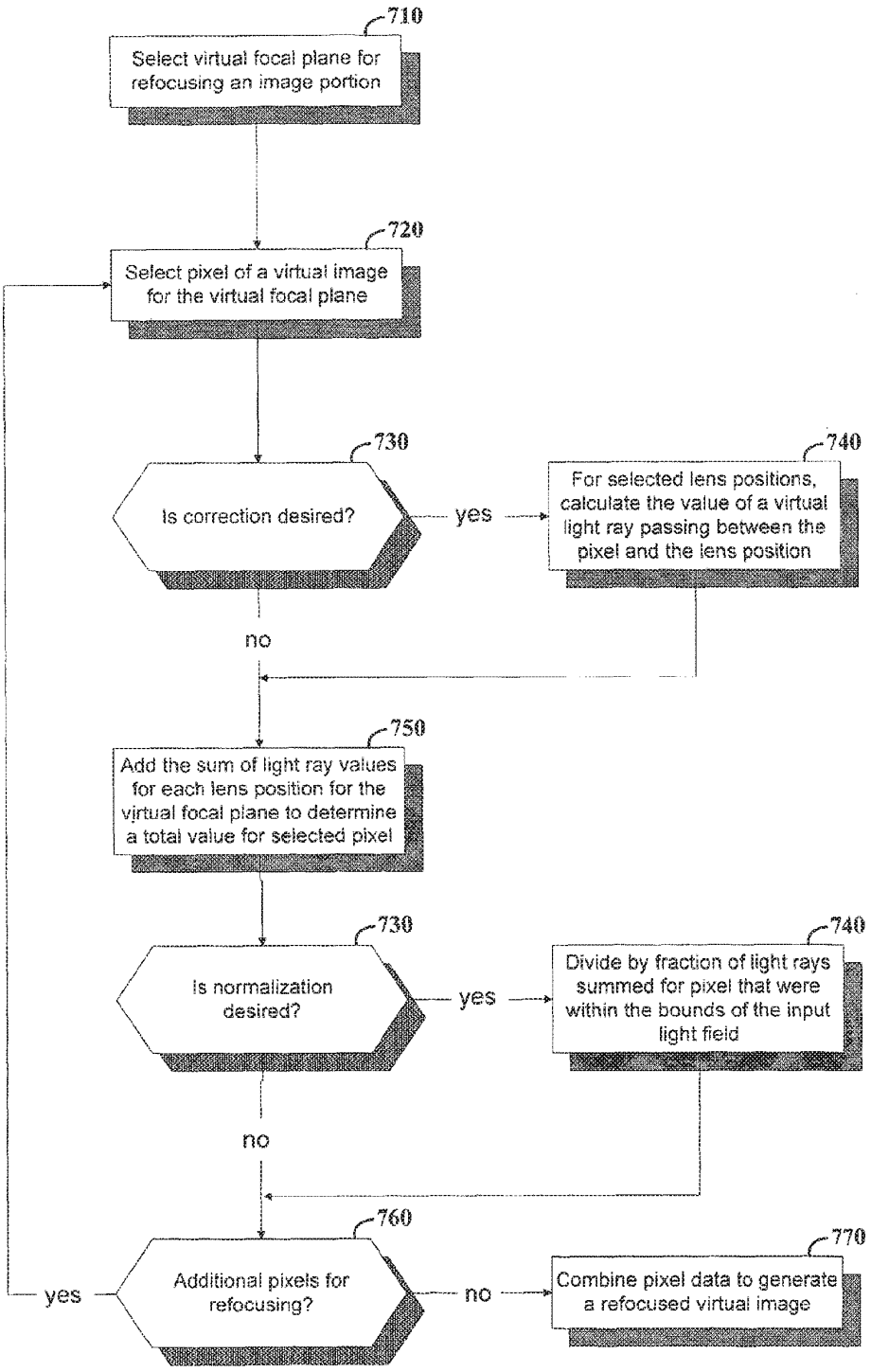

610
Receive raw image data from photosensor array
620
Is refocusing desired?
yes
630
Refocus image data
no
640
Is image correction desired?
yes
650
Correct image data
no
660
Generate resultant image using processed image data

FIG. 6

FIG. 7


710
Select virtual focal plane for refocusing an image portion
720
Select pixel of a virtual image for the virtual focal plane
730
Is correction desired?
yes
740
For selected lens positions, calculate the value of a virtual light ray passing between the pixel and the lens position
no
750
Add the sum of light ray values for each lens position for the virtual focal plane to determine a total value for selected pixel
730
Is normalization desired?
yes
740
Divide by fraction of light rays summed for pixel that were within the bounds of the input light field
no
760
Additional pixels for refocusing?
yes
no
770
Combine pixel data to generate a refocused virtual image

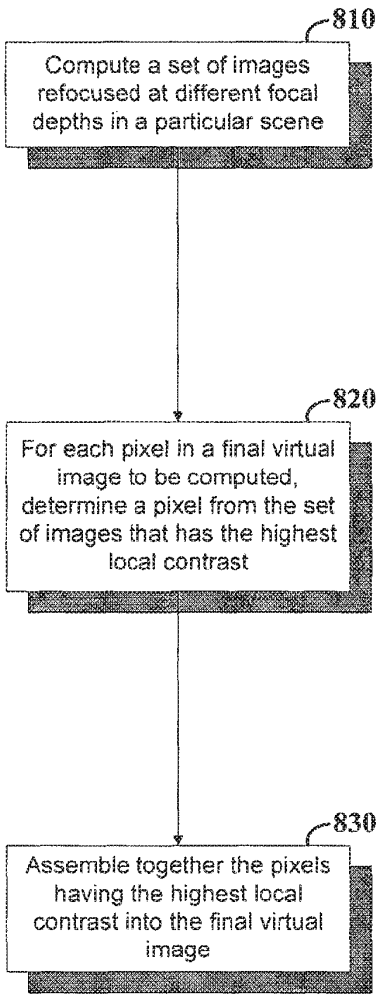

810
Compute a set of images refocused at different focal depths in a particular scene
820
For each pixel in a final virtual image to be computed, determine a pixel from the set of images that has the highest local contrast
830
Assemble together the pixels having the highest local contrast into the final virtual image

FIG. 8

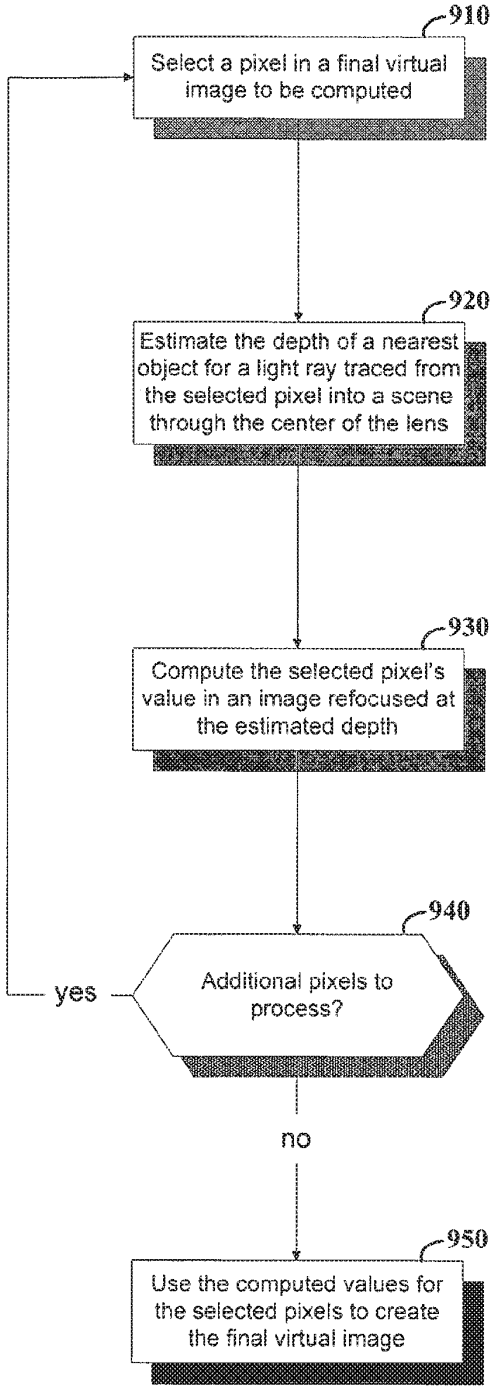

910
Select a pixel in a final virtual image to be computed
920
Estimate the depth of a nearest object for a light ray traced from the selected pixel into a scene through the center of the lens
930
Compute the selected pixel's value in an image refocused at the estimated depth
940
Additional pixels to process?
yes
no
950
Use the computed values for the selected pixels to create the final virtual image

FIG. 9

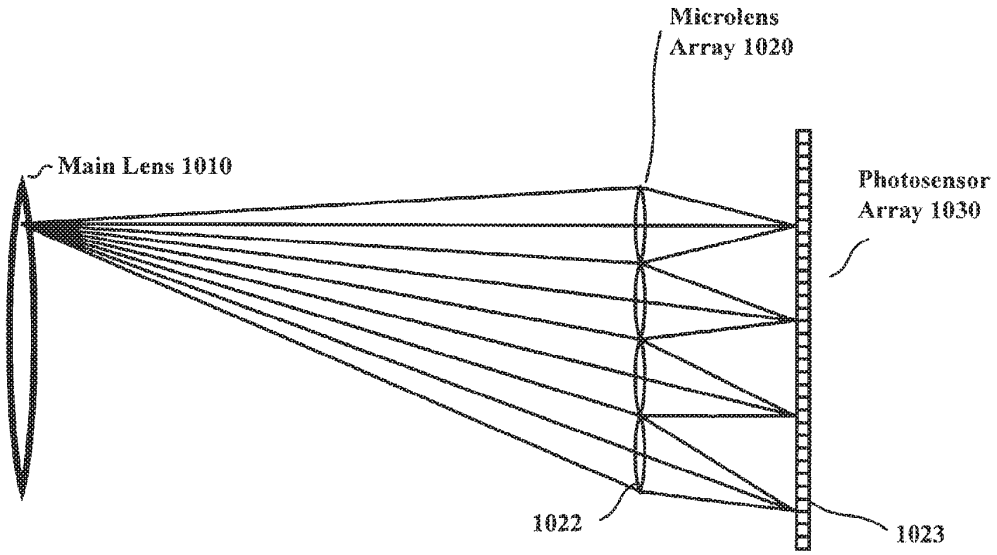

Microlens
Array 1020
Main Lens 1010
Photosensor
Array 1030
1022
1023

FIG. 10

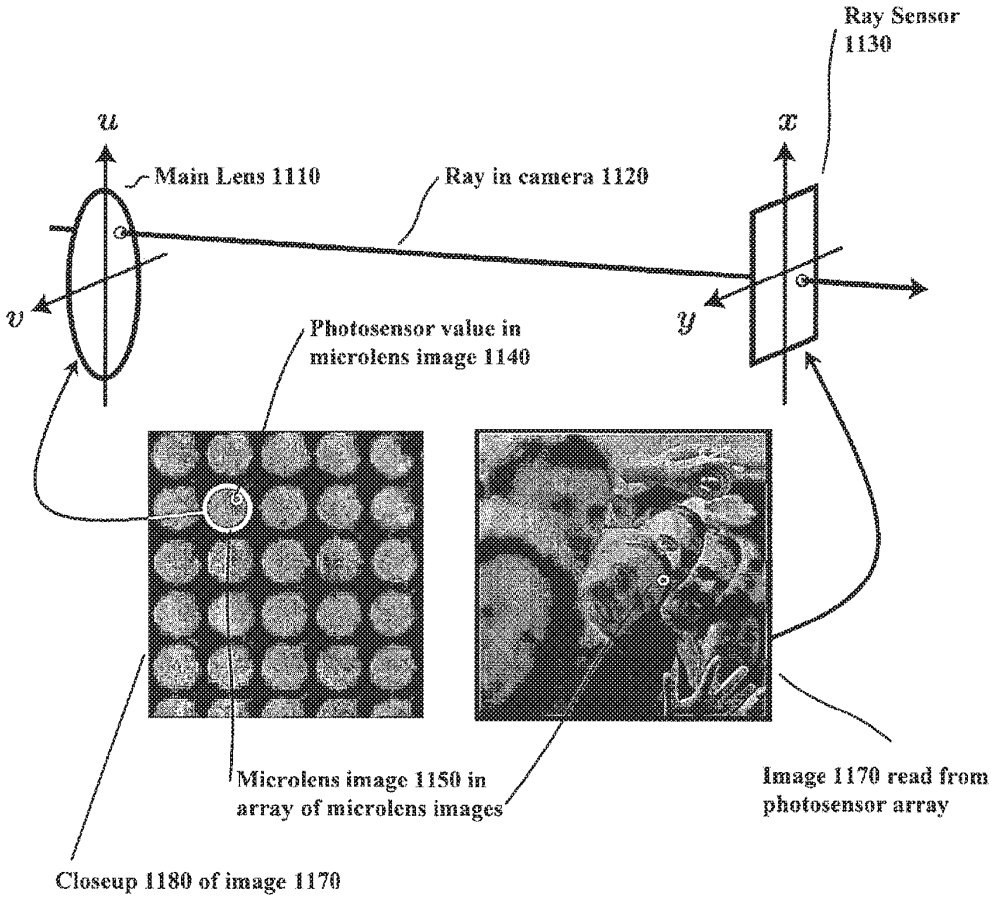

Ray Sensor
1130
u
x
Main Lens 1110
Ray in camera 1120
v
y
Photosensor value in
microlens image 1140
Microlens image 1150 in
array of microlens images
Image 1170 read from
photosensor array
Closeup 1180 of image 1170

FIG. 11

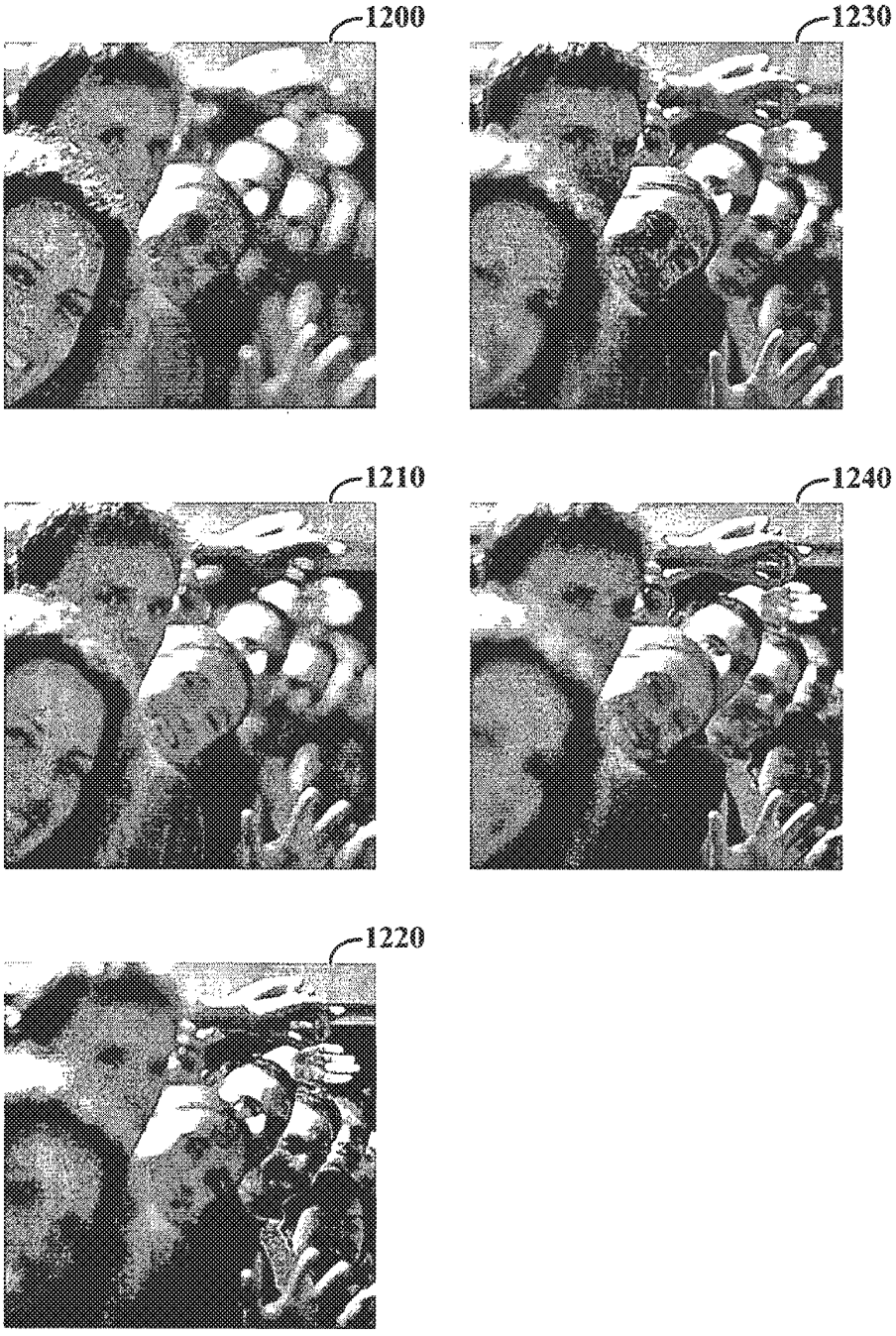


FIG. 12

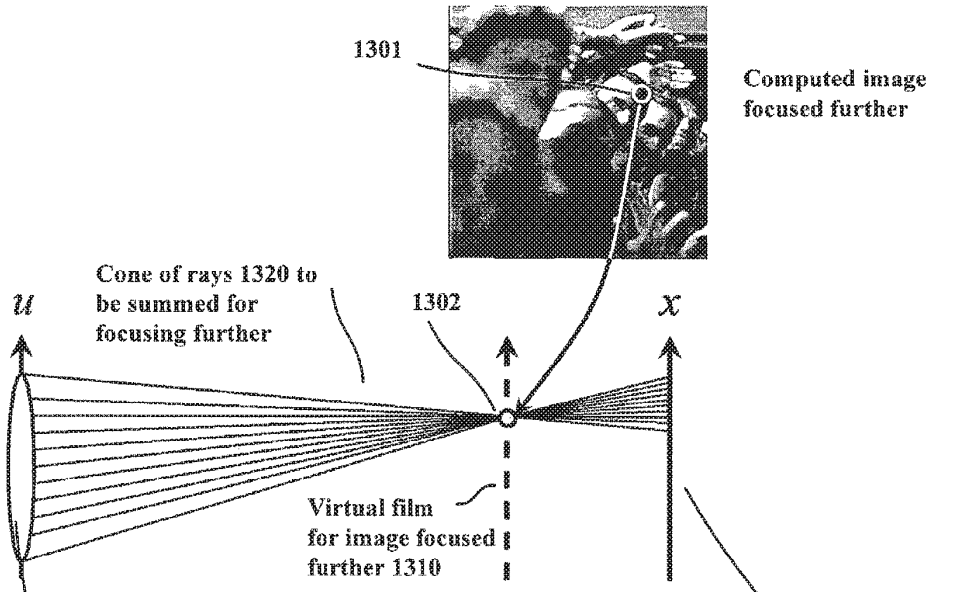


FIG. 13A

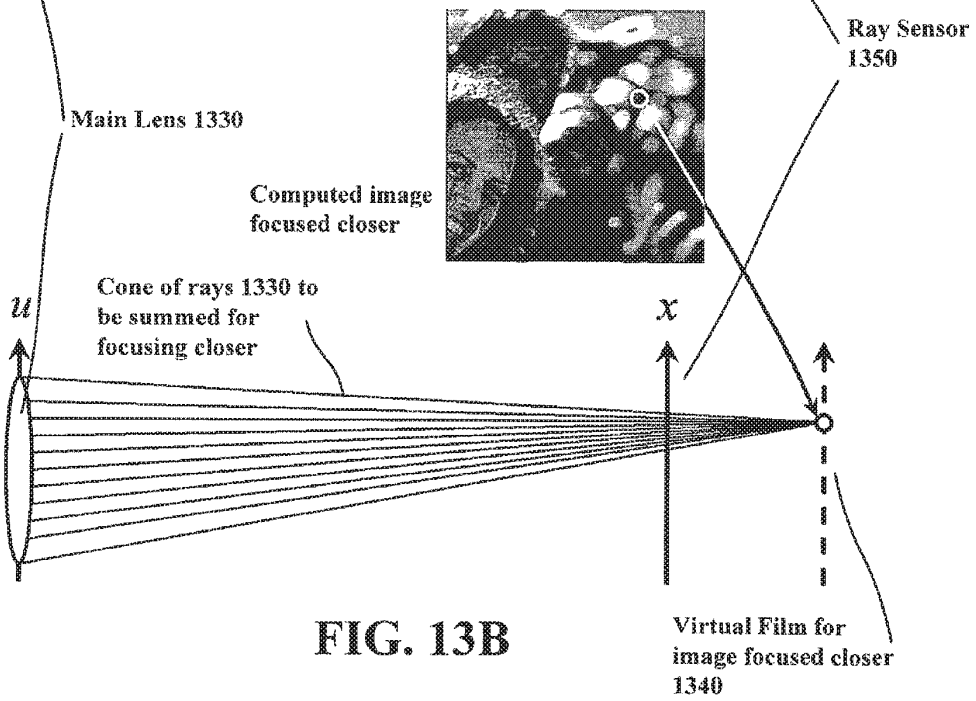
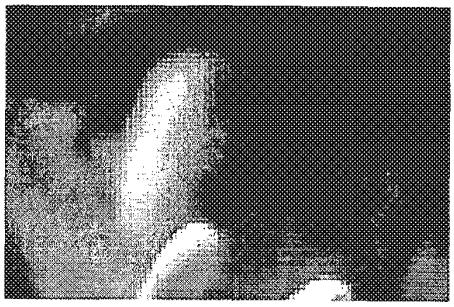


FIG. 13B





Closup

FIG. 14A

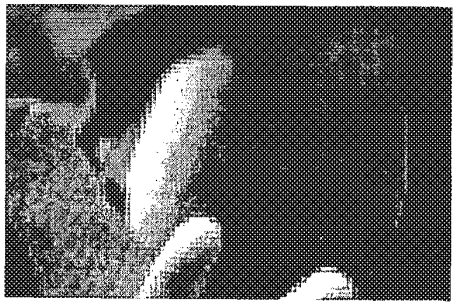




Closup

FIG. 14B





Closup

FIG. 14C

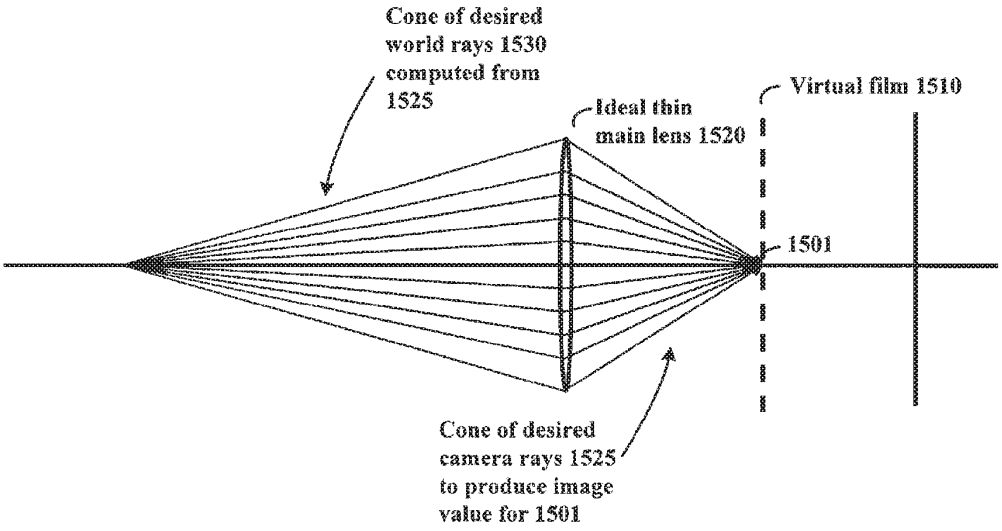

Cone of desired world rays 1530 computed from 1525
Ideal thin main lens 1520
Virtual film 1510
1501
Cone of desired camera rays 1525 to produce image value for 1501

FIG. 15

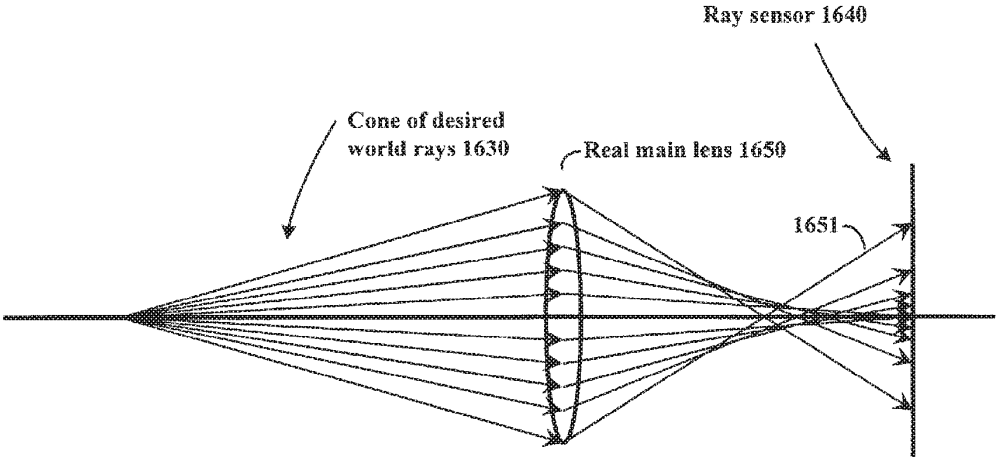

Ray sensor 1640
Cone of desired world rays 1630
Real main lens 1650
1651

FIG. 16



FIG. 17A

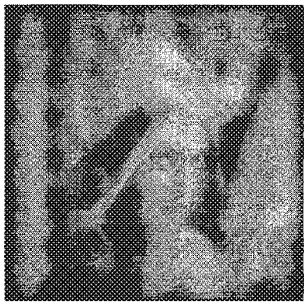


FIG. 17B



FIG. 17C

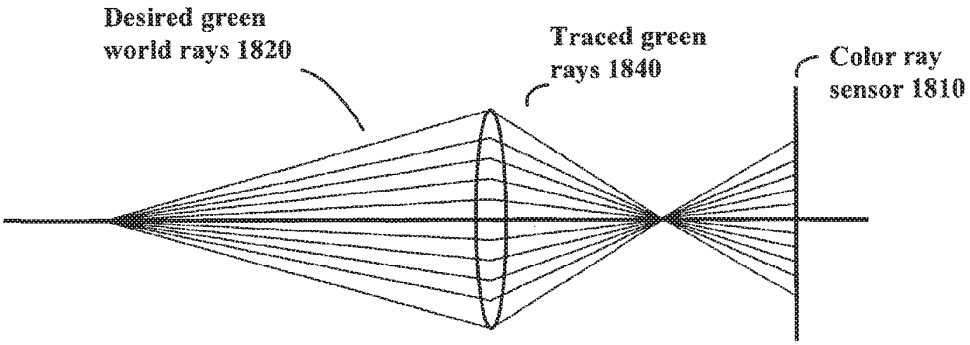


FIG. 18A

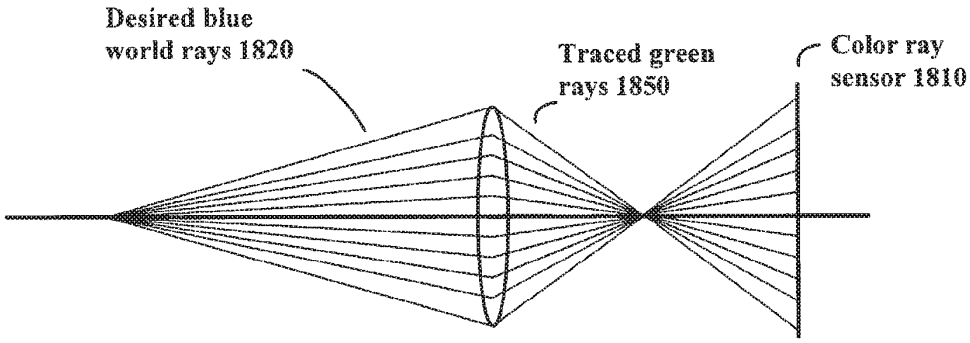


FIG. 18B

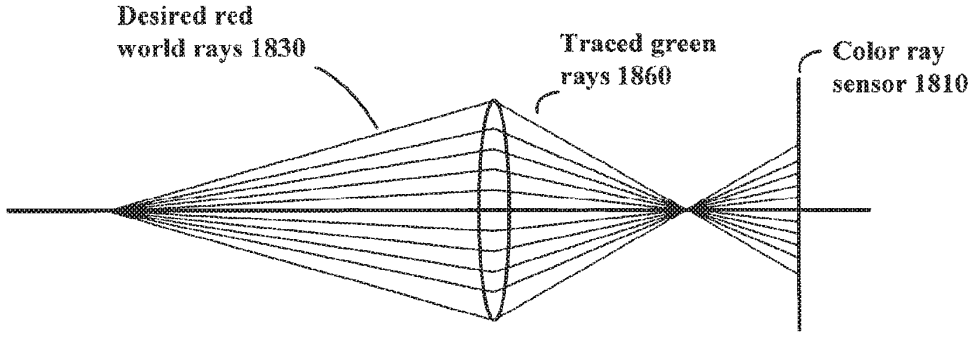


FIG. 18C

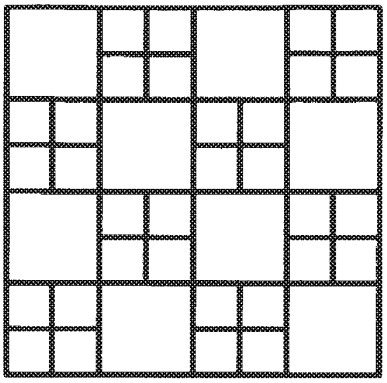


FIG. 19A

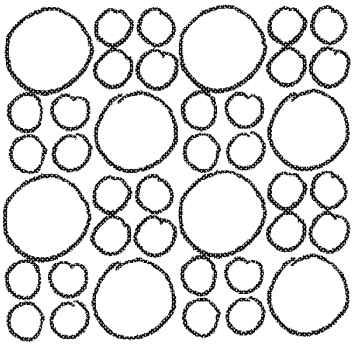


FIG. 19B



FIG. 19C

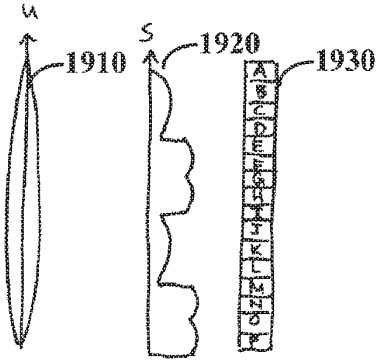


FIG. 19D

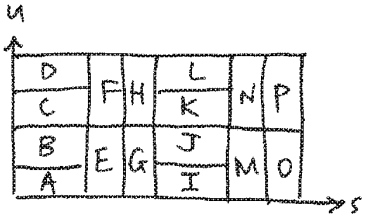


FIG. 19E

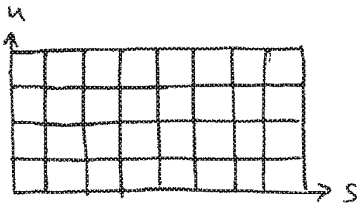


FIG. 19F

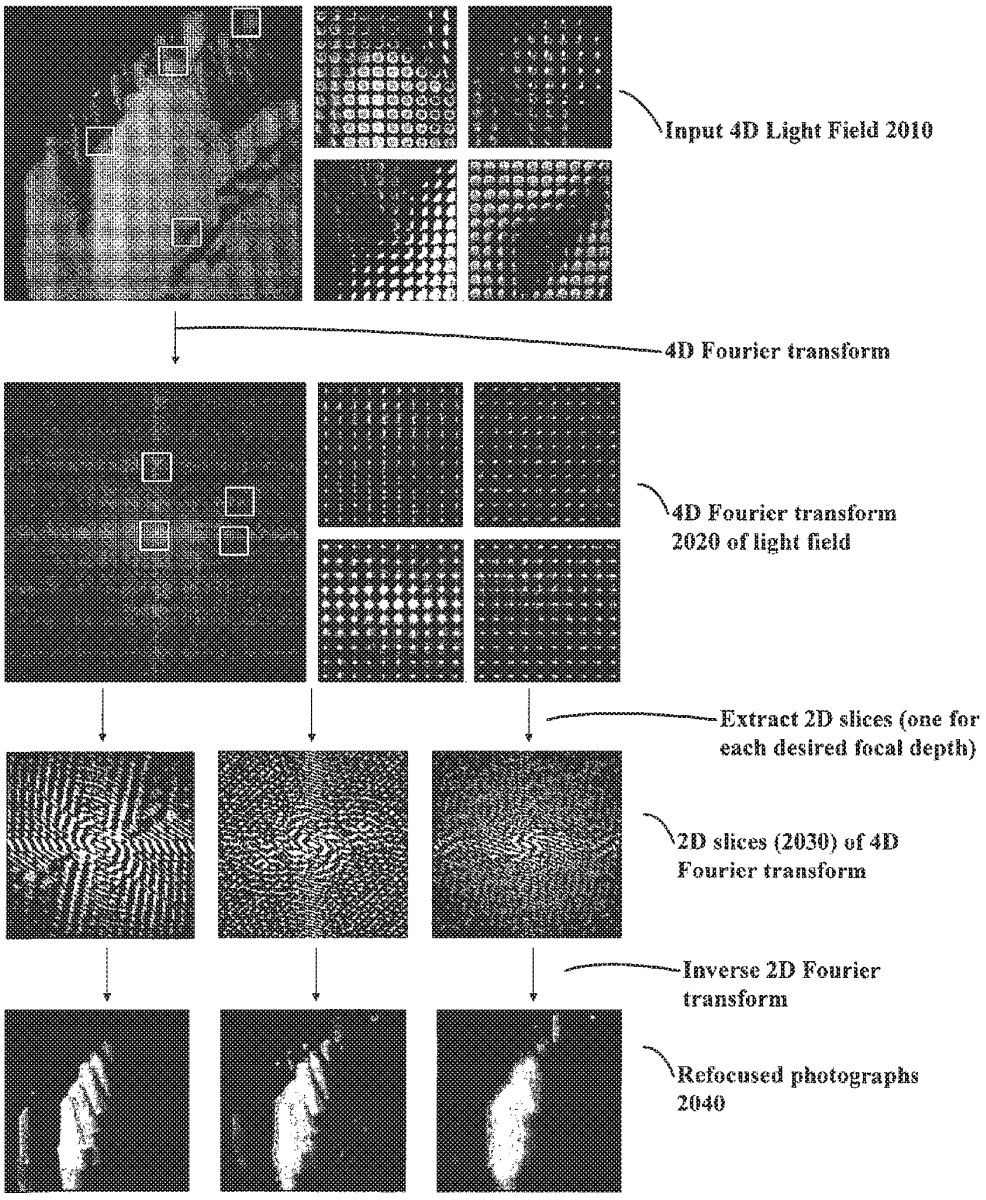

Input 4D Light Field 2010
4D Fourier transform
4D Fourier transform 2020 of light field
Extract 2D slices (one for each desired focal depth)
2D slices (2030) of 4D Fourier transform
Inverse 2D Fourier transform
Refocused photographs 2040

FIG. 20

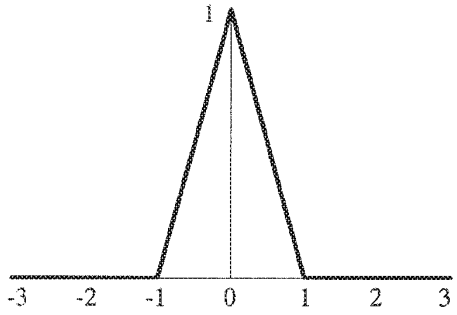


FIG. 21A

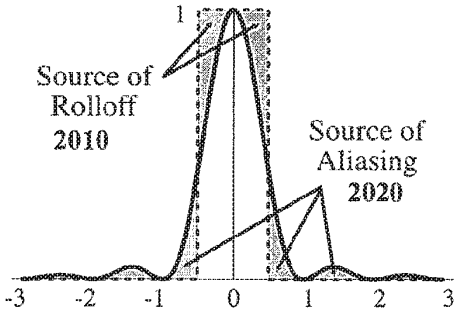


FIG. 21B

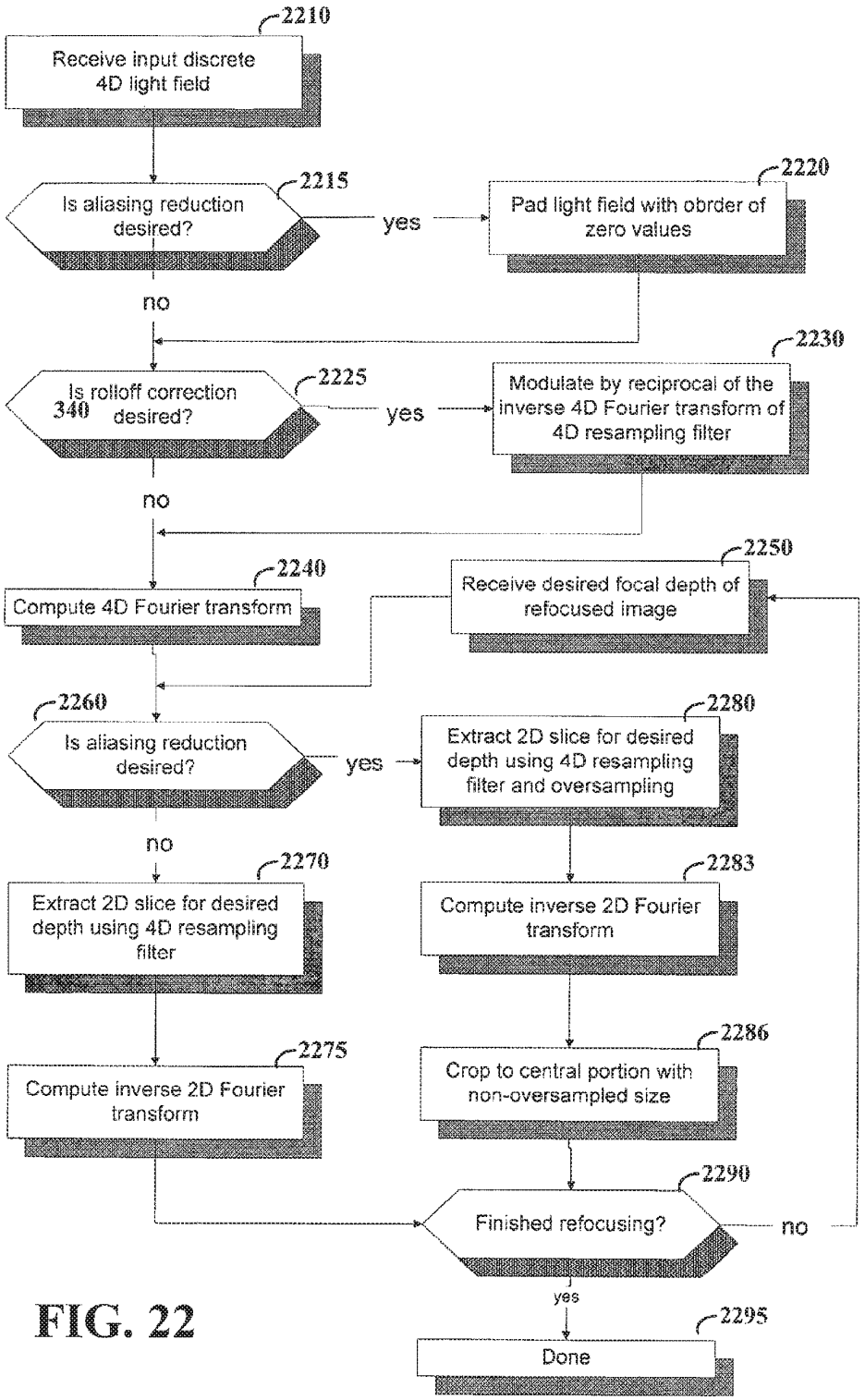

2210
Receive input discrete 4D light field
2215
Is aliasing reduction desired?
yes
2220
Pad light field with obrder of zero values
no
2230
Is rolloff correction 340 desired?
2225
yes
Modulate by reciprocal of the inverse 4D Fourier transform of 4D resampling filter
no
2250
Receive desired focal depth of refocused image
2240
Compute 4D Fourier transform
2260
Is aliasing reduction desired?
yes
2280
Extract 2D slice for desired depth using 4D resampling filter and oversampling
no
2270
Extract 2D slice for desired depth using 4D resampling filter
2283
Compute inverse 2D Fourier transform
2275
Compute inverse 2D Fourier transform
2286
Crop to central portion with non-oversampled size
2290
Finished refocusing?
no
yes
2295
Done

FIG. 22

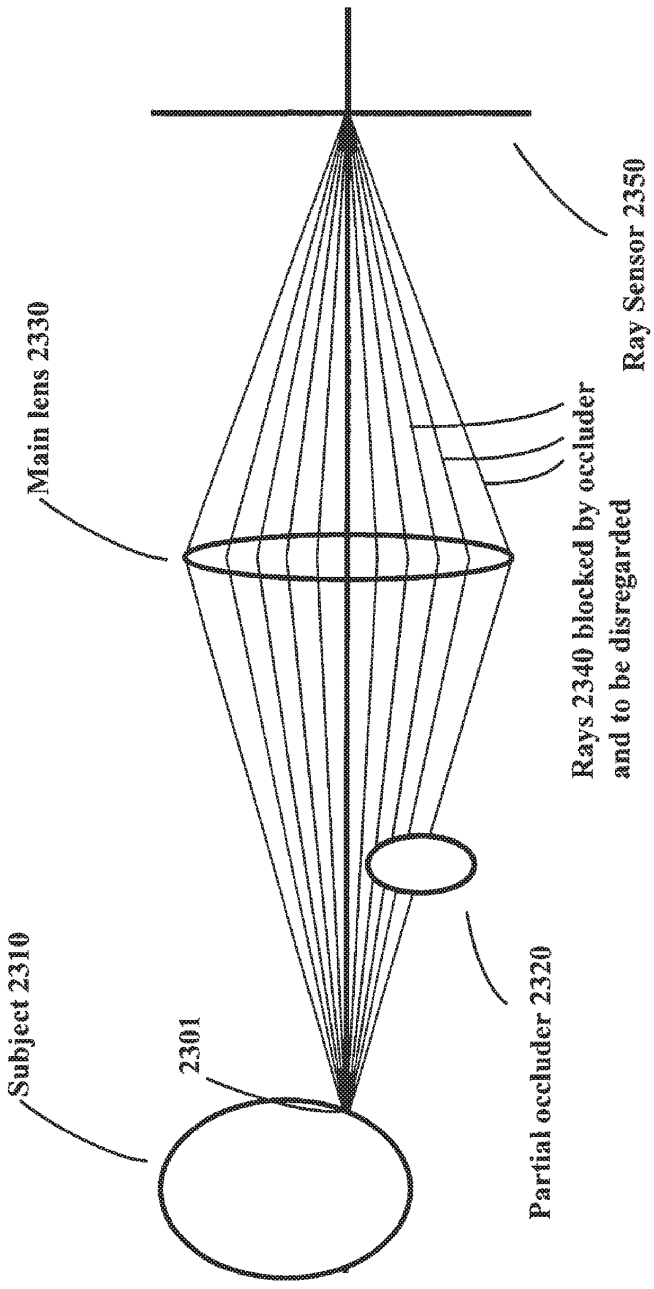


FIG. 23

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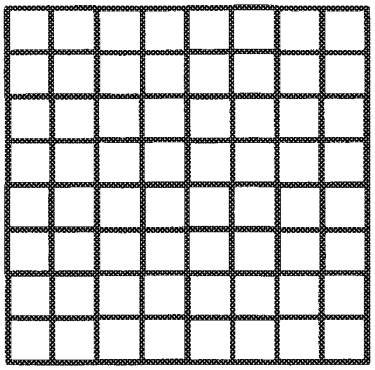


FIG. 24A

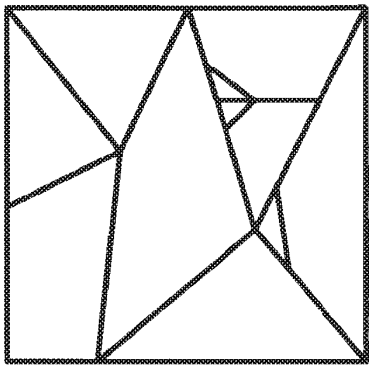


FIG. 24B

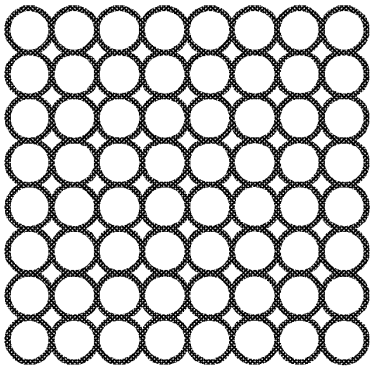


FIG. 24C

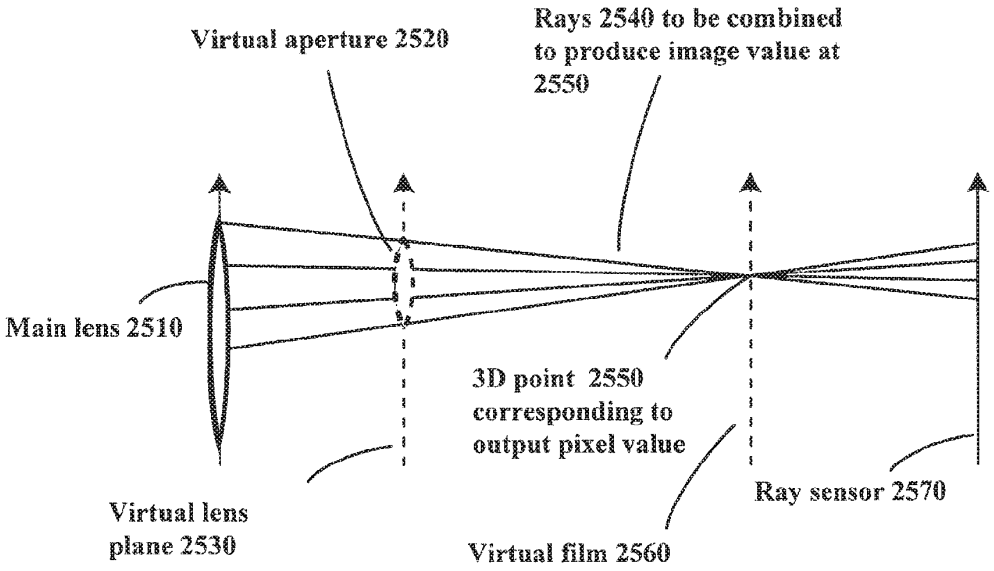

Virtual aperture 2520
Rays 2540 to be combined to produce image value at 2550
Main lens 2510
3D point 2550 corresponding to output pixel value
Ray sensor 2570
Virtual lens plane 2530
Virtual film 2560

FIG. 25

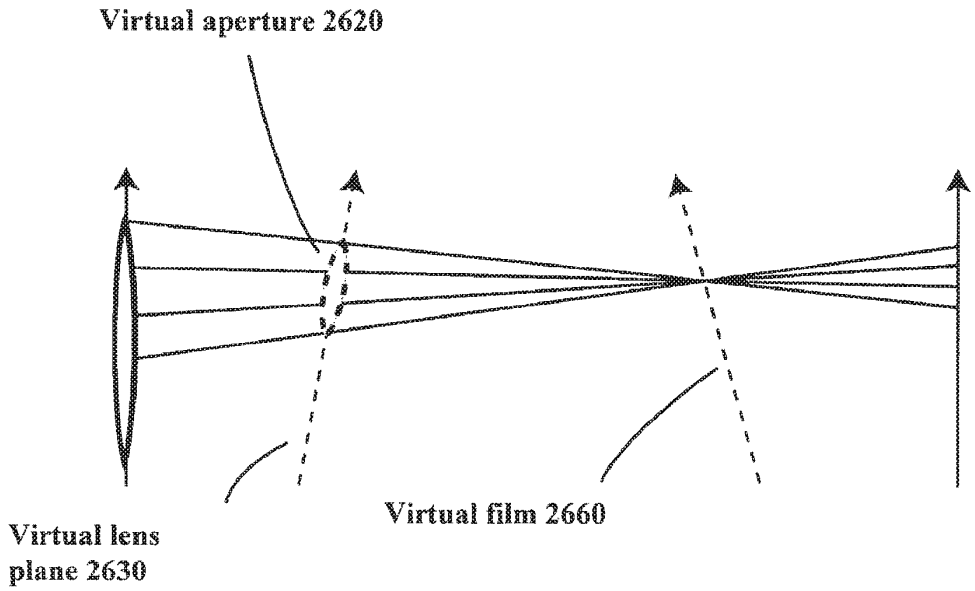

Virtual aperture 2620
Virtual film 2660
Virtual lens plane 2630

FIG. 26

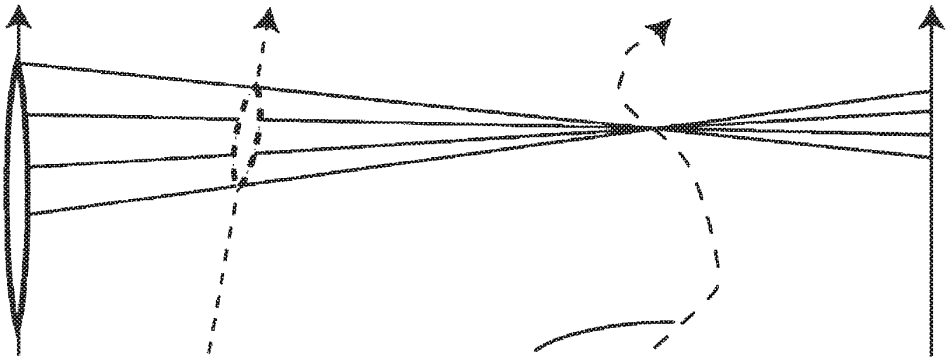


FIG. 27

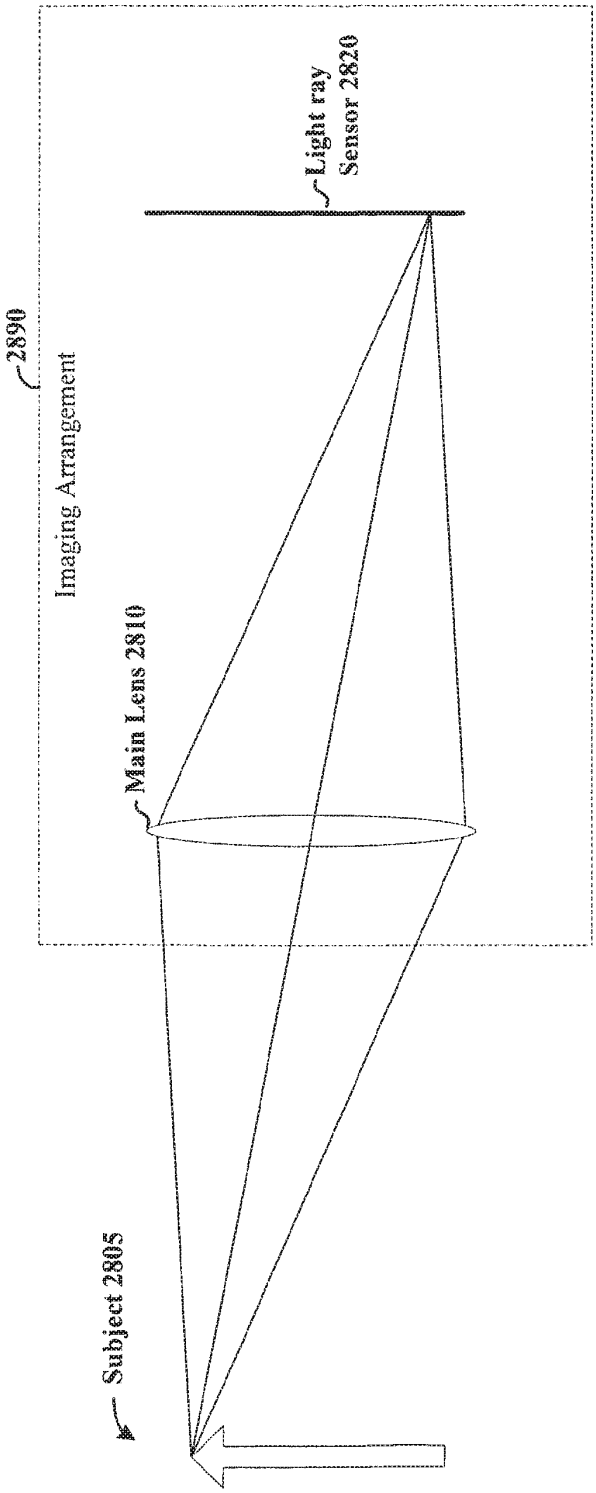

2890
Imaging Arrangement
Main Lens 2810
Light ray
Sensor 2820
Subject 2805

FIG. 28

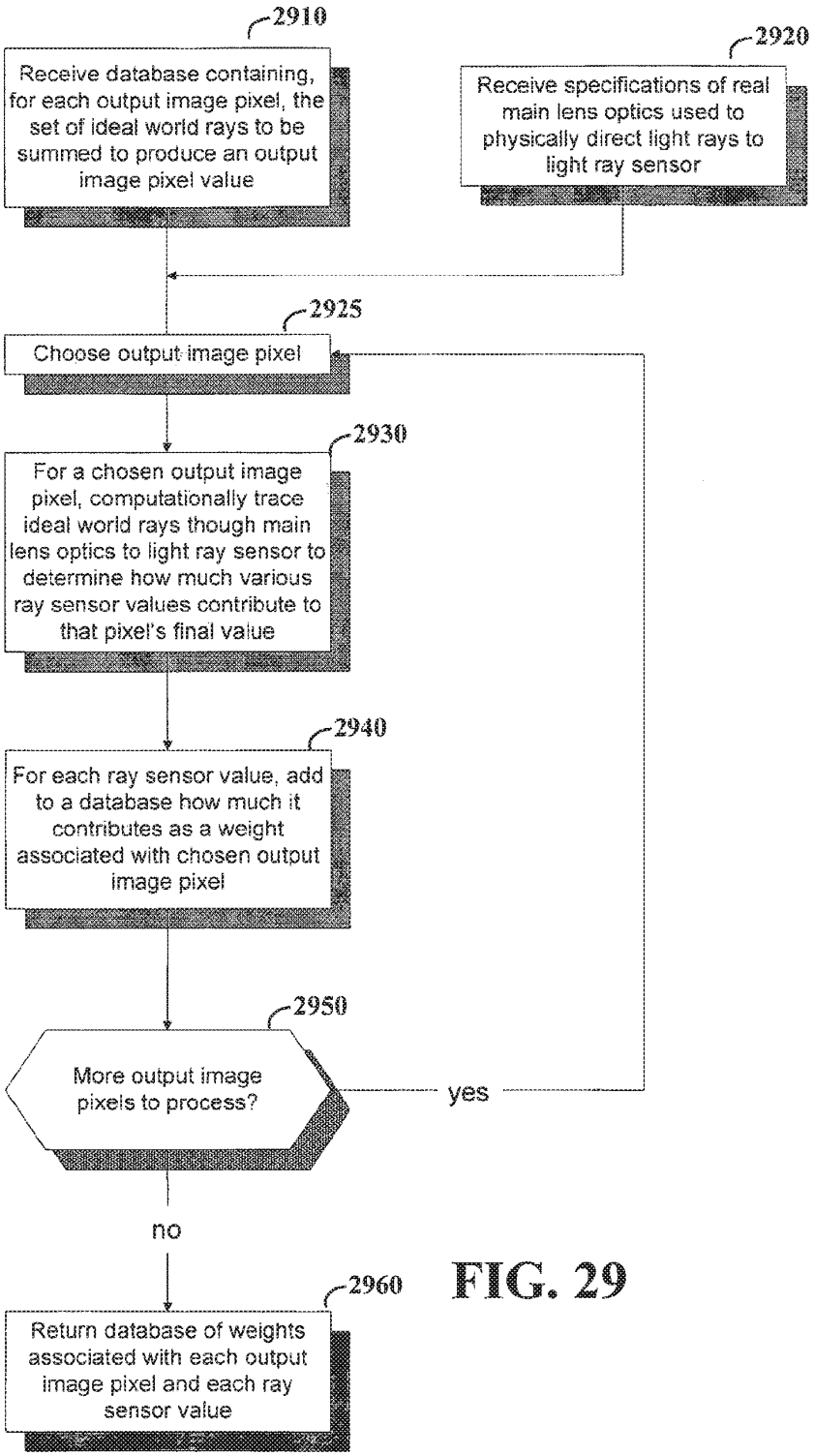

2910
Receive database containing, for each output image pixel, the set of ideal world rays to be summed to produce an output image pixel value
2920
Receive specifications of real main lens optics used to physically direct light rays to light ray sensor
2925
Choose output image pixel
2930
For a chosen output image pixel, computationally trace ideal world rays though main lens optics to light ray sensor to determine how much various ray sensor values contribute to that pixel's final value
2940
For each ray sensor value, add to a database how much it contributes as a weight associated with chosen output image pixel
2950
More output image pixels to process?
yes
no
2960
Return database of weights associated with each output image pixel and each ray sensor value

FIG. 29

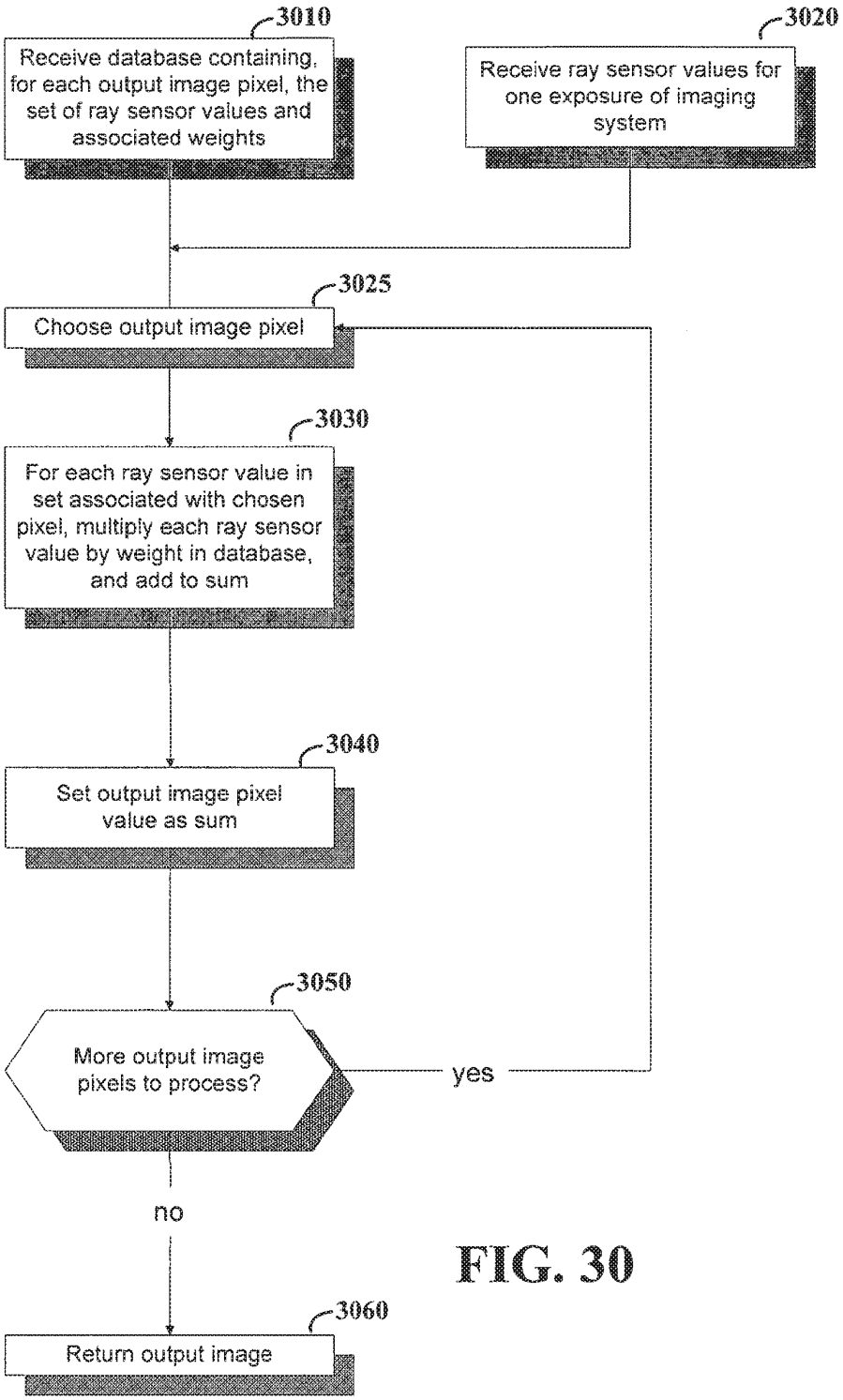

3010
Receive database containing, for each output image pixel, the set of ray sensor values and associated weights
3020
Receive ray sensor values for one exposure of imaging system
3025
Choose output image pixel
3030
For each ray sensor value in set associated with chosen pixel, multiply each ray sensor value by weight in database, and add to sum
3040
Set output image pixel value as sum
3050
More output image pixels to process?
yes
no
3060
Return output image

FIG. 30

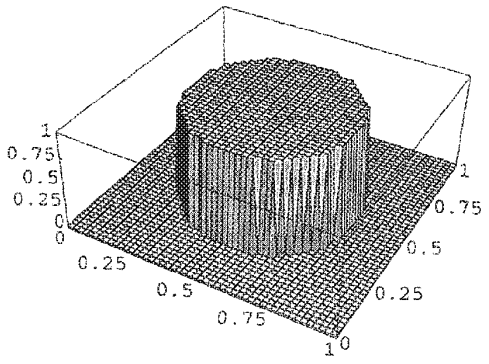


FIG. 31A

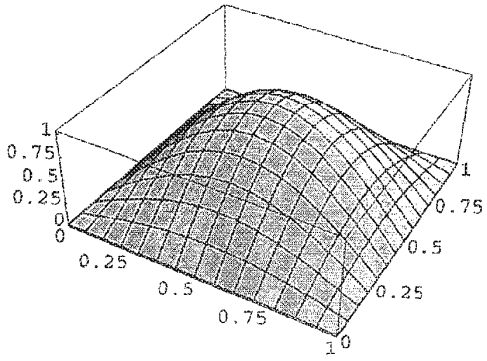


FIG. 31B

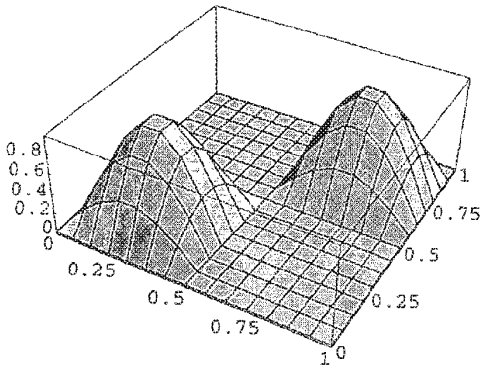


FIG. 31C

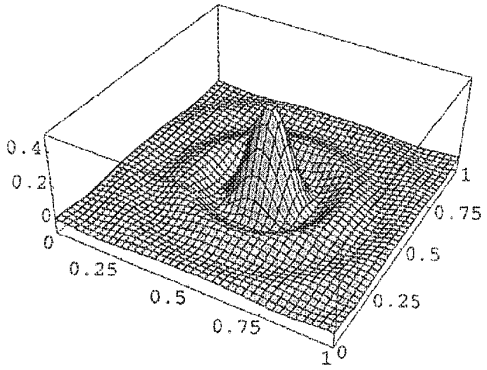


FIG. 31D

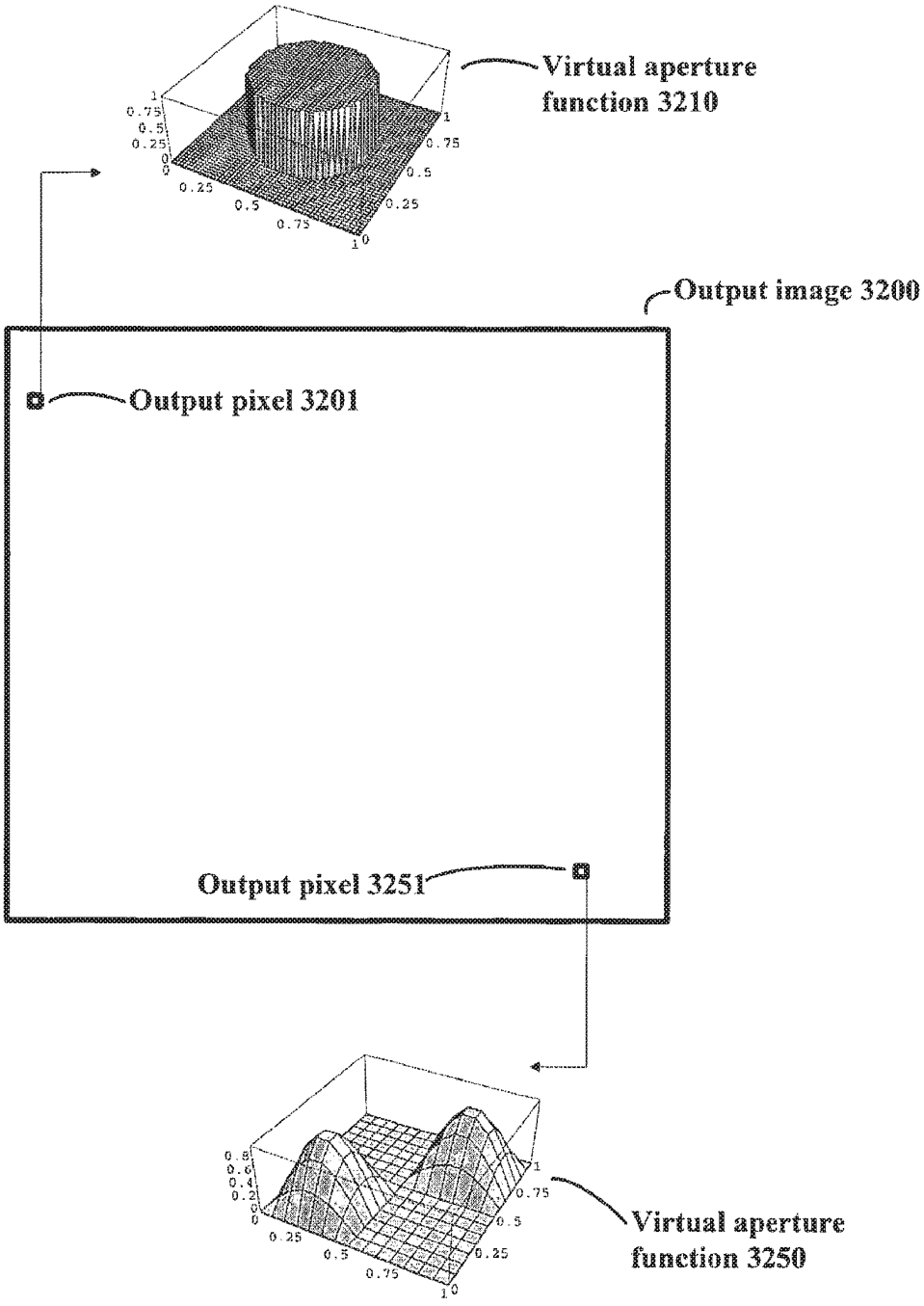

Virtual aperture function 3210
Output image 3200
Output pixel 3201
Output pixel 3251
Virtual aperture function 3250

FIG. 32

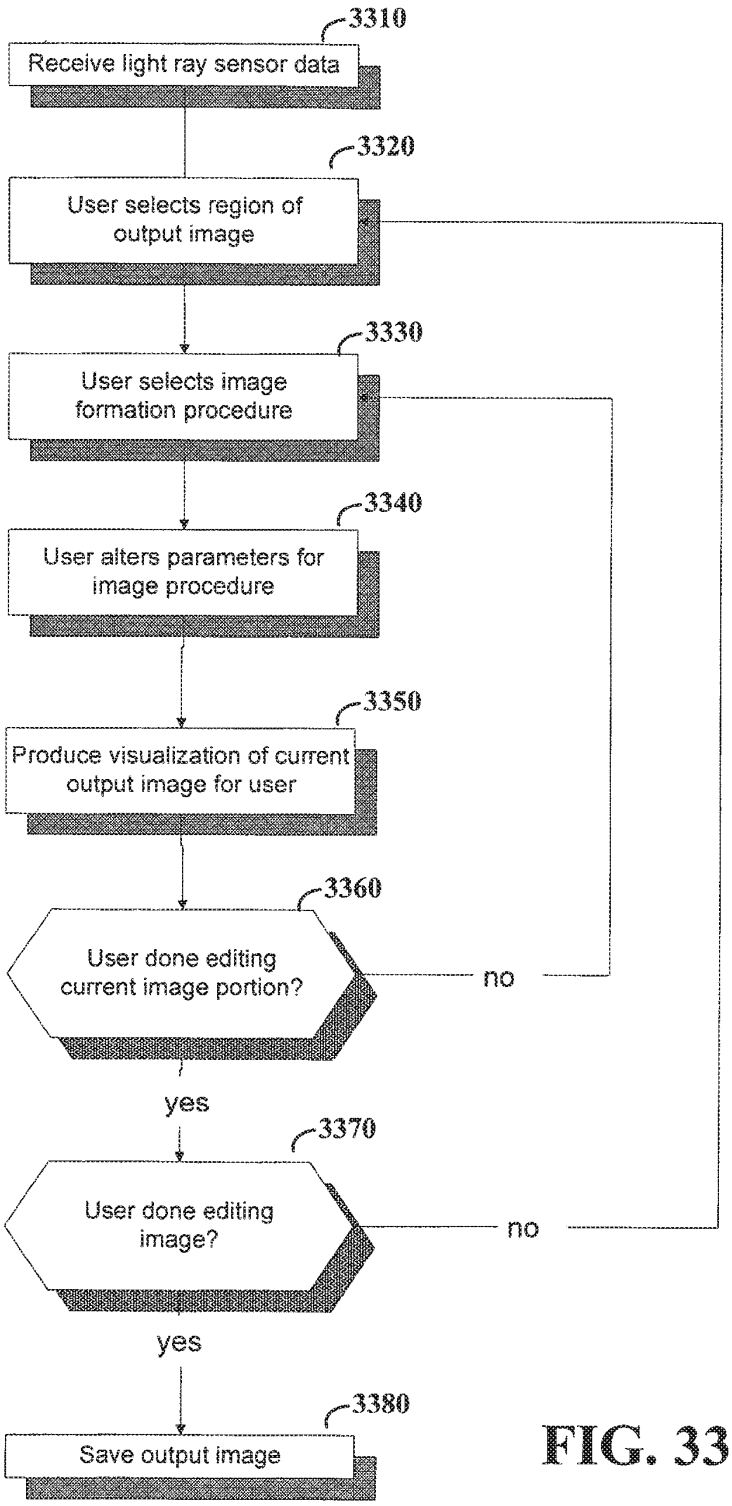

3310
Receive light ray sensor data
3320
User selects region of output image
3330
User selects image formation procedure
3340
User alters parameters for image procedure
3350
Produce visualization of current output image for user
3360
User done editing current image portion?
no
yes
3370
User done editing image?
no
yes
3380
Save output image

FIG. 33

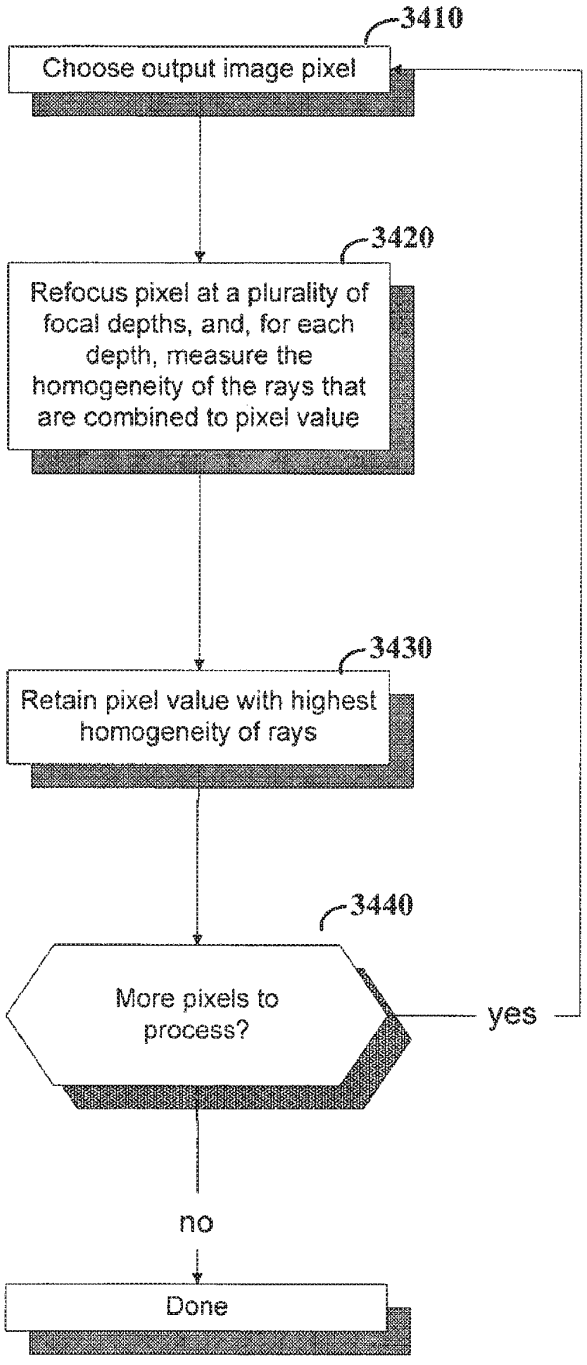

3410
Choose output image pixel
3420
Refocus pixel at a plurality of focal depths, and, for each depth, measure the homogeneity of the rays that are combined to pixel value
3430
Retain pixel value with highest homogeneity of rays
3440
More pixels to process?
yes
no
Done

FIG. 34

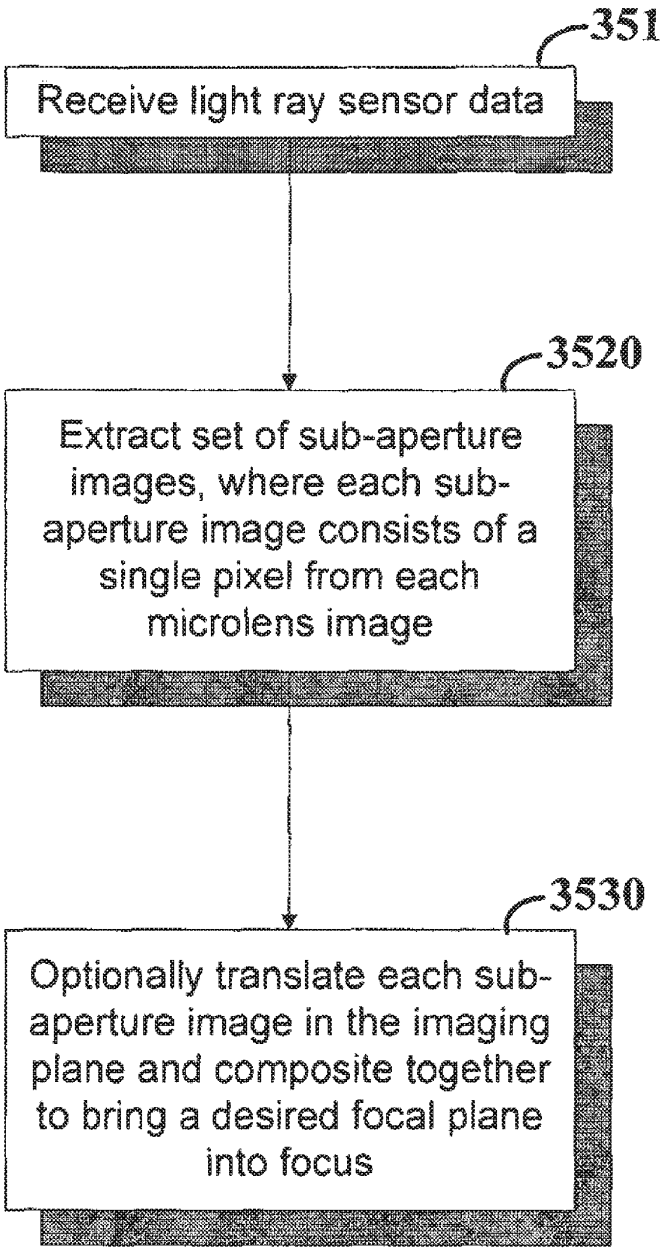

3510
Receive light ray sensor data
3520
Extract set of sub-aperture images, where each sub-aperture image consists of a single pixel from each microlens image
3530
Optionally translate each sub-aperture image in the imaging plane and composite together to bring a desired focal plane into focus

FIG. 35

IMAGING ARRANGEMENTS AND METHODS THEREFOR

RELATED PATENT DOCUMENTS

This patent application is the national stage filing under 35 U.S.C. 371 of International Application No. PCT/US2005/035189 filed on Sep. 30, 2005, which claims benefit under 35 U.S.C. §119(e) of U.S. Provisional Application Ser. No. 60/615,179 filed on Oct. 1, 2004; and of U.S. Provisional Application Ser. No. 60/647,492 filed on Jan. 27, 2005.

FEDERALLY-SPONSORED RESEARCH AND DEVELOPMENT

This invention was made with Government support under contract 0085864 awarded by the National Science Foundation. The U.S. Government has certain rights in this invention.

FIELD OF THE INVENTION

The present invention relates generally to imaging applications, and more specifically to processing image data to focus and/or correct the image data.

BACKGROUND

Imaging applications such as those involving cameras, video cameras, microscopes, telescopes and more have generally been limited in the amount of light that is collected. That is, most imaging devices do not record most of the information about light distribution entering the device. For example, conventional cameras such as digital still cameras and video cameras do not record most of the information about the light distribution entering from the world. In these devices, collected light is often not amenable to manipulation for a variety of approaches, such as for focusing at different depths (distances from the imaging device), correcting for lens aberrations or manipulating an angle of view.

For still-imaging applications, typical imaging devices capturing a particular scene generally focus upon a subject or object in the scene, with other parts of the scene left out of focus. For video-imaging applications, similar problems prevail, with a collection of images used in video applications failing to capture scenes in focus.

Many imaging applications suffer from aberrations with the equipment (lenses) used to collect light. Such aberrations may include, for example, spherical aberration, chromatic aberration, distortion, curvature of the light field, oblique astigmatism and coma. Correction for aberrations has typically involved the use of corrective optics, when tend to add bulk, expense and weight to imaging devices. In some applications benefiting from small-scale optics, such as camera phones and security cameras, the physical limitations associated with the applications make it undesirable to include additional optics.

Difficulties associated with the above have presented challenges to imaging applications, including those involving the acquisition and altering of digital images.

SUMMARY

The present invention is directed to overcoming the above-mentioned challenges and others related to imaging devices and their implementations. The present invention is exemplified in a number of implementations and applications, some of which are summarized below.

According to an example embodiment of the present invention, a light is detected with directional information characterizing the detected light. The directional information is used with the detected light to generate a virtual image, corresponding to one or both of a refocused image and a corrected image.

According to another example embodiment of the present invention, two or more subjects at different focal depths in a scene are imaged, with portions of the scene corresponding to each subject focused at different focal planes. Light from the scene is focused upon a physical focal plane and detected, together with information characterizing the direction from which the light arrived at particular locations on the physical focal plane. For at least one subject that is located at a depth of field that is not focused upon the physical focal plane, a virtual focal plane that is different than the physical focal plane is determined. Using the detected light and directional characteristics thereof, portions of the light corresponding to a focused image of the at least one subject upon the virtual focal plane are collected and added to form a virtual focused image of the at least one subject.

According to another example embodiment of the present invention, a scene is digitally imaged. Light from the scene that is passed to different locations on a focal plane is detected, and the angle of incidence of the light detected at the different locations on the focal plane is detected. A depth of field of a portion of the scene from which the detected light came is detected and used together with the determined angle of incidence to digitally re-sort the detected light. Depending upon the application, the re-sorting includes refocusing and/or correcting for lens aberrations.

The above summary of the present invention is not intended to describe each illustrated embodiment or every implementation of the present invention. The figures and detailed description that follow more particularly exemplify these embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be more completely understood in consideration of the detailed description of various embodiments of the invention that follows in connection with the accompanying drawings, in which:

FIG. **1** is a light ray capturing and processing arrangement, according to an example embodiment of the present invention;

FIG. **2** is an optical imaging device, according to another example embodiment of the present invention;

FIG. **3** is a process flow diagram for image processing, according to another example embodiment of the present invention;

FIG. **4** is a process flow diagram for generating a preview image, according to another example embodiment of the present invention;

FIG. **5** is a process flow diagram for processing and compressing image data, according to another example embodiment of the present invention;

FIG. **6** is a process flow diagram for image synthesis, according to another example embodiment of the present invention;

FIG. **7** is a process flow diagram for image refocusing, according to another example embodiment of the present invention;

FIG. **8** is a process flow diagram for extending the depth of field in an image, according to another example embodiment of the present invention;

FIG. **9** is a process flow diagram for another approach to extending the depth of field in an image, according to another example embodiment of the present invention;

FIG. **10** illustrates one example approach to separating light rays, according to another example embodiment of the present invention;

FIG. **11** illustrates an approach to the mapping of sensor pixel locations to rays in the L(u,v,s,t) space with respect to data collected, according to another example embodiment of the invention;

FIG. **12** illustrates several images refocused at different depths, according to another example embodiment of the present invention;

FIG. **13**A shows an imaging configuration in 2D, according to another example embodiment of the present invention;

FIG. **13**B shows a cone of rays from a 3D point summed for a pixel, according to another example embodiment of the present invention;

FIGS. **14**A-**14**C show an approach to computing images with different depths of field, according to another example embodiment of the present invention;

FIG. **15** illustrates an approach to the tracing of rays from a 3D point on a virtual film plane, according to another example embodiment of the present invention;

FIG. **16** shows an approach to finding the value of light, according to another example embodiment of the present invention;

FIG. **17**A shows an ideal 512×512 photograph, according to another example embodiment of the present invention;

FIG. **17**B shows an image that would be produced with an f/2 bi-convex spherical lens, according to another example embodiment of the present invention;

FIG. **17**C shows an image computed using an image correction approach, according to another example embodiment of the present invention;

FIGS. **18**A-**18**C illustrate the tracing of light rays common in color imaging systems, according to another example embodiment of the present invention;

FIGS. **19**A-**19**F illustrate approaches to implementing a mosaic array, according to another example embodiment of the present invention;

FIG. **20** is a process flow diagram of computational approaches to refocusing in a Fourier domain, according to another example embodiment of the present invention;

FIG. **21**A shows a triangle filter approach, according to another example embodiment of the present invention;

FIG. **21**B shows a Fourier transformation of the triangle filter approach; according to another example embodiment of the present invention;

FIG. **22** is process flow diagram of an approach to refocusing in a frequency domain, according to another example embodiment of the present invention;

FIG. **23** shows a set of rays which pass through a desired focal point, according to another example embodiment of the present invention;

FIGS. **24**A-B show differing views of a portion of a microlens array, according to another example embodiment of the present invention,

FIG. **24**C illustrates images that appear on a photosensor, according to another example embodiment of the present invention;

FIG. **25** illustrates an example embodiment of the present invention, in which a virtual image is computed as it would have appeared on virtual film;

FIG. **26** shows an approach to manipulating a virtual lens plane, according to another example embodiment of the present invention;

FIG. **27** illustrates that the virtual film may take any shape, according to another example embodiment of the present invention;

FIG. **28** shows an imaging arrangement; according to another example embodiment of the present invention;

FIG. **29** is a process flow diagram for pre-computing a database of weights associated with each output image pixel and each ray sensor value, according to another example embodiment of the present invention;

FIG. **30** is a process flow diagram for computing an output image using a database of weights, according to another example embodiment of the present invention;

FIGS. **31**A-D illustrate various scalar functions which are selectively implemented as a virtual aperture function, according to another example embodiment of the present invention;

FIG. **32** shows a virtual aperture function which varies from pixel to pixel; according to another example embodiment of the present invention;

FIG. **33** is a process flow diagram of a user selecting a region of an output image, editing an image portion and saving the output image, according to another example embodiment of the present invention;

FIG. **34** is a process flow diagram for extending the depth of field in an image, according to another example embodiment of the present invention; and

FIG. **35** is a process flow diagram for computing a refocused image from received light ray sensor data, according to another example embodiment of the present invention.

While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention.

DETAILED DESCRIPTION

The present invention is believed to be useful for a variety of different types of devices, and the invention has been found to be particularly suited for electronic imaging devices and applications. While the present invention is not necessarily limited to such applications, various aspects of the invention may be appreciated through a discussion of various examples using this context.

According to an example embodiment of the present invention, a four-dimensional (4D) light field (e.g., the light traveling along each ray in a region such as free space) is detected using an approach involving the determination of the amount and direction of light arriving at a sensor located at a focal plane. The two-dimensional position of light in the focal plane is detected, together with information characterizing the direction from which the light arrived at particular locations in the plane. With this approach, the directional lighting distribution arriving at different locations on the sensor are determined and used to form an image. In various discussions herein, the assembly or assemblies implemented for sensing and/or measuring of a light field are referred to as a "light ray sensor," or a "ray sensor."

In one application, an approach similar to the above is implemented using an imaging system having optics and sensors that sample the space of light rays that are incident on an imaging plane, with computational functionality that renders images from the set of measured rays in different ways. Each of the optics, sensors and computational functionality is

implemented using a variety of approaches, in combination or distinctly, depending upon the implementation. For example, a camera having lenses (optics) that focus an image upon a photosensor array (sensors) located at an imaging plane can be used to sample the space of light rays. An output from the photosensor array is used with computational functions (e.g., at a processor internal and/or external to the camera) to render images, such as by computing photographs that are focused at different depths or with different depths of field, and/or computationally correcting lens aberrations to produce higher quality images.

In another example embodiment, optics and sensor components of an imaging system direct rays of light onto sensor elements such that each sensor element senses a set of rays including rays emanating from specific directions. In many applications, this set of rays is a bundle of rays that is localized in both space and direction. For many applications, this bundle of rays will converge to a single geometric ray of light as the optics and sensor resolutions increase. In this regard, various portions of the description herein refer to the values sensed by the sensor elements as "rays of light" or "light rays" or simply "rays," even though in general they may not be limited to geometric rays.

Turning now to the figures, FIG. **28** shows an imaging arrangement **2890**, according to another example embodiment of the present invention. The imaging arrangement **2890** includes a main lens **2810**, and a light ray sensor that measures the value of light arriving at different locations on the sensor and from difference incident directions. In this context, measuring the value of light may be implemented by detecting light arriving at different locations at the sensor, together with characteristics of that light such as intensity to generate a value.

FIG. **1** shows an imaging system **100**, according to another example embodiment of the present invention. The imaging system **100** includes an imaging arrangement **190** having a main lens **110**, a microlens array **120** and a photosensor array **130**. In this case, the microlens array **120** and photosensor array **130** implement a light ray sensor. Although FIG. **1** illustrates a particular main lens **110** (single element) and particular microlens array **120**, those skilled in the art will recognize that a variety of lenses and/or microlens arrays (currently available or developed in the future) are selectively implemented with a similar approach by, for example, replacing the shown main lens and/or microlens array.

Rays of light from a single point on a subject **105** in an imaged scene are brought to a single convergence point on the focal plane of the microlens array **120**. For instance, when the imaged point on the subject **105** is at a distance from the main lens that is conjugate to the distance from the microlens array to the main lens, the dimension "d" is about equal to the dimension "s" as shown. A microlens **122** at this convergence point separates these rays of light based on the direction of the light, creating a focused image of the aperture of the main lens **110** on the photosensors underneath the microlens.

The photosensor array **130** detects light incident upon it and generates an output that is processed using one or more of a variety of components. In this application, the output light data is passed to sensor data processing circuitry **140**, which uses the data together with positional information about each photosensor providing the data in generating an image of the scene (e.g., including subjects **105**, **106** and **107**). The sensor data processing circuitry **140** is implemented, for example, with a computer or other processing circuit selectively implemented in a common component (e.g., a chip) or in different components. In one implementation, a portion of the sensor data processing circuitry **140** is implemented in the imaging arrangement **390**, with another portion of implemented in an external computer. Using the detected light (and, e.g., characteristics of the detected light) together with a known direction from which the light arrived at the microlens array (as computed using a known location of each photosensor), the sensor data processing circuitry **140** selectively refocuses and/or corrects light data in forming an image (where refocusing may be correcting). Various approaches to processing detected light data are described in detail below, with and without reference to other figures. These approaches may be selectively implemented with the sensor data processing circuitry **140** consistent with the above.

Different portions of the imaging system **100** are selectively implemented in a common or separate physical arrangement, depending upon the particular application. For example, when implemented with a variety of applications, the microlens array **120** and the photosensor array **130** are combined into a common arrangement **180**. In some applications, the microlens array **120** and the photosensor array **130** are coupled together on a common chip or other circuit arrangement. When implemented with a hand-held device such as a camera-like device, the main lens **110**, microlens array **120** and photosensor array **130** are selectively combined into a common imaging arrangement **190** integrated with the hand-held device. Furthermore, certain applications involve the implementation of some or all of the sensor data processing circuitry **140** in a common circuit arrangement with the photosensor array **130** (e.g., on a common chip).

In some applications, the imaging arrangement **100** includes a preview arrangement **150** for presenting a preview image to a user capturing images. The preview arrangement is communicatively coupled to receive image data from the photosensor array **130**. A preview processor **160** processes the image data to generate a preview image that is displayed on a preview screen **170**. In some applications, the preview processor **160** is implemented together with the image sensor **180**, on a common chip and/or in a common circuit. In applications where the sensor data processing circuitry **140** is implemented with the photosensor array **130** as discussed above, the preview processor **160** is selectively implemented with the sensor data processing circuitry **140**, with some or all of the image data collected by the photosensor array **130** used to generate the preview image.

The preview image may be generated using relatively fewer computational functions and/or less data than that used to generate a final image. For instance, when implemented with a hand-held imaging device such as a camera or cell phone, a preview image that does not effect any focusing or lens correction may be sufficient. In this regard, it may be desirable to implement processing circuitry that is relatively inexpensive and/or small to generate the preview image. In such applications, the preview processor generates the image at a relatively low-computational cost and/or using less data, for example by using the first extended depth of field computational method as described above.

The imaging system **100** is implemented in a variety of manners, depending upon the application. For instance, while the microlens array **120** is shown with several distinguishable microlenses by way of example, the array is generally implemented with a multitude (e.g., thousands or millions) of microlenses. The photosensor array **130** generally includes a relatively finer pitch than the microlens array **120**, with several photosensors for each microlens in the microlens array **120**. In addition, the microlenses in the microlens array **120** and the photosensors in the photosensor array **130** are gener-

ally positioned such that light passing via each microlens to the photosensor array does not overlap light passed via adjacent microlenses.

In various applications, the main lens **110** is translated along its optical axis (as shown in FIG. **1**, in a horizontal direction) to focus on a subject of interest at a desired depth "d" as exemplified between the main lens and an example imaging subject **105**. By way of example, light rays from a single point on the subject **105** are shown for purposes of this discussion. These light rays are brought to a single convergence point at microlens **122** on the focal plane of the microlens array **120**. The microlens **122** separates these rays of light based on direction, creating a focused image of the aperture of the main lens **110** on a set of pixels **132** in the array of pixels underneath the microlens. FIG. **10** illustrates one example approach to separating light rays, such that all rays emanating from a point on a main lens **1010** and arriving anywhere on the surface of the same microlens (e.g., **1022**) are directed by that microlens to converge at the same point on a photosensor (e.g., **1023**). This approach shown in FIG. **10** may, for example, be implemented in connection with FIG. **1** (i.e., with the main lens **1010** implemented for main lens **110**, with microlens array **1020** implemented for microlens array **120**, and with photosensor array **1030** implemented for photosensor array **130**).

The image that forms under a particular microlens in the microlens array **122** dictates the directional resolution of the system for that location on the imaging plane. In some applications, directional resolution is enhanced by facilitating sharp microlens images, with the microlenses focused on the principal plane of the main lens. In certain applications the microlenses are at least two orders of magnitude smaller than the separation between the microlens array and the main lens **110**. In these applications, the main lens **110** is effectively at the microlenses' optical infinity; to focus the microlenses, the photosensor array **130** is located in a plane at the microlenses' focal depth.

The separation "s" between the main lens **110** and the microlens array **120** is selected to achieve a sharp image within the depth of field of the microlenses. In many applications, this separation is accurate to within about $\Delta x_p \cdot (f_m/\Delta x_m)$, where Δx_p is the width of a sensor pixel, f_m is the focal depth of the microlenses and Δx_m is the width of the microlenses. In one particular application, Δx_p is about 9 microns, f_m is about 500 microns and. Δx_m is about 125 microns, with the separation between the microlens array **120** and the photosensor array **130** being accurate to about 36 microns.

The microlens array **120** is implemented using one or more of a variety of microlenses and arrangements thereof. In one example embodiment, a plane of microlenses with potentially spatially varying properties is implemented as the microlens array **120**. For example, the microlens array may include lenses that are homogeneous and/or inhomogeneous, square in extent or non-square in extent, regularly distributed or non-regularly distributed, and in a pattern than is repeating or non-repeating, with portions that are optionally masked. The microlenses themselves may be convex, non-convex, or have an arbitrary profile to effect a desired physical direction of light, and may vary in profile from microlens to microlens on the plane. Various distributions and lens profiles are selectively combined. These various embodiments provide sampling patterns that are higher spatially (correspondingly lower angularly) in some regions of the array, and higher angularly (correspondingly lower spatially) in other regions. One use of such data facilitates interpolation to match desired spatial and angular resolution in the 4D space.

FIG. **24**A illustrates a view (line of sight perpendicular to the plane) of a portion of a microlens array, according to another example embodiment of the present invention. The microlenses are square-shaped and regularly distributed in an array.

FIG. **24**B illustrates a view of a portion of a microlens array, according to another example embodiment of the present invention. The microlens plane distribution is not regular or repeating, and the microlenses are arbitrarily shaped.

FIG. **24**C illustrates images that appear on the photosensor in connection with another example embodiment of the present invention, using a distribution such as that shown in FIG. **24**A with a convex profile and a main lens having a circular aperture.

In other example embodiments, a regular mosaic of larger and smaller microlenses is used. In one implementation, the resulting photosensor data is interpolated to provide a homogeneous sampling that has the maximum spatial and angular resolutions of a microlens or microlenses in the mosaic.

FIGS. **19**A-**19**F illustrate approaches to implementing a mosaic array such as that described above, in connection with one or more example embodiments of the present invention. FIG. **19**A is an overhead view of a plane showing example relative sizes and arrangement of the microlenses. FIG. **19**B is an illustration of the shape of the images that form on the photosensor array after projection through each microlens in FIG. **19**A. FIG. **19**C is a cross-sectional view of the array in FIG. **19**A, illustrating that the microlenses have the same f-number and their focal points share a common plane. This requires that the smaller microlenses are positioned closer to the focal plane than the larger ones. This causes the images of the main lens that appear underneath each microlens to be large without overlapping, and all appear in-focus on a photosensor that is placed at the plane containing the focal points.

FIG. **19**D shows a cross-sectional view of the microlenses shown in FIGS. **19**A and **19**C implemented in a full imaging arrangement containing a main lens **1910**, a mosaic microlens array **1920** and photosensor arrangement **1930**, according to another example embodiment of the present invention. Note that although the diagram has been shown with several microlenses and several pixels per microlens, the actual number of microlenses and pixels is selected using a variety of approaches, such as by determining the resolution requirements of the given application and implementing appropriate numbers of each.

FIG. **19**E is a Cartesian ray diagram representing the space of rays starting at u on the main lens **1910** and terminating at s on the microlens array **1920** (the space of rays is shown in 2D for clarity, although the full space of rays is 4D). The set of rays that are summed by each photosensor (labeled A-P) in FIG. **19**C is shown on the Cartesian ray diagram in FIG. **19**D. In the full 4D space of rays, each photosensor integrates a 4D box of rays. The 4D boxes for photosensors under the larger microlenses have half the width (twice the resolution) in the (u, v) directional axes, and twice the width (half the resolution) in the (x, y) spatial axes compared to photosensors under the smaller microlenses.

In another example embodiment, photosensor values are interpolated to a regular grid so that the resolution in all axes matches the maximum resolution in all axes. FIG. **19**F illustrates such an approach, wherein the boxes of rays that represent each photosensor value are split by interpolating nearby box values. In the 2D ray space illustrated, each box is split into two, but in the 4D space, each box is split into four (split into two along each of its two longer sides). In some embodiments, the interpolated values are computed by ana-

lyzing the nearby values. In another embodiment, the interpolation is implemented as a weighted sum of the values of the original, unsplit boxes in a neighborhood of the desired value.

In some applications, the weighting is implemented in a manner that depends on a decision function based on the values in a neighborhood. For example, the weighting may interpolate along the axes that are least likely to contain an edge in the 4D function space. The likelihood of an edge near that value can be estimated from the magnitude of the gradient of the function values at those locations, as well as the components of the Laplacian of the function.

In another example embodiment, each of the microlenses (e.g., in the array **1920** of FIG. **19**D or similar) is tilted inwards so that their optical axes are all centered on the main lens aperture. This approach reduces aberrations in the images that form under microlenses towards the edges of the array.

Referring again to FIG. **1**, the aperture sizes of the main lens **110** and of the microlenses in the microlens array **120** (e.g., the effective sizes of the opening in the lenses) are also selected to meet specific applications in which the imaging arrangement **100** is implemented. In many applications, the relative aperture sizes are selected so that collected images are as large as possible without overlapping (i.e., such that light does not undesirably overlap onto an adjacent photosensor). This approach is facilitated by matching the f-numbers (focal ratios; i.e., the ratio of the aperture to the effective focal length of the lens) of the main lens and the microlenses. In this instance, the effective focal length, in terms of the f-number, for the main lens **110** is the ratio of the diameter of the aperture of the main lens to the distance "s" between the main lens **110** and the microlens array **120**. In applications in which the principal plane of the main lens **110** is translated relative to the plane at which the microlens array **120** is located, the aperture of the main lens is selectively modified so as to maintain the ratio and thus the size of the images forming under each microlens in the microlens array. In some applications, different main lens aperture shapes such as a square aperture are used to achieve desirable (e.g., efficient) packing of the array of images under the microlens array on the photosensor surface.

The following discussion refers to a general application of the imaging arrangement **100** of FIG. **1**, in connection with one or more example embodiments of the present invention. Considering a two-plane light field "L" inside the imaging arrangement **100**, L(u,v,s,t) denotes the light traveling along a light ray that intersects the main lens **110** at (u, v) and that intersects the plane of the microlens array **120** at (s,t). Assuming ideal microlenses in the microlens array **120** and ideal photosensors (e.g., pixels) on aligned grids in the photosensor array **130**, all the light that passes to a photosensor also passes through its square parent microlens in the microlens array **120**, and through the photosensor's conjugate square on the main lens **110**. These two square regions on the main lens **110** and microlens specify a small four-dimensional box in the light field, and the photosensor measures the total amount of light in the set of rays represented by this box. Correspondingly, each photosensor detects such a four-dimensional box in the light field; the light field detected by the photosensor array **130** thus is a box-filtered, rectilinear sampling of L(u, v,s,t).

FIG. **11** illustrates an approach to the mapping of sensor pixel locations to rays in the L(u,v,s,t) space with respect to data collected, according to another example embodiment of the invention. The approach shown in FIG. **11** and discussed herein may be applicable, for example, to FIG. **1** with each photosensor in the photosensor array **130** corresponding to a sensor pixel. Image **1170** in the bottom right is a downsampling of raw data read from a ray sensor (photosensor) **1130**, with the circular image **1150** that forms under one microlens circled. Image **1180** in the bottom left is a close-up representation of a portion of the raw data around the circled microlens image **1150**, with one photosensor value **1140** circled within the microlens image. Since this circular image **1150** is an image of the lens aperture, the location of the selected pixel within the disk provides the (u, v) coordinates of the starting position of the illustrated ray **110** on the main lens. The location of the microlens image **1150** within the sensor image **1170** provides the (x, y) coordinates of the ray **1120**.

Although the mapping of sensor elements to rays is discussed with respect to the figures (and other example embodiments), values associated with the various sensor elements are selectively represented by the value of the set of rays that is directed through optics to each particular sensor element. In the context of FIG. **1**, each photosensor in the photosensor array can thus be implemented to provide a value that represents a set of light rays directed via the main lens **110** and microlens array **120** to the photosensor. That is, each photosensor generates an output in response to the light incident upon the photosensor, and the position of each photosensor, relative to the microlens array **120**, is used to provide directional information about the incident light.

In one example embodiment, the resolution of the microlens array **120** is selected to match a particular application's desired resolution for final images. The resolution of the photosensor array **130** is selected so that each microlens covers as many photosensors as required to match the desired directional resolution of the application, or the finest resolution of photosensors that may be implemented. In this regard, the resolution of the imaging system **100** (and other systems discussed herein) is selectively tailored to particular applications, with considerations such as the type of imaging, cost, complexity and available equipment used to arrive at a particular resolution.

Once image data is captured via optics and sensors (e.g., using imaging arrangement **190** in FIG. **1**), a variety of computational functions and arrangements are implemented to selectively process the image data. In one example embodiment of the present invention, different sets of photosensors capture these separated light rays from each microlens and pass information about the captured light rays to a computational component such as a processor. Images of the scene are computed from the set of measured light rays.

In the context of FIG. **1**, sensor data processing circuitry **140** is implemented to process the image data and compute images of the scene including subjects **105**, **106** and **107**. In some applications, a preview arrangement **150** is also implemented to generate a preview image using a preview processor **160**, with the preview image displayed on a preview screen **170**. The previous processor **160** is selectively implemented with the sensor data processing circuitry **140**, with a preview image generated in a manner not inconsistent, for example, with approaches discussed below.

In another embodiment, for each pixel in an image output from a sensor arrangement, the computational component weights and sums a subset of the measured rays of light. In addition, the computational component may analyze and combine a set of images computed in the manner described above, for example, using an image compositing approach. Although the present invention is not necessarily limited to such applications, various aspects of the invention may be appreciated through the discussion of several specific example embodiments of such a computational component.

In connection with various example embodiments, image data processing involves refocusing at least a portion of an image being captured. In some embodiments, an output image is generated in the context of a photograph focused on desired elements of a particular scene. In some embodiments, the computed photograph is focused at a particular desired depth in the world (scene), with misfocus blur increasing away from the desired depth as in a conventional photograph. Different focal depths are selected to focus upon different subjects in the scene.

FIG. **12** illustrates several images **1200**-**1240** refocused at different depths, computed from a single light field measured in accordance with another example embodiment of the present invention. The approach shown in FIG. **12** may, for example, be implemented using an imaging arrangement such as that shown in FIG. **1**.

FIGS. **13**A and **13**B show a refocusing approach, according to another example embodiment of the present invention. This approach may be implemented, for example, with a computational/processor component of an imaging system, such as the sensor data processing circuitry **140** in FIG. **1**. Each output pixel (e.g., **1301**) from an imaging arrangement corresponds to a three-dimensional (3D) point (e.g., **1302**) on a virtual film plane **1310**. This virtual film plane **1310** is located behind a main lens **1330**, where the plane **1310** is optically conjugate to the desired focal plane in the world (not shown). That is, the virtual film plane **1310** is located at a position at which a film plane would desirably be located to capture a simple two-dimensional (2D) image (e.g., the position is comparable to the position at which a photographic film would be located with a conventional camera in order to capture a 2D image). By separating light by direction (e.g., using the microlens array **120** of FIG. **1**), the light arriving at the virtual film plane **1310** can be selectively computed. In this regard, the value for the output pixel **1301** is computed by summing the cone of light rays **1320** that converge on the corresponding 3D point **1302**. Values for these rays are gleaned from the data collected by the ray sensor **1350**. FIG. **13**A shows an imaging configuration in 2D for visual simplicity. In FIG. **13**B, a cone of rays **1330** from the 3D point **1340** is summed for the same pixel **1301**, with the chosen world focal depth if closer to the main lens.

In some embodiments, the required light ray values do not correspond exactly to the discrete sample locations captured by the ray sensor. In some embodiments, the light ray value is estimated as a weighted sum of selected close sample locations. In some implementations, this weighting approach corresponds to a four-dimensional filter kernel that reconstructs a continuous four-dimensional light field from the discrete sensor samples. In some implementations, this four-dimensional filter is implemented with a four-dimensional tent function corresponding to quadrilinear interpolation of the 16 nearest samples in the four dimensional space.

FIG. **35** is a process flow diagram for computing a refocused image from received light ray sensor data, according to another example embodiment of the present invention. At block **3520** a set of sub-aperture images is extracted from light ray sensor data **3510**, where each sub-aperture image consists of a single pixel under each microlens image where the pixels are at the same relative position under its microlens. At block **3530**, the set of sub-aperture images is combined to produce the final output image. The sub-aperture images are optionally translated relative to one another and composited to bring a desired plane into focus.

In another example embodiment, darkening associated with pixels near a border of an output image is mitigated. For instance, with the pixels near the border of an output image, some required rays may not have been captured in the measured light field (they may exceed the spatial or directional bounds of the imaging arrangement, such as the microlens array **120** and photosensor array **130** in FIG. **1**). For applications in which this darkening is undesirable, the pixel values are normalized by dividing a value associated with the pixels (e.g., as captured by a photosensor array) by the fraction of rays that are actually found in the measured light field.

As discussed above, a variety of different computational approaches are chosen for different applications. The following discussion addresses various such approaches. In some applications, reference is made to figures, and in other applications, the approaches are discussed generally. In each of these applications, the particular approaches may be implemented using a computational-type component, such as the sensor data processing circuitry **140** shown in FIG. **1**.

In another example embodiment, an imaging methodology for each output pixel for a particular imaging system corresponds to a virtual camera model in which a virtual film is rotated or deformed, arbitrarily and/or selectively, and a virtual main lens aperture is correspondingly moved and modified in size as appropriate. By way of example, FIG. **25** illustrates an example embodiment in which a virtual image is computed as it would have appeared on virtual film **2560** if it had been present behind a virtual lens aperture **2520** of arbitrary size on a virtual lens plane **2530** that is permitted to be non-coincident with the physical main lens plane **2510**. The value of the pixel corresponding to point **2550** on the virtual film **2560** is computed by summing the rays passing through the virtual aperture **2520** and converging on point **2550**, which are found by their intersection point and incident direction on ray sensor **2570**.

FIG. **26** shows an approach to manipulating a virtual lens plane, according to another example embodiment of the present invention. A virtual lens plane **2630** and/or virtual film plant **2660** selectively tilted, relative to a physical main lens or other reference. An image computed using this approach has a resulting world focal plane that is not parallel to the imaging plane.

In another example embodiment, as exemplified in FIG. **27**, the virtual film **2560** need not be planar, but may take any shape.

A variety of approaches involve selective implementation of different apertures. In one example embodiment, the virtual aperture on the virtual lens plane is a generally circular hole, and in other example embodiments, the virtual aperture is generally non-circular and/or is implemented with multiple distinct regions of any shape. In these and other embodiments, the notion of "virtual aperture" can be generalized, and in some applications, corresponds to an approach involving the processing of light data to correspond to light that would be received via a selected "virtual" aperture.

In various embodiments, a virtual aperture approach is implemented with a pre-determined but arbitrary function on a virtual lens plane. FIGS. **31**A-**31**D illustrate various scalar functions that are selectively implemented as the virtual aperture function in connection with one or more example embodiments. The various functions include, for example, smoothly varying values (as exemplified in FIG. **31**B), implementing a plurality of distinct regions (as exemplified in FIG. **31**A), and taking on negative values (as exemplified in FIG. **31**D). To compute the value of a point on a virtual film, all rays that start at different points on the virtual lens and converge on the point on the virtual film are weighted by the virtual aperture function and summed. In various other embodiments, the final value is computed with an arbitrary computational function that depends on the ray values. For example, the compu-

tational function may not correspond to a weighting by a virtual aperture function, but may contain discontinuous program branches depending on the value of test functions computed on the ray values.

In other example embodiments, as may be implemented in combination with the other example embodiments described herein, a method of computing output pixels is chosen independently. For example, in one example embodiment, parameters including the orientation of a virtual lens plane and the size of the virtual aperture are varied continuously for each output pixel. In another example, as illustrated in FIG. **32**, the virtual aperture function used to integrate rays for each output pixel is varied from pixel to pixel. In an output image **3200**, pixel **3201** uses virtual aperture function **3210** and pixel **3251** uses virtual aperture function **3250**.

In another example embodiment, a virtual aperture function varies from pixel to pixel. In one specific embodiment, the function is chosen to mask out rays from undesired portions of a particular scene, such as an undesired object in the foreground.

In another example embodiment, a human user chooses virtual aperture parameters interactively, with light data processed in accordance with the selections. FIG. **33** is a process flow diagram showing one such example embodiment. In the first block **3310**, the process receives data from a light ray sensor. In block **3320**, a user selects a region of an output image; in block **3330** a user selects an image formation method; and in block **3340**, the user alters parameters for the selected method and visually examines a computed image of the scene at block **3350** (for example on a computer monitor). Block **3360** checks if the user is done editing the image portion, and if not returns to block **3330**. Block **3370** checks whether the user is done choosing portions of the image to edit, and if not returns to block **3320**. If editing is complete, block **3380** saves the final edited image.

In another example embodiment, an image with extended depth of field is computed by focusing on more than one subject at the same time. In one implementation, the depth of field of the output image is extended by simulating conventional photographic imaging with a stopped-down (reduced size) main lens aperture. For each output pixel, an evaluation is performed using the rays of light that would have converged at the output pixel through an aperture (on the virtual lens plane) that is smaller than the aperture used in ray sensing.

In one implementation involving the example system **100** shown in FIG. **1**, the depth of field is extended by extracting a photosensor value under each microlens image, where each photosensor is located at the same relative position within each microlens image. With respect to FIG. **1**, extending the depth of field produces an image in which not only the subject **105** is in focus (due to the correlation between the distances "d" and "s") but also objects at a different depth, such as subjects **106** and **107**, which may otherwise be blurry due to misfocus. This approach to extending the depth of field, coupled with optional downsampling of the resulting image, is computationally efficient. This approach is selectively implemented in applications where noise generated with the image is tolerable, such as where the image generated is for preview purposes (e.g., for display at the preview screen **170** in FIG. **1**). FIG. **4**, discussed below, is further directed to approaches to the generation of a preview image.

FIGS. **14**A and **14**B illustrate an approach to computing images with different depths of field, in connection with one or more example embodiments. FIG. **14**A shows an image and close-up computed with refocusing. Note that the face in the close-up is blurry due to shallow depth of field. The middle row of FIG. **14**B shows the final image computed with an extended depth of field approach such as that described in the previous paragraph.

FIG. **8** is a process flow diagram for another computational approach to extending the depth of field in an image, according to another example embodiment of the present invention. At block **810**, a set of images refocused at all focal depths in a particular scene is refocused. At block **820** and for each pixel, a pixel is determined from a set of images that has the highest local contrast. At block **830**, the pixels having the highest local contrast are assembled into a final virtual image. With this approach, a desirable signal-to-noise ratio (SNR) can be obtained, using a relatively high number of pixels (e.g., relative to selecting a single pixel (photosensor) for each microlens in a microlens array). Referring to FIG. **14**C, the example image shown is produced using an approach similar to that described in connection with FIG. **8** and exhibits relatively low image noise.

In one alternative embodiment, a minimum set of refocused images to compute is defined as follows, in terms of the distance between a virtual film plane for each refocused image and the principal plane of the main lens via which the light for the image is passed to the virtual film plane. A minimum distance is set at the focal length of the main lens, and the maximum distance set at the conjugate depth for the closest object in the scene. The separation between each virtual film plane is no more than $\Delta x_m f/A$, where Δx_m is the width of a microlens, f is the separation between the main lens and the microlens array, and A is the width of the lens aperture.

In another example embodiment, refocused images are combined to produce an extended depth of field image at each final pixel to retain the pixel that is best focused in any of the set of refocused images. In another embodiment pixels to retain are chosen by enhancing the local contrast and coherence with neighboring pixels. For general information regarding imaging, and for specific information regarding approaches to imaging involving enhancing local contrast, reference may be made to Agarwala, A., Dontcheva, M., Agrawala, M., Drucker, S., Colburn, A., Curless, B., Salesin, D., Cohen, M., Interactive Digital Photomontage, in ACM Transactions on Graphics, 23, 3 (2004), 292-300, which is fully incorporated herein by reference.

In another example embodiment of the present invention, an extended depth of field image is computed as follows. For each output image pixel, a refocusing computation is performed at the pixel to focus at different depths. At each depth, a measure of the homogeneity of the rays that converge is computed. The depth that produces the (relative) maximum homogeneity is chosen and kept for that pixel value. With this approach, where an image pixel is in focus, all of its rays originate from the same point in the scene and thus are likely to have similar color and intensity.

Although the measure of homogeneity can be defined in various ways, for many applications, the following measure of homogeneity is used: for each color component of each ray, the squared difference of that color intensity is computed from the corresponding color component of the central ray (the ray that arrives at the pixel at an angle closest to the optical axis of the main lens). All of these squared differences are summed, and the homogeneity is taken to be the reciprocal of the sum.

FIG. **34** is a process flow diagram for extending the depth of field in an image, according to another example embodiment of the present invention. At block **3410**, a pixel is selected in a virtual image to be computed. At block **3420**, the pixel is refocused at a plurality of focal depths, and the homo-

geneity of the rays that are combined to refocus at each depth is computed. At block **3430**, the refocused pixel value associated with the highest homogeneity of rays that are combined is retained as the final output image pixel value. The process continues at block **3440** until all pixels are processed.

In another example embodiment, the above process is adapted so that the selection of final pixel values takes into account the neighboring pixel values, and the homogeneity of the associated rays that are combined to compute those pixel values.

In other example embodiments of the present invention, the depth of field is extended by focusing each pixel on the depth of the closest object in that direction. FIG. **9** is a process flow diagram for extending the depth of field in an image, according to one such example embodiment. At block **910**, a pixel is selected in a final virtual image to be computed. At block **920**, the depth of a nearest object is estimated for a light ray (or set of light rays) traced from the selected pixel into a scene through the center of the lens.

At block **930**, the selected pixel's value is computed in an image refocused at the estimated depth. If additional pixels are desirably processed at block **940**, another pixel is selected at block **910** and the process continues at block **920** for the newly-selected pixel. When no additional pixels are desirably processed at block **940**, the computed values for each selected pixel are used to create the final virtual image.

In some embodiments involving the extension of the depth of field, a value at each output pixel is computed by disregarding light rays that originate at depths closer than the depth of a desired object to mitigate or eliminate artifacts such as those generally referred to as "blooming" or "halo" artifacts around the borders of objects closer to the lens. By way of example, FIG. **23** illustrates the set of rays that pass through a desired focal point **2301** in the world on a subject of interest **2310**. Some of these rays are occluded from the main lens by object **2320**, and these correspond to the light rays **2340** that are detected by ray sensor **2350** but disregarded in computing an image value for point **2301**. In some embodiments, rays to be disregarded are detected by a mismatch with the color of the central ray. In some embodiments the resulting pixel value is normalized by dividing by the fraction of rays that are not disregarded. These embodiments may be used in isolation or combination with each other and any other embodiments, including those directed to extending the depth of field.

As discussed above, light data is processed in accordance with various example embodiments to focus and/or correct images. A variety of approaches to the latter correction approach are discussed as follows. In some of these embodiments, aberrations are corrected by tracing rays through the actual optical elements of the optics (e.g., lens or lenses) used in capturing the rays, and mapping the traced rays to particular photosensors capturing the light. Light data is rearranged, using knownd defects exhibited by the optics as well as the known position of the sensors detecting the light.

In one correction-type embodiment, the world of rays that contribute to each pixel as formed through idealized optics is computed for each pixel on a film of a synthesized photograph. In one implementation, these rays are computed by tracing rays from the virtual film location back through the ideal optics into the world. FIG. **15** illustrates an approach to the tracing of rays from a 3D point **1501** on a virtual film plane **1510** through an ideal thin main lens **1520** out into a cone of world rays **1530**, in connection with one such example embodiment. In some implementations, the set of desired rays **1525** may not necessarily correspond to direction through a real lens, but may correspond to any set of rays that are to be weighted and summed to produce a desired image value.

FIG. **16** shows an approach to finding the value of light traveling along ideal rays for a particular application, in connection with another example embodiment. These values are computed by tracing desired ideal world rays **1630** through a real main lens **1650**, having a single element with spherical interfaces, used to physically direct the real world light rays to the ray sensor **1640** at the time the rays are measured (detected). In this embodiment, the rays that ideally converge to a single 3D point (**1601**) do not converge, representing a defect of lenses with spherical interfaces called spherical aberration. The ray sensor **1640** provides individual values for each of the aberrated rays (such as **1651**), which are used to correct for the spherical aberration.

FIGS. **17A-17C** illustrate example results using a computer simulation with an approach to lens correction. The image in FIG. **17A** is an ideal 512×512 photograph (as seen through perfect optics). The image in FIG. **17B** is an image that would be produced with a real f/2 bi-convex spherical lens, which has loss in contrast and blurring. The image in FIG. **17C** is a photograph computed using an approach to image correction described above, using an optics and sensor arrangement facilitating 10×10 directional (u, v) resolution at each of 512×512 microlenses.

In another example embodiment of the present invention, chromatic aberrations are corrected in a main lens used to capture an image. Chromatic aberration is caused by the divergence of rays of light as they are physically directed through optics because of differences in the physical direction dependent on the wavelength of light. The incoming rays are traced through the actual optics, taking into account the wavelength-dependent refraction of light that occurs in the actual optics. In some applications, each color component of the system is traced separately based on the primary wavelength.

In another example embodiment, each of the red, green and blue components common in color imaging systems is traced separately, as illustrated in FIG. **18A**. The green world light rays are computationally traced back into the imaging system to produce green rays **1830**, and to determine where they intersect a color ray sensor **1810** and at what direction they intersect the color ray sensor **1810**. Similarly, FIG. **18B** illustrates computationally tracing the desired blue world light rays **1820**, which are refracted to a greater extent than the green light rays. FIG. **18C** illustrates computationally tracing the desired red world light rays **1830**, which are refracted to a lesser extent than the green light rays. The values for each ray are computed from the values from the ray sensor **1810** using, for example, approaches discussed in connection with other example embodiments described herein. The light field values for each ray are integrated to calculate the corrected image value for each particular film pixel. For some applications, chromatic aberration is ameliorated by refocusing each color channel on the plane at which its wavelengths best come into focus.

The desired light rays may not converge exactly on one of the discrete ray values sampled by the ray sensor. In some embodiments, the value to be used for such rays is computed as a function of the discrete ray values. In some embodiments, this function corresponds to a weighted sum of the value of discrete rays in a neighborhood of the desired light ray. In some implementations, this weighted sum corresponds to a 4D convolution of the discrete sample values with a predetermined convolution kernel function. In other implementations, the weighting may correspond to a quadrilinear interpolation from the 16 nearest neighbors. In still other

implementations, the weighting may correspond to a cubic or bicubic interpolation from the 16 nearest neighbors.

It is worth noting that example correction processes have been described in terms of ray-tracing for conceptual simplicity; a variety of other approaches are implemented with correction. In one embodiment, for each desired output pixel, the set of photosensor values that contribute are pre-computed along with their relative weights. As described above, these weights are a property of a number of factors that may include the optics, sensor, desired set of rays to be weighted and summed for each output pixel and desired light field reconstruction filter. These weights are pre-computed, selectively using ray-tracing, and stored. A corrected image is formed by weighting and adding the appropriate sensed light field values for each output pixel.

FIG. **29** and FIG. **30** illustrate other example embodiments for use in connection with the above correction approach. FIG. **29** is a process flow diagram for pre-computing a database of weights associated with ray (light) sensors and an output pixel value associated with each ray sensor. In the first two blocks **2910** and **2920**, a data set (e.g., in a database) is received for a desired image formation process consisting (for each output image pixel) of a set of ideal world light rays to be summed to produce an output image pixel value, and a specification for real main lens optics used to physically direct light rays to a light ray sensor. At block **2925**, an image pixel is chosen. For the output value of this pixel, the associated set of world rays is computationally traced at block **2930** through a virtual representation of the main lens optics to the ray sensor. This results in a set of weights to be applied to each ray sensor value to compute the output pixel value. These values are stored in an output database in block **2940**. Block **2950** checks whether all pixels have been processed, returning to block **2925** if not. If all pixels have been processed, the final block **2960** saves the completed database.

FIG. **30** is a flow diagram for a process that computes an output image using a database of weights that may have been computed by a process as in FIG. **29**. In block **3010** and **3020**, the process receives the database and a set of ray sensor values captured with the main lens optics used in computing the database. At block **3025**, a pixel in the output image is selected, so that its final image value may be computed. For the selected pixel, block **3030** uses the database to find the set of ray sensor that contributes and their weights. In block **3040**, each sensor value given in **3020** is weighted and added to a sum for that image pixel value. At block **3050**, a check is performed to see whether all image pixels have been processed. If not, the process returns to block **3025**, and if so, the output image is saved at block **3060**.

In a variety of example embodiments, light data is processed in the frequency domain, with certain approaches directed to computational approaches to refocusing that operate in the Fourier domain. FIG. **20** is a flow diagram illustrating one such approach, in connection with another example embodiment. The input to the algorithm is a discrete 4D light field **2010**, which we will refer to as L(s,t,u,v), representing the ray starting at (u, v) on a main lens and terminating at (s, t) on a microlens plane (e.g., from the main lens **110** and terminating at a plane of the microlens array **120** of FIG. **1**). The first step is to compute the discrete 4D Fourier transform **2020** of the light field. The 4D Fourier transform value at (k_s, k_t, k_u, k_v), let us call this value M(k_s, k_t, k_u, k_v) is defined by the following equation:

$$M(k_s,k_t,k_u,k_v)=\iiiint L(s,t,u,v)\exp(-2\pi\sqrt{-1}\cdot(sk_s+tk_t+uk_u+vk_v))dsdtdudv. \quad (1)$$

where the exp function is the exponential function, $\exp(x)=e^x$. In some embodiments the discrete light field is sampled on a rectilinear grid in the 4D space, and the Fourier transform is computed with the Fast Fourier Transform (FFT) algorithm.

The next step, which is executed once for each depth at which we wish to refocus the image, is to extract appropriate 2D slices **2030** of the 4D Fourier transform, and compute the inverse 2D Fourier transforms of the extracted slices, which are photographs focused at different depths **2040**. The inverse 2D Fourier transform, g(x, y), for a function $G(k_x, k_y)$ is defined by the following equation:

$$g(x,y)=\iint G(k_x,k_y)\exp(2\pi\sqrt{-1}\cdot(xk_x+yk_y))dk_xdk_y. \quad (2)$$

The values on the extracted 2D slice are determined by the depth at which we want to refocus. Considering the conjugate plane (on the image-side of the lens) for the desired world focal plane, when the separation between this conjugate plane and the main lens is D and the separation between the microlens plane and the main lens is F, then the value of the extracted 2D slice at coordinates (k_x,k_y) is given by

$$G(k_x,k_y)=1/F^2\cdot M(k_x(1-D/F),k_y(1-D/F),k_xD/F,k_yD/F). \quad (3)$$

Using various approaches, artifacts that result from discretization, resampling and Fourier transformation are selectively ameliorated. In general signal-processing terms, when we sample a signal it is replicated periodically in the dual domain. When we reconstruct this sampled signal with convolution, it is multiplied in the dual domain by the Fourier transform of the convolution filter. In this regard, the original, central replica is isolated, eliminating all other replicas. A desirable filter is a 4D sinc function, sinc(s)sinc(t)sinc(u)sinc(v), where $\mathrm{sinc}(x)=\sin(\pi x)/(\pi x)$; however, this function has infinite extent.

In various approaches, finite-extent filters are used with frequency-domain processing; such filters may exhibit defects, which are selectively mitigated. FIG. **21**A illustrate these defects with respect to a specific 1D filter, with corresponding discussion below directed to mitigation or such defects. FIG. **21**A represents a triangle filter approach implemented with in linear interpolation in 1D (or as the basis for a 4D quadrilinear filter). FIG. **21**B shows the Fourier transform of the triangle filter approach, which is not of unit value within the band-limit (see **2010**), and which gradually decays to smaller fractional values as the frequency increases. In addition, the filter is not truly band-limited, containing energy at frequencies outside the desired stop-band (**2020**).

The first defect described above leads to "rolloff artifacts," which can lead to a darkening of the borders of computed photographs. Decay in the filter's frequency spectrum with increasing frequency means that the spatial light field values, which are modulated by this spectrum, also "roll off" to fractional values towards the edges.

The second defect described above involves aliasing artifacts in computed photographs, which are related to energy at frequencies above the band-limit. The non-zero energy that extends beyond the band-limit means that the periodic replicas are not fully eliminated, leading to two kinds of aliasing. First, the replicas that appear parallel to the slicing plane appear as 2D replicas of the image encroaching on the borders of the final photograph. Second, the replicas positioned perpendicular to this plane are projected and summed onto the image plane, creating ghosting and loss of contrast.

In an example embodiment, correction for rolloff-type defects as described above is eliminated by multiplying the input light field by the reciprocal of the filter's inverse Fourier spectrum, to nullify the effect introduced during resampling. In this example embodiment, multiplication is performed

prior to taking the 4D Fourier transform in the pre-processing step of the algorithm. While it corrects rolloff error, pre-multiplication may accentuate the energy of the light field near its borders, maximizing the energy that folds back into the desired field of view as aliasing.

Three methods of suppressing aliasing artifacts—oversampling, superior filtering and zero-padding—are used individually or in combination in various example embodiments described below. Oversampling within the extracted 2D slice increases the replication period in the spatial domain. This means that less energy in the tails of the in-plane replicas will fall within the borders of the final photograph. Increasing the sampling rate in one domain leads to an increase in the field of view in the other domain. Aliasing energy from neighboring replicas falls into these outer regions, which is cropped away to isolate the original, central image of interest.

Another approach to mitigating aliasing is directed to a finite-extent filter that approximates a perfect spectrum (as would be exhibited via use of an ideal filter) as closely as possible. In an example embodiment, a 4D Kaiser-Bessel separable function, kb4(s,t,u,v)=kb(s)kb(t)kb(u)kb(v), is used as the filter, where

$$kb(x)=1/W\cdot I_0(P\sqrt{1-(2x/W)^2}) \quad (4)$$

In this equation, I_0 is the standard zero-order modified Kaiser-Bessel function of the first kind, W is the width of the desired filter, and P is a parameter that depends on W. In this example embodiment, W values are 5, 4.5, 4.0, 3.5, 3.0, 2.5, 2.0 and 1.5, and the P values are, respectively, 7.4302, 6.6291, 5.7567, 4.9107, 4.2054, 3.3800, 2.3934, and 1.9980. For general information regarding aliasing, and for specific information regarding approaches to mitigating aliasing in connection with one or more example embodiments of the present invention, reference may be made to Jackson J. I., Meyer C. H., Nishimura, D. G. and Macovski, A., 1997, Selection of convolution function for Fourier inversion using gridding. IEEE Transactions on Medical Imaging, 10, 3, 473-478, which is fully incorporated herein by reference. In one implementation, widths "W" of less than about 2.5 are implemented to achieve desirable image quality.

In another example embodiment, aliasing is mitigated by padding a light field with a small border of zero values before pre-multiplication and taking its Fourier transform. This pushes energy slightly further from the borders, and minimizes the amplification of aliasing energy by the pre-multiplication for rolloff correction.

FIG. **22** is a flow diagram showing an approach to refocusing in the frequency domain using various corrections described above, according to another example embodiment of the present invention. At block **2210**, a discrete 4D light field is received. In the pre-processing phase, which occurs once per input light field, block **2215** checks if aliasing reduction is desired, and if so executes block **2220**, which pads the light field with a small border (e.g., 5% of the width in that dimension) of zero values. At block **2225** a check is performed to determine whether rolloff correction is desired, and if so, the light field is modulated at block **2230** by the reciprocal of the Fourier transform of the resampling filter. In the final block of the pre-processing phase, the 4D Fourier transform of the light field is computed at block **2240**.

In the refocusing phase, which occurs once per desired focal depth, the process receives a desired focal depth of refocused image at block **2250**, such as through the direction of a user. At block **2260**, a check is performed to determine whether aliasing reduction is desired. If not, block **2270** extracts a 2D slice of the Fourier transform of the light field, with a desired 4D rsampling filter, where the trajectory of the 2D slice corresponds to the desired focal depth; and block **2275** computes an inverse 2D Fourier transform of the extracted slice and moves to block **2290**. If aliasing reduction was desired at block **2260**, the process moves to block **2280**, at which a 2D slice with desired 4D resampling filter and oversampling (e.g. 2× oversampling in each of the two dimensions) is extracted. At block **2283**, the slice's inverse 2D Fourier transform is computed, and the resulting image is cropped to the original size without oversampling at block **2286**, after which the process moves to block **2290**. At block **2290**, a check is performed to determine whether refocusing is complete. If not, another focal depth is chosen at block **2250** and the process proceeds as described above. If refocusing is complete, the process exits at block **2295**.

The asymptotic computational complexity of this frequency-domain algorithm is less than refocusing by explicitly summing rays as described for the alternate embodiment above. Assume that the input discrete light field has N samples in each of its four dimensions. Then the computational complexity of the algorithm that explicitly sums rays is $O(N^4)$ for refocusing at each new depth. The computational complexity of the frequency-domain algorithm is $O(N^2 \log N)$ for refocusing at each new depth, dominated by the cost of the inverse 2D Fourier transform. However, the pre-processing step costs $O(N^4 \log N)$ for each new light field dataset.

In another example embodiment, the captured light rays are optically filtered. Although not limited to such applications, some examples of such filters are neutral density filters, color filters, polarizing filters. Any filter currently existing or that may be developed in the future may be used to effect a desired filtering of the rays of light. In one implementation, the light rays are optically filtered in groups or individually, so that each group or individual ray is filtered differently. In another implementation, a filtering is applied by the use of a spatially-varying filter attached to a main lens. In one example application, a gradient filter such as a neutral-density gradient filter is used to filter light. In another implementation, spatially varying filters are used in front of one or more of a ray sensor, a microlens array or a photosensor array. Referring to FIG. **1** by way of example, one or more such filters are selectively placed in front of one or more of the main lens **110**, microlens array **120** and photosensor array **130**.

In another example embodiment of the present invention, a computational component such as a processor is programmed to selectively choose rays to combine in computing output pixels in order to effect a desired net filtering for that pixel value. By way of example, consider embodiments involving an optical neutral gradient density filter at the main lens, each image of the lens aperture that appears under a microlens is weighted by the filter gradient across its extent. In one implementation, output images are computed by selecting a photosensor under each microlens at the point of the gradient that matches the desired level of neutral-density filtering for that output image pixel. For example, to produce an image in which every pixel is filtered to a large extent, every pixel value is set to the value of the photosensor under the corresponding microlens that is at the extreme end of the gradient corresponding to maximum filtering.

FIG. **2** is a data-flow diagram showing an approach to processing images in connection with other example embodiments of the present invention. An image sensor arrangement **210** collects image data using microlens/photosensor chip arrangement **212** in a manner similar, for example, to the microlens array **120** and photosensor array **130** shown in FIG. **1** and described above. The image sensor arrangement **210**

optionally includes an integrated processing circuit **214** bearing certain processing circuitry to prepare collected image data for transfer.

Sensor data created at the image sensor arrangement **210** is passed to a signal processor **220**. The signal processor includes a low-resolution image processor **222** and one or both of a compression processor **224** and a (light) ray-direction processor **226**; each of these processors is selectively implemented separately or functionally with a common processor, depending upon the application. Furthermore, each of the processors shown in FIG. **2** is selectively programmed with one or more processing functions described in connection with other figures or elsewhere herein. The signal processor **220** is optionally implemented in a common device or component with the image sensor arrangement **210**, such as on a common circuit and/or in a common image device.

The low-resolution image processor **222** uses sensor data received from the image sensor arrangement **210** to generate low-resolution image data, which is sent to a viewfinder display **230**. An input device **235**, such as a pushbutton on a camera or video camera, sends an image capture request to the signal processor **220** requesting, for example, the capture of a particular image displayed in the viewfinder display **230** and/or to initiate video imaging where so implemented.

In response to the image capture request or as otherwise directed, the signal processor **220** uses the sensor data captured by the image sensor arrangement **210** to generate processed sensor data. In some applications, the compression processor **224** is implemented to generate compressed raw data for transfer to a data storage arrangement **240** (e.g., memory). Such raw data is then selectively processed at the signal processor **220** and/or at an external computer **260** or other processing device, implementing ray-direction processing such as that implemented with the ray-direction processor **226**, which is discussed further below.

In certain applications, the ray-direction processor **226** is implemented to process the sensor data received at the signal processor **220** to rearrange the sensor data for use in generating focused and/or corrected image data. The ray-direction processor **226** uses one or both of sensor data received from the image sensor arrangement **210** and raw data sent to the data storage arrangement **240**. In these applications, the ray-direction processor **226** uses ray-mapping characteristics of the particular imaging device (e.g., camera, video camera or mobile telephone) in which the image sensor arrangement **210** is implemented to determine a rearrangement of light rays sensed with the microlens/photosensor chip **212**. Image data created with the ray-direction processor **226** is sent to the data storage arrangement **240** and/or to a communication link **250** for use in a variety of applications, such as in streaming image data or otherwise sending image data to a remote location.

In some applications, the integrated processing circuit **214** includes some or all of the processing functionality of the signal processor **220** by implementing, for example, a CMOS-type processor or other processor with appropriate functionality. For instance, the low-resolution image processor **222** is selectively included with the integrated processing circuit **214**, with the low-resolution image data sent directly to the viewfinder display **230** from the image sensor arrangement **210**. Similarly, the compression processor **224**, or functionality similar thereto, is selectively implemented with the integrated processing circuit **214**.

In some applications, computation of final images may be performed on the integrated processing circuit **214** (e.g. in some digital still cameras that output only final images). In other applications, the image sensor arrangement **210** may simply transmit the raw light ray data, or a compressed version of these data, to an external computational device, such as a desktop computer. Computation of final images from these data is then performed on the external device.

FIG. **3** is a flow diagram for a method for processing image data, according to another example embodiment of the present invention. At block **310**, image data is captured at a camera or other imaging device, using a main lens or a lens stack with a microlens/photosensor array such as that shown in FIG. **1**. If a preview image is desired at block **320**, the preview image is generated at block **330** using, for example, a viewfinder or other type of display. The preview image is displayed, for example, in a viewfinder of a camera or video camera, using a subset of the captured image data.

Raw data from the photosensor array is processed and compressed for use at block **340**. Light ray data is extracted from the processed and compressed data at block **350**. This extraction involves, for example, detecting a bundle or set of light rays incident upon a particular photosensor in the photosensor array. Ray mapping data is retrieved at block **360** for the imaging arrangement in which the image data is captured. The ray-mapping data and the extracted light ray data is used to synthesize a re-sorted image at block **370**. For example, the extraction, mapping and synthesis blocks **350-370** are selectively implemented by determining a bundle of light rays for a particular pixel of a scene for which the light rays were collected, and integrating the energy of the light rays to synthesize a value for the particular pixel. In some applications, the ray mapping data is used to trace light rays for each particular pixel through actual lenses used to acquire the image data. For example, by determining an appropriate set of rays to add together in order to focus upon a selected subject at a particular focal depth at block **370**, the rays can be re-sorted to arrive at a focused image. Similarly, by determining a proper arrangement of rays to correct for conditions such as lens aberrations in the imaging device, the rays can be re-sorted to generate an image relatively free of characteristics relating to the aberrations or other condition.

A variety of approaches are selectively used to generate preview images for camera-type and other applications. FIG. **4** is a process flow diagram for generating such a preview image, according to another example embodiment of the present invention. The approach shown in FIG. **4** and discussed below may be implemented, for example, in connection with the generation of a preview image at block **330** of FIG. **3**.

A preview instruction with raw sensor image data is received at block **410**. At block **420**, a center pixel is selected from each microlens image in the raw sensor image data. The selected center pixels are collected to form a high depth-of-field image at block **430**. At block **440**, the high depth-of-field image is downsampled to a resolution amenable for use in a viewfinder display. Referring to FIG. **2** by way of example, such downsampling is selectively performed at one or more of the image sensor arrangement **210** or the signal processor **220**. The generated preview image data is sent to the viewfinder display at block **450**, and at block **460**, the viewfinder displays an image with the preview image data.

FIG. **5** is a process flow diagram for processing and compressing image data, according to another example embodiment of the present invention. The approach shown in FIG. **5** and discussed below may be implemented, for example, in connection with the processing and compressing of image data at block **340** of FIG. **3**. When implemented with an arrangement as shown in FIG. **2**, the approach shown in FIG. **5** may, for example, be implemented at one or both of the image sensor arrangement **210** and the signal processor **220**.

At block **510**, raw image data is received from a sensor array. If coloring is desired at block **520**, color filter array values are demosiaced at block **530** to produce color at the sensors. If rectification and alignment is desired at block **540**, microlens images are rectified and aligned with the photosensor array at block **550**. If interpolation is desired at block **560**, pixel values are interpolated at block **570** to an integral number of pixels associated with each microlens. At block **580**, the processed raw image data is compressed and presented for synthesis processing (e.g., to form a refocused and/or corrected image).

FIG. **6** is a process flow diagram for image synthesis, according to another example embodiment of the present invention. The approach shown in FIG. **6** and discussed below may be implemented, for example, in connection with the image synthesis approach shown at block **370** of FIG. **3** and discussed further below.

At block **610**, raw image data is received from a photosensor array. If refocusing is desired at block **620**, image data is refocused at block **630** using, e.g., approaches discussed herein for selectively re-sorting light represented by the raw image data. If image correction is desired at block **640**, image data is corrected at block **650**. In various applications, image correction at block **650** is carried out before or concurrently with refocusing at block **630** in applications where both refocusing and image correction is desirable. A resultant image is generated at block **660** using processed image data including refocused and corrected data, where applicable.

FIG. **7**A is a process flow diagram for image refocusing with a lens arrangement, according to another example embodiment of the present invention. The approach shown in FIG. **7** and discussed below may be implemented, for example, in connection with the refocusing of image data at block **630** in FIG. **6**.

At block **710**, a virtual focal plane for refocusing an image portion is selected. At block **720**, a pixel of a virtual image for the virtual focal plane is selected. If correction (e.g., for lens aberration) is desired at block **730**, the value of a virtual light ray (or virtual set of light rays) passing between the selected pixel and each particular lens position is calculated at block **740**. In one application, this calculation is facilitated by computing the conjugate light ray that would fall upon the selected pixel and tracing that ray through the path in the lens arrangement.

At block **750**, the sum of light ray (or virtual set of light ray) values for each lens position for the particular focal plane are added to determine a total value for the selected pixel. In some applications, the sum added at block **750** is a weighted sum, wherein certain light rays (or set of light rays) are given greater weight than others. If there are additional pixels for refocusing at block **760**, another pixel is selected at block **720** and the process continues until no further pixels are desirably refocused. After the pixels have been refocused, the pixel data is combined at block **770** to generate a refocused virtual image at the virtual focal plane selected in block **710**. The refocusing approaches involving some or all of blocks **720**, **730**, **740** and **750** in FIG. **7** are carried out via more specific functions for a variety of applications.

The sensor data processing circuitry implemented with one or more example embodiments described herein includes one or more microprocessors, Application-Specific Integrated Circuits (ASICs), digital signal processors (DSPs), and/or programmable gate arrays (for example, field-programmable gate arrays (FPGAs)), depending upon the implementation. In this regard, sensor data processing circuitry may be any type or form of circuitry whether now known or later developed. For example, the sensor data processing circuitry may include a single component or a multiplicity of components (microprocessors, ASICs and DSPs), either active and/or passive, which are coupled together to implement, provide and/or perform a desired operation/function/application.

In various applications, the sensor data processing circuitry performs or executes one or more applications, routines, programs and/or data structures that implement particular methods, tasks or operations described and/or illustrated herein. The functionality of the applications, routines or programs are selectively combined or distributed in certain applications. In some applications, the applications, routines or programs are implemented by sensor (or other) data processing circuitry using one or more of a variety of programming languages, whether now known or later developed. Such programming languages include, for example, FORTRAN, C, C++, Java and BASIC, whether compiled or uncompiled code, selectively implemented in connection with one or more aspects of the present invention.

The various embodiments described above are provided by way of illustration only and should not be construed to limit the invention. Based on the above discussion and illustrations, those skilled in the art will readily recognize that various modifications and changes may be made to the present invention without strictly following the exemplary embodiments and applications illustrated and described herein. For instance, such changes may include implementing the various optical imaging applications and devices in different types of applications, increasing or decreasing the number of rays collected per pixel (or other selected image area), or implementing different algorithms and/or equations than the examples described to assemble or otherwise process image data. Other changes may involve using coordinate representations other than or in addition to Cartesian coordinates, such as polar coordinates. Such modifications and changes do not depart from the true spirit and scope of the present invention.

What is claimed is:

1. A method for digitally imaging a scene, the method comprising: generating photosensor image data in response to detecting light rays incident on a physical focal plane using a photosensor array, having a plurality of photosensors, wherein the plurality of photosensors simultaneously detect the light rays from the scene that are incident on a microlens array and passed to different locations on the physical focal plane; determining an angle of incidence of the light rays incident at different locations on the physical focal plane using the photosensor image data; and generating a virtual output image which corresponds to the scene by selectively combining the photosensor image data based on the angle of incidence of the light rays, such that at least a selected portion of the image is refocused via the selective combination of photosensor image data representing different ones of the light rays.

2. The method of claim **1**, wherein generating a virtual an output image comprises forming an image having at least a portion thereof focused at a virtual focal plane that is different than the physical focal plane.

3. The method of claim **2**, wherein generating a virtual output image further comprises:

determining a set of light rays from the detected light rays that make up the at least a portion of the image focused at a virtual focal plane that is different than the physical focal plane; and

combining the determined set of light rays to form the portion of the output image focused at the virtual focal plane.

4. The method of claim 1, wherein combining the determined set of light rays further comprises correcting for conditions of optics used in detecting the light.

5. The method of claim 1, wherein combining the determined set of light rays further comprises correcting for lens aberration.

6. A digital imaging system for generating a virtual image of a scene, wherein the virtual image includes a plurality of pixels, the system comprising:

a photosensor array, having a plurality of photosensors, configured to detect light including a plurality of light rays from the scene, wherein each photosensor, in response to detecting the light incident thereon, generates light data, the photosensor array further configured to detect a set of the plurality of light rays that concurrently arrive at the particular portion of the physical focal plane at different angles of incidence;

an optics arrangement, having a physical focus, configured to direct light rays from the scene to the photosensor array via a physical focal plane; and

processing circuitry to compute a pixel value of each pixel of the virtual image by combining light data from selected photosensors based on angles of incidence of the light rays detected by each photosensor, as characterized by the location of each photosensor relative to the physical focal plane, the virtual image having a virtual focus and a virtual focal plane that are respectively different from the physical focus and the physical focal plane.

7. The system of claim 6, wherein the optics arrangement includes a microlens array, the microlens array including a plurality of microlenses, each microlens being configured to separate light rays incident upon the microlens and to direct the separated rays to a predetermined plurality of photosensors in the photosensor array.

8. The system of claim 7, wherein the processing circuitry further determines the angles of incidence of light upon each photosensor using a position of each photosensor relative to the microlens.

9. The system of claim 6, wherein the processing circuitry further determines a focus depth of a subject in the scene from which the light rays emanate, and uses the focus depth and the angles of incidence to compute the virtual image focused upon a virtual focal plane that is different from the physical focal plane.

10. The system of claim 6, wherein the processing circuitry is further configured to:

determine an angle of incidence of the detected light rays as characterized by the location of each photosensor detecting the light, and

map a path of the detected light rays through the system using the angles of incidence of the detected light rays.

11. The system of claim 6, wherein the optics arrangement includes a microlens array having a plurality of microlenses, each microlens being associated with a plurality of the photosensors and configured to direct light rays from the optics arrangement onto the associated plurality of photosensors.

12. The system of claim 6, wherein the processing circuitry is configured to combine the light data from selected photosensors based on data indicative of a virtual focal plane and the angles of incidence of the light rays detected by each photosensor, to generate a virtual image of the scene having the virtual focus at the virtual focal plane.

13. The system of claim 6, wherein:

the optics arrangement is configured to project light from the scene onto the physical focal plane with a physical depth of field, and

the processing circuitry is configured to generate the virtual image of the scene by combining light data from selected photosensors, based on a selected virtual depth of field and the angles of incidence of the light rays detected by each photosensor, to generate a virtual image of the scene having the selected virtual depth of field, the selected virtual depth of field being different from the physical depth of field.

14. The system of claim 6, wherein:

the optics arrangement is configured to project light from the scene onto the physical focal plane with a physical depth of field, and

the processing circuitry is configured to generate the virtual image of the scene by combining light data from selected photosensors, based on a selected virtual depth of field and the angles of incidence of the light rays detected by each photosensor, to provide a virtual image of the scene having the selected virtual depth of field, the selected virtual depth of field being greater than the physical depth of field.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO.	: 7,936,392 B2
APPLICATION NO.	: 11/576438
DATED	: May 3, 2011
INVENTOR(S)	: Ng et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 25, line 1 and line 4, the claim reference numeral "1", each occurrence, should read -3-.

Signed and Sealed this
First Day of May, 2012

David J. Kappos

David J. Kappos
Director of the United States Patent and Trademark Office

US007738015B2

(12) **United States Patent**
Steinberg et al.

(10) **Patent No.: US 7,738,015 B2**
(45) **Date of Patent: *Jun. 15, 2010**

(54) **RED-EYE FILTER METHOD AND APPARATUS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1230 days.

This patent is subject to a terminal disclaimer.

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Related U.S. Application Data

(63) Continuation-in-part of application No. 10/772,767, filed on Feb. 4, 2004, now Pat. No. 7,352,394, which is a continuation-in-part of application No. 10/635,862, filed on Aug. 5, 2003, now Pat. No. 7,630,006, which is a continuation-in-part of application No. 10/170,511, filed on Jun. 12, 2002, now Pat. No. 7,042,505, which is a continuation of application No. 08/947,603, filed on Oct. 9, 1997, now Pat. No. 6,407,777.

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(52) **U.S. Cl.** **348/223.1**; 348/224.1; 396/158; 382/117

(58) **Field of Classification Search** 348/223, 348/224; 382/117, 260, 275
See application file for complete search history.

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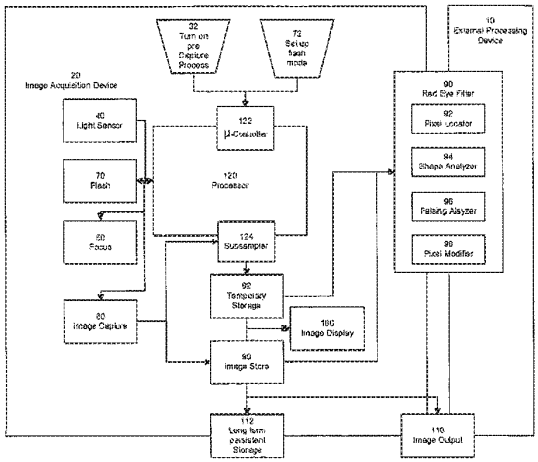
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(57) **ABSTRACT**

A digital image acquisition system having no photographic film, such as a digital camera, has a flash unit for providing illumination during image capture and a red-eye filter for detecting a region within a captured image indicative of a red-eye phenomenon, the detection being based upon a comparison of the captured image and a reference image of nominally the same scene taken without flash. In the embodiment the reference image is a preview image of lower pixel resolution than the captured image, the filter matching the pixel resolutions of the captured and reference images by up-sampling the preview image and/or sub-sampling the captured image. The filter also aligns at least portions of the captured image and reference image prior to comparison to allow for, e.g. movement in the subject.

35 Claims, 10 Drawing Sheets



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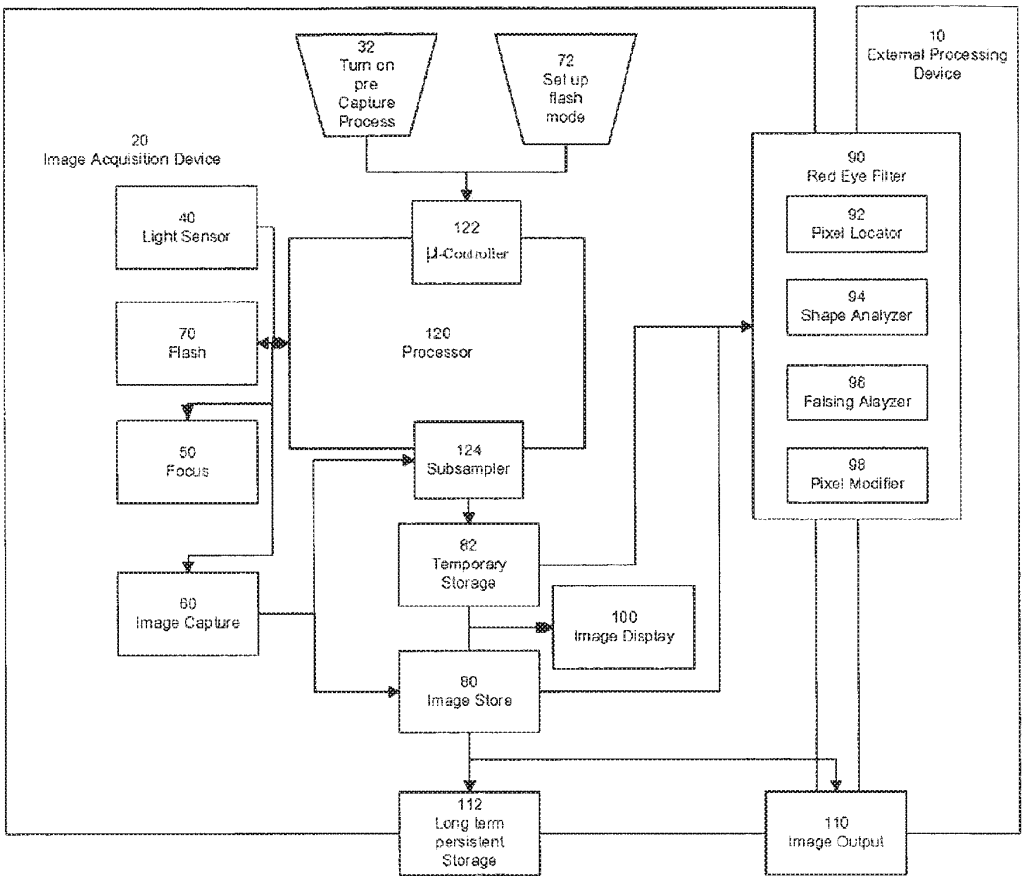

32
Turn on pre Capture Process
72
Set up flash mode
10
External Processing Device
20
Image Acquisition Device
90
Red Eye Filter
92
Pixel Locator
94
Shape Analyzer
96
Falsing Alayzer
98
Pixel Modifier
40
Light Sensor
122
µ-Controller
70
Flash
120
Processor
50
Focus
124
Subsampler
82
Temporary Storage
60
Image Capture
100
Image Display
80
Image Store
112
Long term persistent Storage
110
Image Output

Figure 1

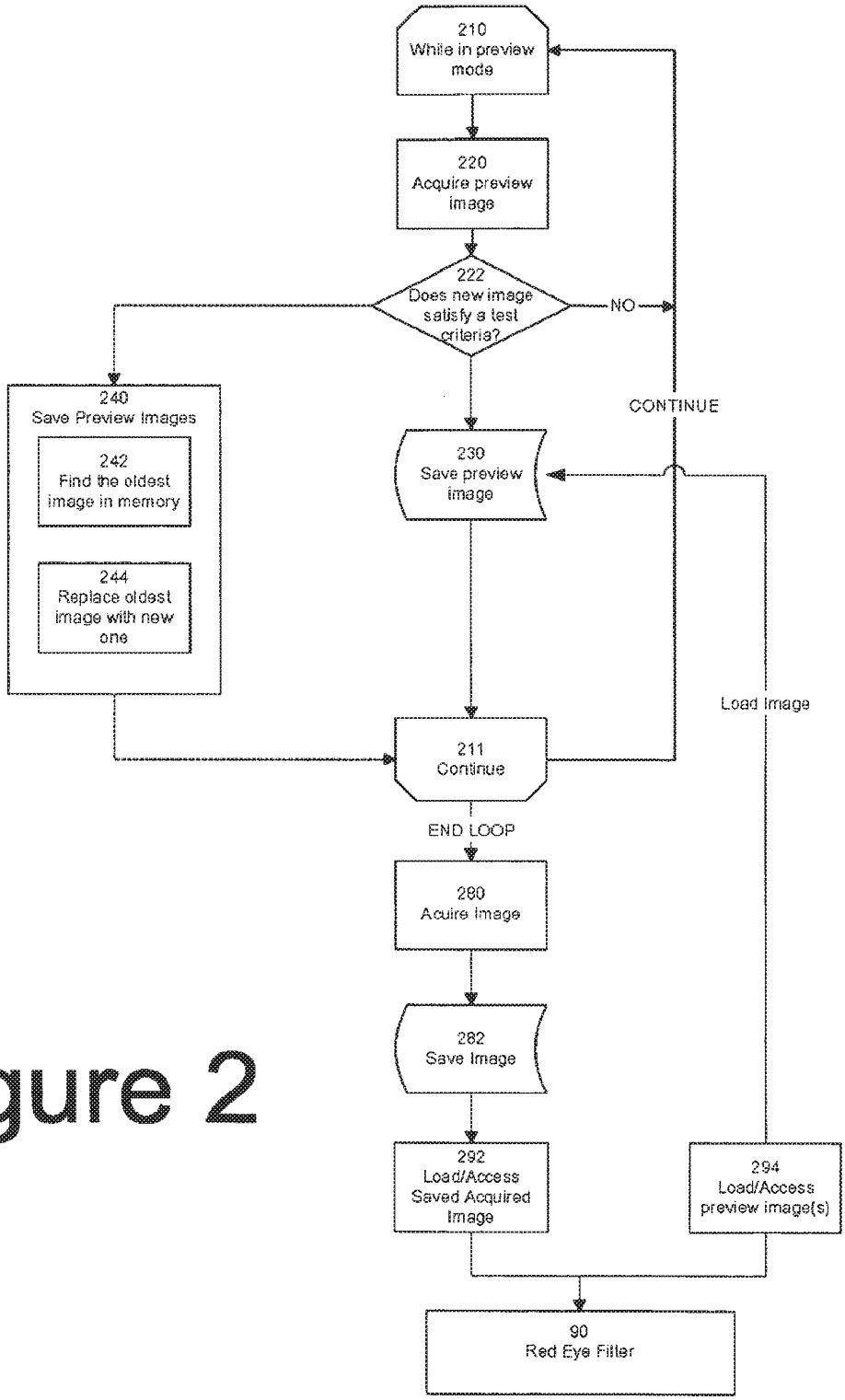

210
While in preview mode
220
Acquire preview image
222
Does new image satisfy a test criteria?
NO
CONTINUE
240
Save Preview Images
242
Find the oldest image in memory
244
Replace oldest image with new one
230
Save preview image
Load Image
211
Continue
END LOOP
280
Acuire Image
282
Save Image
292
Load/Access Saved Acquired Image
294
Load/Access preview image(s)
90
Red Eye Filter

Figure 2

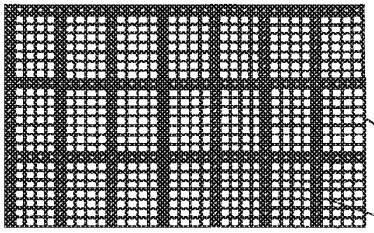


Figure 3-a

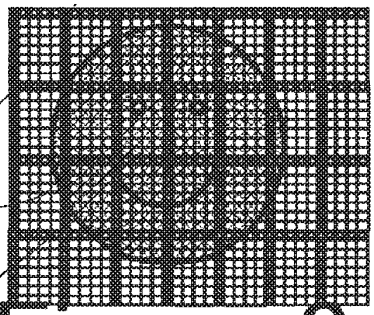


Figure 3-b

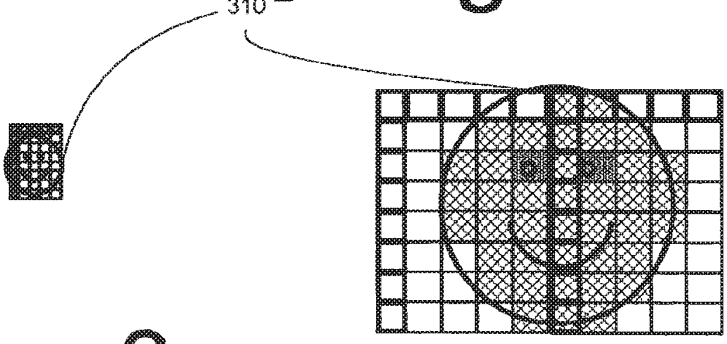


Figure 3-c

Figure 3-d

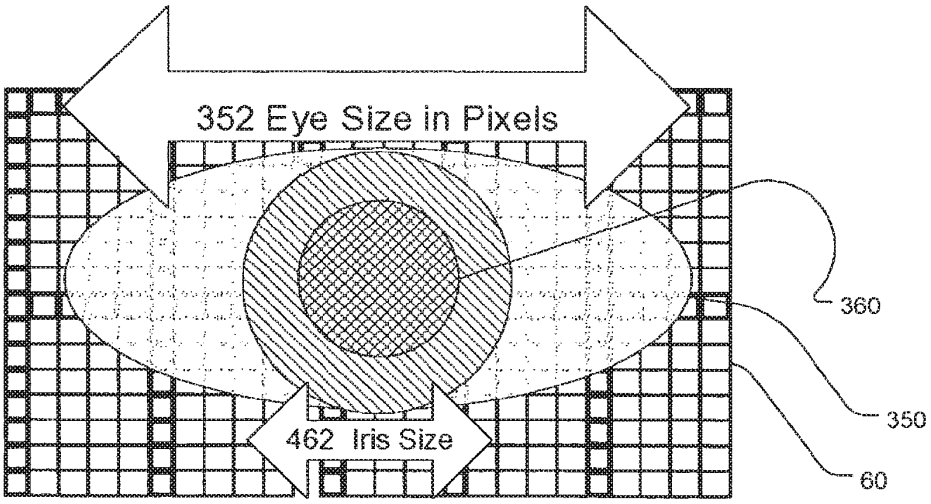


Figure 3-e

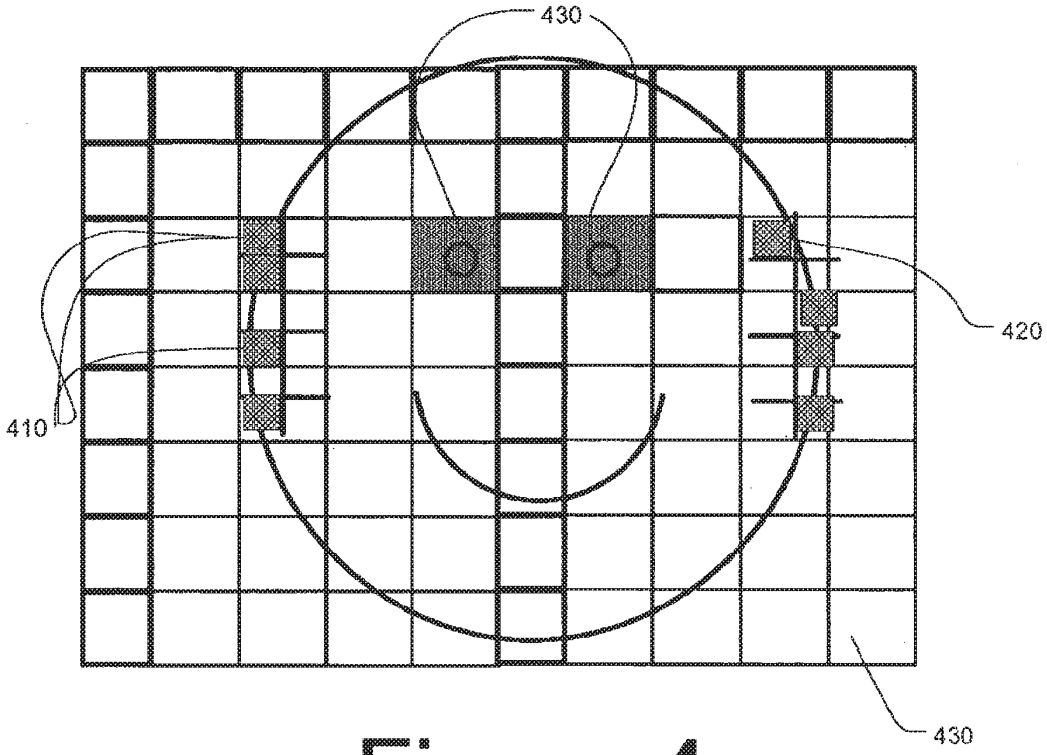


Figure 4

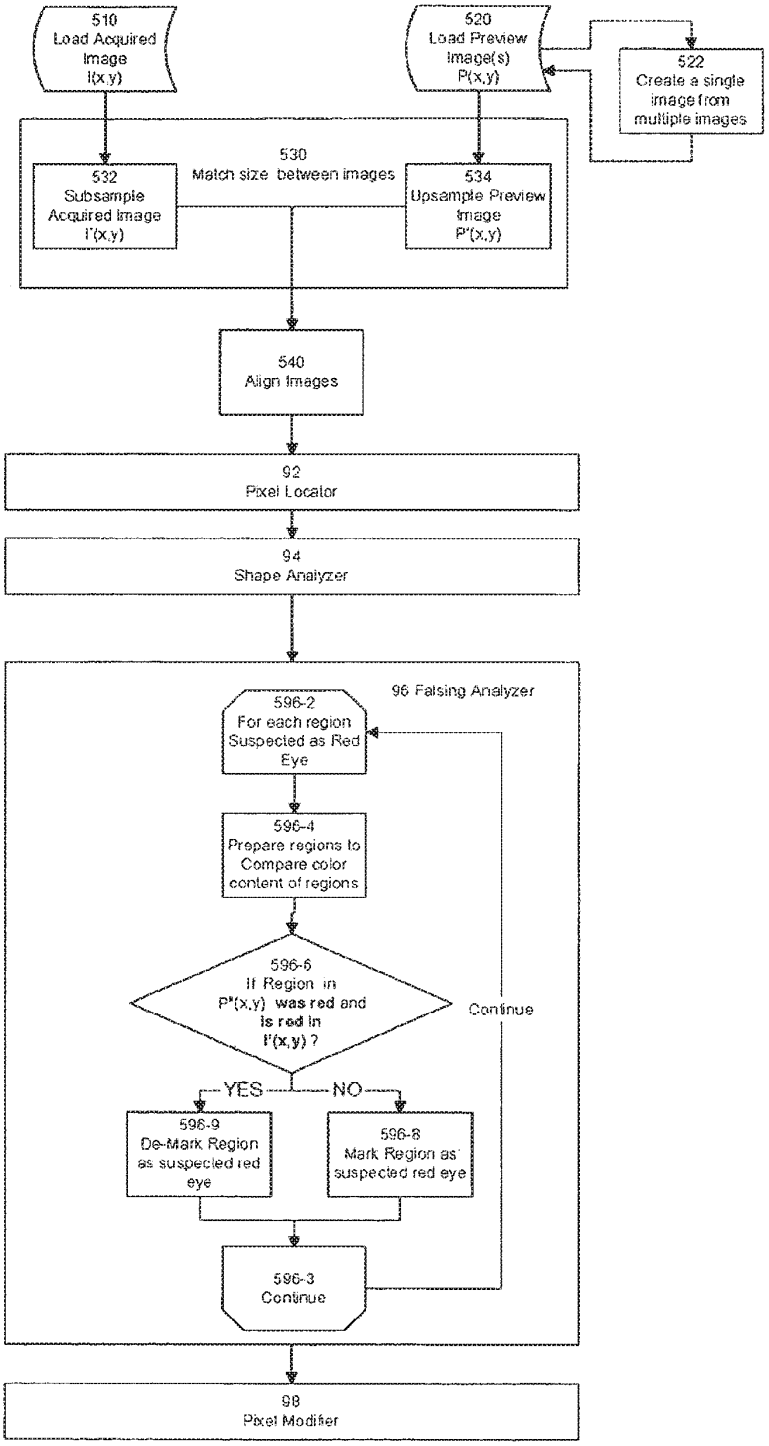

510
Load Acquired Image I(x,y)
520
Load Preview Image(s) P(x,y)
522
Create a single image from multiple images
530
Match size between images
532
Subsample Acquired Image I'(x,y)
534
Upsample Preview Image P'(x,y)
540
Align Images
92
Pixel Locator
94
Shape Analyzer
96 Falsing Analyzer
596-2
For each region Suspected as Red Eye
596-4
Prepare regions to Compare color content of regions
596-6
If Region in P'(x,y) was red and is red in I'(x,y) ?
Continue
YES
NO
596-9
De-Mark Region as suspected red eye
596-8
Mark Region as suspected red eye
596-3
Continue
98
Pixel Modifier

Figure 5-a

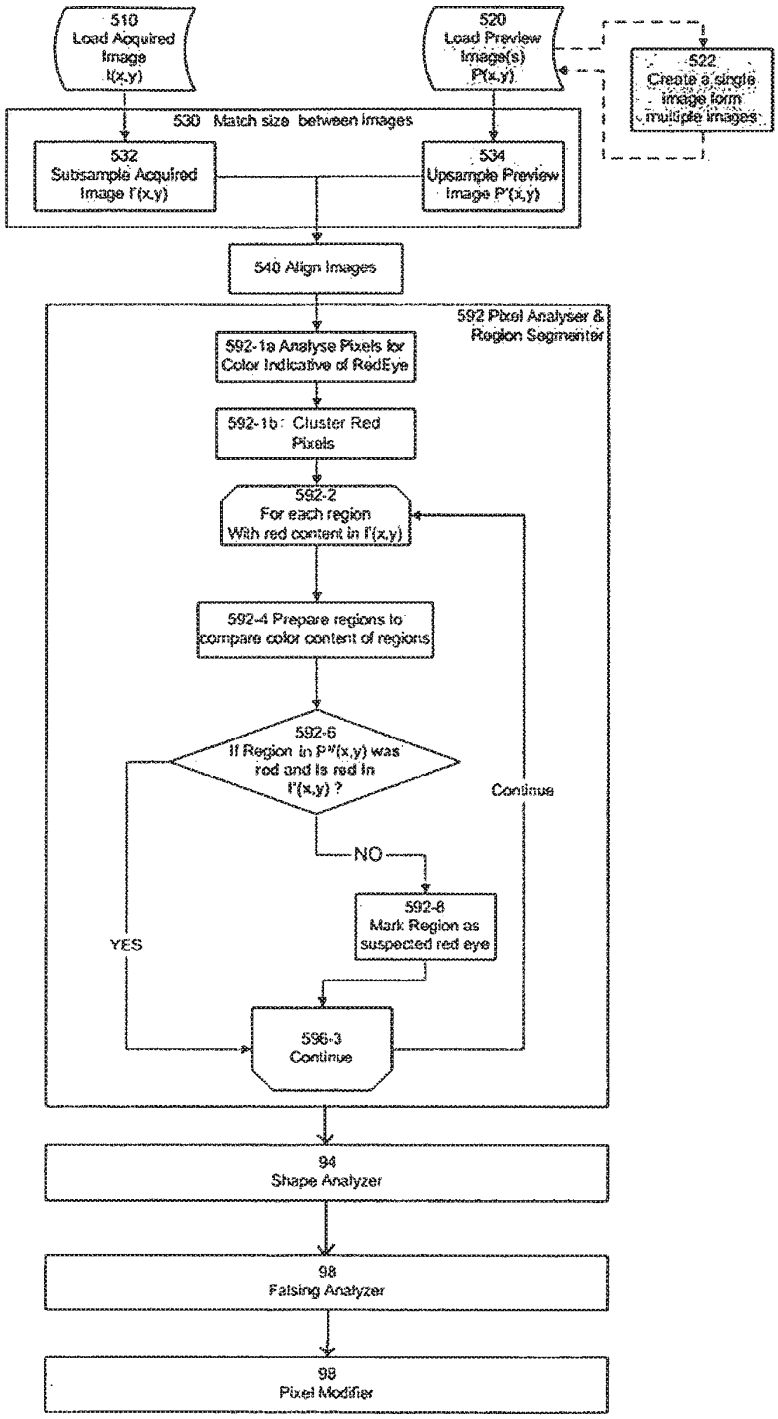

510
Load Acquired Image I(x,y)
520
Load Preview Image(s) P(x,y)
522
Create a single image form multiple images
530 Match size between images
532
Subsample Acquired Image I'(x,y)
534
Upsample Preview Image P'(x,y)
540 Align Images
592 Pixel Analyser & Region Segmenter
592-1a Analyse Pixels for Color Indicative of RedEye
592-1b Cluster Red Pixels
592-2
For each region With red content in I'(x,y)
592-4 Prepare regions to compare color content of regions
592-6
If Region in P'(x,y) was red and is red in I'(x,y) ?
Continue
NO
YES
592-8
Mark Region as suspected red eye
596-3
Continue
94
Shape Analyzer
98
Faising Analyzer
98
Pixel Modifier

Figure 5-b

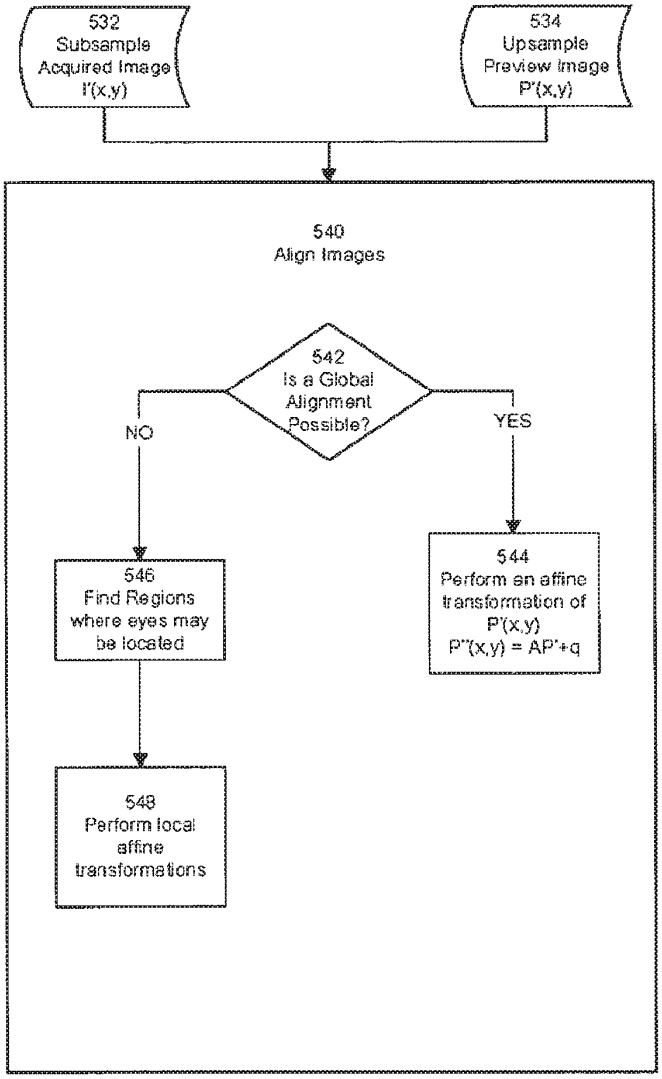

532
Subsample
Acquired Image
I'(x,y)
534
Upsample
Preview Image
P'(x,y)
540
Align Images
542
Is a Global
Alignment
Possible?
NO
YES
546
Find Regions
where eyes may
be located
544
Perform an affine
transformation of
P'(x,y)
P''(x,y) = AP'+q
548
Perform local
affine
transformations

Figure 5-c

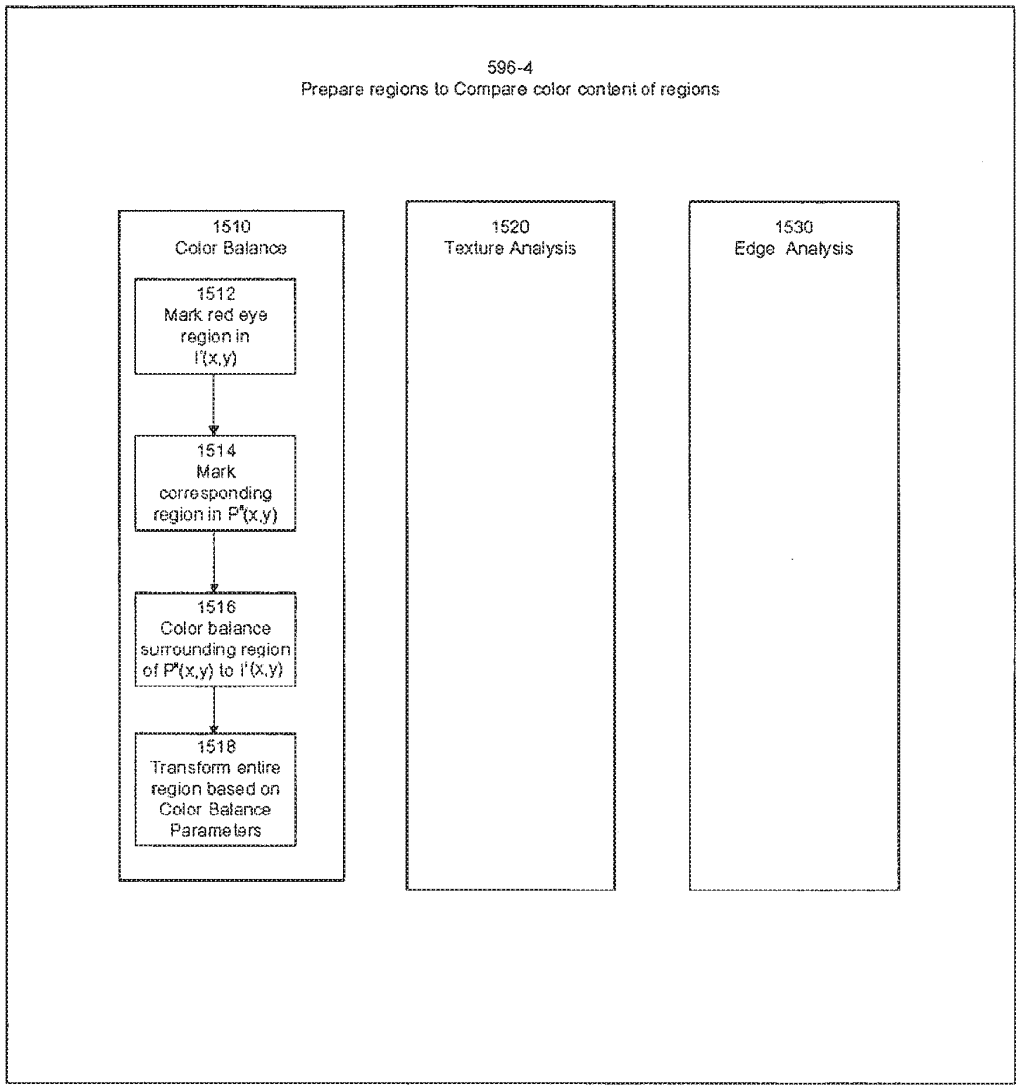

596-4
Prepare regions to Compare color content of regions
1510
Color Balance
1512
Mark red eye region in I'(x,y)
1514
Mark corresponding region in P'(x,y)
1516
Color balance surrounding region of P'(x,y) to I'(x,y)
1518
Transform entire region based on Color Balance Parameters
1520
Texture Analysis
1530
Edge Analysis

Figure 5-d

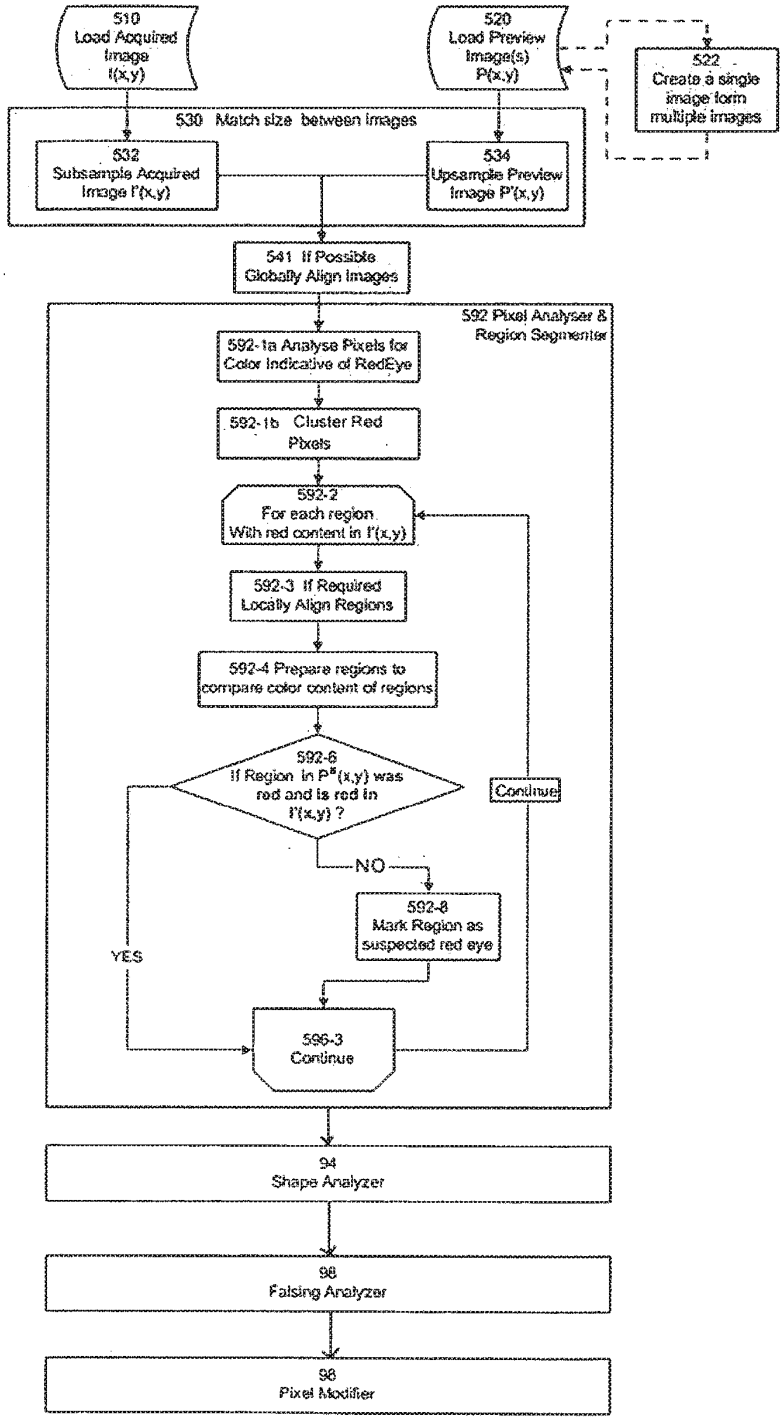

510
Load Acquired Image I(x,y)
520
Load Preview Image(s) P(x,y)
522
Create a single image form multiple images
530 Match size between images
532
Subsample Acquired Image I'(x,y)
534
Upsample Preview Image P'(x,y)
541 If Possible Globally Align Images
592 Pixel Analyser & Region Segmenter
592-1a Analyse Pixels for Color Indicative of RedEye
592-1b Cluster Red Pixels
592-2
For each region With red content in I'(x,y)
592-3 If Required Locally Align Regions
592-4 Prepare regions to compare color content of regions
592-6
If Region in P'(x,y) was red and is red in I'(x,y) ?
Continue
NO
592-8
Mark Region as suspected red eye
YES
596-3
Continue
94
Shape Analyzer
96
Faising Analyzer
98
Pixel Modifier

Figure 6-a

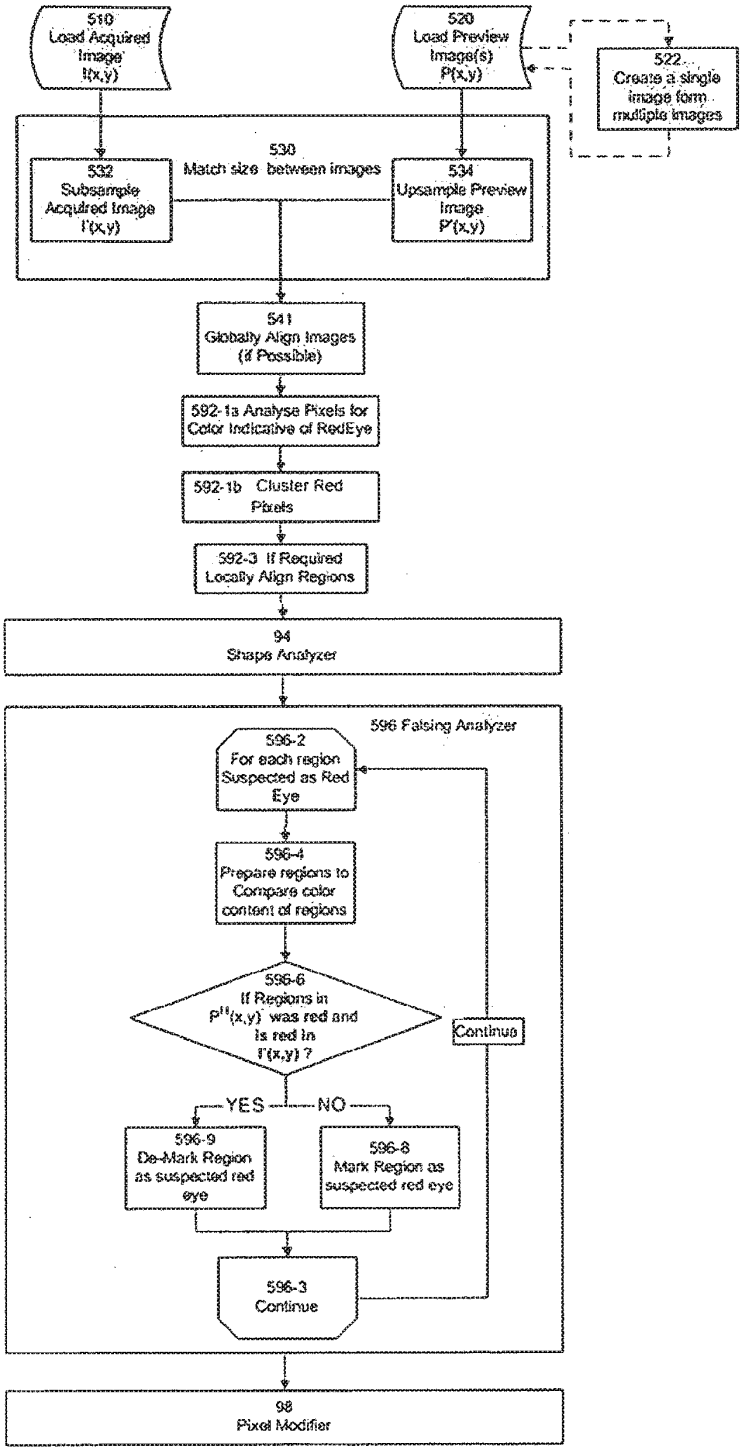

510
Load Acquired Image
I(x,y)
520
Load Preview Image(s)
P(x,y)
522
Create a single image form multiple images
530
Match size between images
532
Subsample Acquired Image
I'(x,y)
534
Upsample Preview Image
P'(x,y)
541
Globally Align Images (if Possible)
592-1a Analyse Pixels for Color Indicative of RedEye
592-1b Cluster Red Pixels
592-3 If Required Locally Align Regions
94
Shape Analyzer
596 Faising Analyzer
596-2
For each region Suspected as Red Eye
596-4
Prepare regions to Compare color content of regions
596-6
If Regions in P''(x,y) was red and is red in I'(x,y) ?
Continue
YES
NO
596-9
De-Mark Region as suspected red eye
596-8
Mark Region as suspected red eye
596-3
Continue
98
Pixel Modifier

Figure 6-b

RED-EYE FILTER METHOD AND APPARATUS

PRIORITY AND RELATED APPLICATIONS

This application is a continuation-in-part (CIP) application which claims the benefit of priority to U.S. patent application Ser. No. 10/772,767, filed Feb. 4, 2004, now U.S. Pat. No. 7,352,394, issued Apr. 1, 2008, which is a CIP that claims the benefit of priority to U.S. patent application Ser. No. 10/635,862 filed Aug. 5, 2003, now U.S. Pat. No. 7,630,006 which is a CIP that claims the benefit of priority to U.S. patent application Ser. No. 10/170,511, filed Jun. 12, 2002, now U.S. Pat. No. 7,042,505, issued May 9, 2006, which is a continuation of U.S. patent application No. 08/947,603, filed Oct. 9, 1997, now U.S. Pat. No. 6,407,777, issued Jun. 18, 2002, which are each hereby incorporated by reference. This application is also related to U.S. patent applications Ser. No. 10/635,918, filed Aug. 5, 2003, and Ser. No. 10/773,092, filed Feb. 4, 2004.

FIELD OF THE INVENTION

The invention relates generally to the area of digital photography, and more specifically to filtering "red-eye" artefacts from a flash-induced digital camera image.

BACKGROUND OF THE INVENTION

"Red-eye" is a phenomenon in flash photography where a flash is reflected within a subject's eye and appears in a photograph as a red dot where the black pupil of the subject's eye would normally appear. The unnatural glowing red of an eye is due to internal reflections from the vascular membrane behind the retina, which is rich in blood vessels. This objectionable phenomenon is well understood to be caused in part by a small angle between the flash of the camera and the lens of the camera. This angle has decreased with the miniaturization of cameras with integral flash capabilities. Additional contributors include the relative closeness of the subject to the camera and ambient light levels.

The red-eye phenomenon can be minimized by causing the iris to reduce the opening of the pupil. This is typically done with a "pre-flash", a flash or illumination of light shortly before a flash photograph is taken. This causes the iris to close. Unfortunately, the pre-flash is an objectionable 0.2 to 0.6 seconds prior to the flash photograph. This delay is readily discernible and easily within the reaction time of a human subject. Consequently the subject may believe the pre-flash is the actual photograph and be in a less than desirable position at the time of the actual photograph. Alternately, the subject must be informed of the pre-flash, typically loosing any spontaneity of the subject captured in the photograph.

Those familiar with the art have developed complex analysis processes operating within a camera prior to invoking a pre-flash. Various conditions are monitored prior to the photograph before the pre-flash is generated; the conditions include the ambient light level and the distance of the subject from the camera. Such a system is described in U.S. Pat. No. 5,070,355, which is hereby incorporated by reference. Although that invention minimizes the occurrences where a pre-flash is used, it does not eliminate the need for a pre-flash.

Digital cameras are becoming more popular and smaller in size. Digital cameras have several advantages over film cameras. Digital cameras eliminate the need for film as the image is digitally captured and stored in a memory array for display on a display screen on the camera itself. This allows photographs to be viewed and enjoyed virtually instantaneously as opposed to waiting for film processing. Furthermore, the digitally captured image may be downloaded to another display device such as a personal computer or color printer for further enhanced viewing. Digital cameras include microprocessors for image processing and compression and camera systems control. It is possible to exploit the computation capabilities of such microprocessors for performing operations to improve the red-eye detection and elimination. Thus, what is needed is a method of better tools for eliminating red-eye phenomenon within, for example, a digital camera having a flash unit without the distraction of a pre-flash.

U.S. Patent Application 2002/0150306 (Baron), which is hereby incorporated by reference, describes a method for the removal of flash artefacts by capturing two digital images of a subject, one with flash and one without flash, and subtracting one image from the other to provide an artefact image which is then thresholded and subtracted from the flash image. However, the technique is directed to flash artefacts in general, and not specifically to red-eye removal. There is no attempt to identify red-eye regions as compared to any other flash-induced artefacts. Indeed, there is no attempt to identify particular regions at all, since the technique is simply one of subtraction and thresholding.

BRIEF SUMMARY OF THE INVENTION

A system in accordance with the present invention there is provided a digital image acquisition system having no photographic film, comprising a portable apparatus for capturing digital images, a flash unit for providing illumination during image capture, and a red-eye filter for detecting a region within a captured image indicative of a red-eye phenomenon, said detection being based upon a comparison of said captured image and at least one reference eye color characteristic.

According to one embodiment of the invention, the at least one reference eye color characteristic includes a reference image of nominally the same scene taken without flash.

According to this embodiment, the reference image may be a preview image of lower pixel resolution than the captured image, the filter may include programming code for matching the pixel resolutions of the captured and reference images by up-sampling the preview image and/or sub-sampling the captured image.

To allow for inadvertent movement in the subject between taking the two images, preferably the filter may further include programming code for aligning at least portions of the captured image and reference image prior to said comparison.

In the embodiment the filter detects said region indicative of a red-eye phenomenon by identifying a region in the captured image at least having a color indicative of a red-eye phenomenon and comparing said identified region with the corresponding region in the reference image. The filter may further designate the region as indicative of a red-eye phenomenon if said corresponding region does not have a color indicative of a red-eye phenomenon. The decision as to whether a region has a color indicative of a red-eye phenomenon may be determined on a statistical basis as a global operation on the entire region.

According to a further embodiment, the filter includes a shape analyser so that the filter is configured to identify a region in the captured image having both a shape and color indicative of a red-eye phenomenon for subsequent comparison with a reference eye shape characteristic and the reference eye color characteristic, respectively.

In another embodiment, a pixel modifier is included for modifying the color of the pixels within a region indicative of a red-eye phenomenon.

A method in accordance with the present invention is also provided for detecting a red-eye phenomenon within a digital image acquired by a digital image acquisition device having no photographic film. The device includes a portable apparatus for capturing digital images, and a flash unit for providing illumination during image capture. The method includes identifying a region within a captured image indicative of a red-eye phenomenon including comparing the captured image and at least one reference eye color characteristic.

According to one embodiment, the at least one reference eye color characteristic includes an eye color characteristic of a reference image of nominally the same scene taken without flash.

The reference image may be a preview image of lower pixel resolution than the captured image. The method may further include matching the pixel resolutions of the captured and reference images including up-sampling the preview image or sub-sampling the captured image, or a combination thereof.

The method may further include aligning at least portions of the captured image and reference image prior to said comparison.

The method may further include analysing a shape so that the identifying comprises identifying a region in the captured image having both a shape and color indicative of a red-eye phenomenon for subsequent comparison with the corresponding region in the reference image. A shape may be analysed to determine subsequent to the comparison whether a region designated as indicative of a red-eye phenomenon has a shape indicative of a red-eye phenomenon.

The method may also include detecting a region indicative of a red-eye phenomenon by identifying a region in the captured image at least having a color indicative of a red-eye phenomenon and comparing the identified region with the corresponding region in the reference image, and designating the region as indicative of a red-eye phenomenon if the corresponding region does not have a color indicative of a red-eye phenomenon.

The method may also include deciding whether a region has a color indicative of a red-eye phenomenon by determining on a statistical basis as a global operation on the entire region.

The method may also include modifying the color of the pixels within a region indicative of a red-eye phenomenon.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a camera apparatus operating in accordance with an embodiment of the present invention.

FIG. **2** illustrates the workflow of the initial stage of a red-eye filter using preview data according to the embodiment.

FIGS. **3**-*a* to **3**-*d* illustrates the pixelation process of an image in different resolutions.

FIG. **3**-*e* is a enlargement of a hypothetical digitization of an eye in an image.

FIG. **4**. illustrates the pixel differences between a red-eye image and a non red-eye image.

FIGS. **5**-*a* to **5**-*d* and **6**-*a* and **6**-*b* illustrate the detailed workflow of the red-eye filter according to the embodiment, and alternatives.

DESCRIPTION OF A PREFERRED EMBODIMENT

FIG. **1** shows a block diagram of a image acquisition system such as a digital camera apparatus operating in accordance with the present invention. The digital acquisition device, also generically referred to in this application as a camera **20**, includes a processor **120**. It can be appreciated that many of the processes implemented in the digital camera may be implemented in or controlled by software operating in a microprocessor (μProc), central processing unit (CPU), controller, digital signal processor (DSP) and/or an application specific integrated circuit (ASIC), collectively depicted as block **120** and termed as "processor". Generically, all user interface and control of peripheral components such as buttons and display is controlled by a μ-controller **122**. The processor **120**, in response to a user input at **122**, such as half pressing a shutter button (pre-capture mode **32**), initiates and controls the digital photographic process. Ambient light exposure is determined using light sensor **40** in order to automatically determine if a flash is to be used. The distance to the subject is determined using focusing means **50** which also focuses the image on image capture means **60**. If a flash is to be used, processor **120** causes the flash means **70** to generate a photographic flash in substantial coincidence with the recording of the image by image capture means **60** upon full depression of the shutter button. The image capture means **60** digitally records the image in color. The image capture means is known to those familiar with the art and may include a CCD (charge coupled device) or CMOS to facilitate digital recording. The flash may be selectively generated either in response to the light sensor **40** or a manual input **72** from the user of the camera. The image recorded by image capture means **60** is stored in image store means **80** which may comprise computer memory such a dynamic random access memory or a non-volatile memory. The camera is equipped with a display **100**, such as an LCD, for preview and post-view of images. In the case of preview images, which are generated in the pre-capture mode **32**, the display **100** can assist the user in composing the image, as well as being used to determine focusing and exposure. In case of postview, the image display can assist the user in viewing suspected red-eye regions and to manually decide if the region should be corrected or not after viewing it. A temporary storage space **82** is used to store one or plurality of the preview images and be part of the image store means **80** or a separate component. The preview image is usually generated by the same image capture means **60**, and for speed and memory efficiency reasons may be generated by subsampling the image **124** using software which can be part of the general processor **120** or dedicated hardware, before displaying **100** or storing **82** the preview image. Depending on the settings of this hardware subsystem, the pre-acquisition image processing may satisfy some predetermined criteria prior to storing the preview image. Such criteria may be chronological—such as save images every 0.5 seconds; more sophisticated criteria may be analysis of the image for changes, or the detection of faces in the image. A straightforward preferred embodiment is to constantly replace the previous saved preview image with a new captured preview image during the pre-capture mode **32**, until the final full resolution image is captured by full depression of the shutter button.

The red-eye filter **90** can be integral to the camera **20** or part of an external processing device **10** such as a desktop computer, a hand held device, a cell phone handset or a server. In this embodiment, the filter receives the captured image from the full resolution image storage **80** as well as one or a plu-

rality of preview images from the temporary storage **82**. The filter **90** analyzes the stored image for characteristics of red-eye and, if found, modifies the image and removes the red-eye phenomenon from the image as will be describe in more detail. The red-eye filter includes a pixel locator **92** for locating pixels having a color indicative of red-eye; a shape analyzer **94** for determining if a grouping of at least a portion of the pixels located by the pixel locator comprise a shape indicative of red-eye; an falsing analyzer **96** for processing the image around the grouping for details indicative of an image of an eye; and a pixel modifier **98** for modifying the color of pixels within the grouping. The modified image may be either displayed on image display **100**, saved on a persistent storage **112** which can be internal or a removable storage such as CF card, SD card or the like, or downloaded to another device, such as a personal computer, server or printer via image output means **110** which can be tethered or wireless.

In a further embodiment where the red-eye filter **90** is located on an external application in a separate device, **10**, such as a desktop computer, the final captured image stored in block **80** along with a representation of the preview image as temporarily stored in **82**, may be stored prior to modification on the storage device **112**, or transferred together via the image output means **110** onto the external device **10**, later to be processed by the red-eye filter **90**.

FIG. **2** details the initial stage of the workflow of this embodiment. It will be understood both this initial stage as well as the subsequent red-eye correction stage (See FIGS. **5***a* to **5***d*) will typically be performed by software in the camera and/or separate device **10**. A preview image (normally of lesser resolution than the final image) is generated while the camera is in the pre-capture mode **32** such as when the user half presses the shutter button. While in this mode, shown in FIG. **2** as the preview mode **210**, the camera constantly captures the preview images **220**. The capture interval is usually semi-real time which means fractions of a tenth of a second or less. The camera saves each new preview image if it satisfies some test criteria, **122**. If not, the camera continues, **211**, to capture the next preview image without saving the previous one. The process will continue until the final full resolution image is acquired **280** and saved **282** by fully depressing the shutter button.

In a simple embodiment, if the test criteria are met, or if no test criteria exist, the system will constantly replace the previous saved preview image with the new preview image, **230**. Alternatively, where multiple preview images can be saved, **240**, the new image will be placed on a chronological FIFO stack, namely First In First Out, where the system continuously captures and saves new preview images **244** while each time clearing the oldest image **242** from the stack, until the user takes the final picture. The reason for storing multiple preview images is based on the fact that the last image, or any single image, may not be the best reference image for comparison with the final full resolution image in the red-eye correction process. By storing multiple images, a better reference image can be achieved, and a closer alignment between the preview and the final captured image can be achieved. This concept will be further discussed in FIGS. **5***a* to **5***c*, in the alignment stage **540**. Other reasons for capturing multiple images are that a single image may be blurred due to motion, the subject had their eyes closed, the exposure was not set, etc. In a yet alternative embodiment, the multiple images may assist in creating a single higher quality reference image; either higher resolution or by taking different portions of different regions from the multiple images. This concept of sub-pixel resolution may be combined with the upsampling process as described in FIGS. **5***a* to **5***c*, block **534**.

The test criteria **222** may involve the actual analysis of the preview image content before deciding whether the new preview image should replace a previously saved image. Such criteria may be based on image analysis such as the existence of faces in the image, detection of eyes or metadata analysis such as the exposure condition, whether a flash is going to happen, the distance to the subjects, etc.

As part of the red-eye filter **90** the full resolution image **292** and the preview image or images **294** will be loaded into working memory, **292** and **294**, unless they are already in memory in which they will just be accessed through a pointer. Referring to FIGS. **3***a*-**3***e*, the digitization process in various resolutions is explained and depicted. FIG. **3***a* illustrates the grid like nature of a sensor as illustrated in FIG. **1**, block **60**. The sensor comprises multiple cells **302** which determine the camera resolution. For example a sensor of 2000×3000 cells will be a 6 Million pixel sensor (it will be understood that each cell in fact comprises a plurality of individual sensor elements sensitive to different colors, e.g. RGB or RGBG, to create each colored image pixel).

FIG. **3**-*b* depicts the optical projection of a face **310** onto the sensor **60**. Each of the cells **302** records the average light information it receives for the image. This is the process of digitization and quantization.

The degree of details is determined by the resolution of the sensor as depicted in FIG. **3**-*c*. In this illustration a much smaller sensor is used, and in this case the same face **310** is digitized into a smaller number of pixels, or alternatively subsampled from the full resolution sensor data into a smaller number of pixel representations.

FIG. **3**-*d* describes the inverse process where the subsampled image of FIG. **3**-*c* is upsampled to the same size as the original. When comparing the resolution, naturally the some of the details are lost in this process. For illustrative example, while in FIG. **3**-*b* the face was roughly 25×25=625 pixels, in FIG. **3**-*d* the face is made of only 5×5=25 pixels.

Of course, the above are only for illustration purposes. In practice, due to the larger resolution of the sensors than in this illustration, a normal eye will be depicted by a much larger pixel count to be noticeable. FIG. **3**-*e* displays such a digitized eye. In this figure, an eye **350**, as imaged on a sensor **60**, will consist of roughly 25 pixels wide, **352**. In particular interest for this invention the inner portion, the iris **360**, in this case will be roughly 8 pixels in diameter, as illustrated in **462**.

According to a preferred embodiment of this invention, the preview image and the final image, or portions of them, need to be aligned as depicted in FIG. **5**, block **540**. As explained above, the reference image and the final image may have different resolutions. The discrepancy in resolution may lead to differences in content, or pixel values, even though no data was changed in the subject image. In particular, edge regions when downsampled and then upsampled may have a blurring or an averaging effect on the pixels. Thus direct comparison of different resolution images, even when aligned, may lead to false contouring. In addition, the reference image may be acquired prior to or after the final image is captured. Due to the above reasons, there is a need to match the two images, both in content and pixel resolution, as described below.

FIG. **4** better illustrates the effect of the sub- and up-sample process in finding the difference pixelwise between two images. In this case, the input images are the ones illustrated in FIGS. **3**-*b* and **3**-*d* respectively high resolution and low resolution. In this figure, white squares such as **430** means that there is no difference between the two. Checkered squares or pixels, such as **420** means that there is a difference between the images.

The flat regions should display no significant differences due to resolution changes. The main difference will be caused be two reasons namely edge regions where changes in value occur such as in blocks **410**. However, there is another cause for difference which is of interest to this invention and displayed in **430**. In these pixels, the difference is caused by the actual change in the color of the eye from normal eyes to red-eyes. Not only is there a change in the pixel value but the change is also more specifically reflected as change to a red or light color from the normal color of the iris or form the black color of the pupil.

FIGS. **5**-*a* to **5**-*d* illustrate the workflow of the red-eye filter **90** of this embodiment, as well as variations thereof.

Referring first to FIG. **5**-*a*, there are two input images into the filter, namely a full resolution image **510**, I(x,y) which is the one that was captured by full depression of the shutter button and needs to be analyzed for red-eye artefacts, and a preview image **520**, P(x,y) which is used as a reference image and is nominally the same scene as the image I(x,y) but taken without the flash. The preview image may be a result of some image processing taking into account multiple preview images and creating a single image, **522**. Methods of improving image quality based on multiple images are familiar to those versed in the art of image processing. The resulting output from the analysis process of **522** is a single preview image.

The preview image **520** is normally, but not necessarily, of lower resolution than the full resolution image **510**, typically being generated by clocking out a subset of the sensor cells or by averaging the raw sensor data. Therefore, the two images, or alternatively the relevant regions in the images (i.e. the regions containing or suspected to contain eyes, which can be determined by image processing techniques known in the art), need to be matched in pixel resolution, **530**. In the present context "pixel resolution" means the size of the image, or relevant region, in terms of the number of pixels constituting the image or region concerned. Such a process may be done by either upsampling the preview image, **534**, downsampling the acquired image, **532**, or a combination thereof. Those familiar in the art will be aware of several techniques best used for such sampling methods. The result of step **530** is a pair of images I'(x,y) and P'(x,y) corresponding to the original images I(x,y) and P(x,y), or relevant regions thereof, with matching pixel resolution. The system and method of the preferred embodiment involves the detection and removal of red-eye artefacts. The actual removal of the red-eye will eventually be performed on the full resolution image. However, all or portions of the detection of red-eye candidate pixel groupings, the subsequent testing of said pixel groupings for determining false red-eye groupings, and the initial step of the removal, where the image is presented to the user for user confirmation of the correction, can be performed on the entire image, the subsampled image, or a subset of regions of the entire image or the subsampled image.

Although nominally of the same scene, the preview image and the finally acquired full resolution image may differ spatially due to the temporal lag between capturing the two images. Therefore, the two images, or relevant regions thereof, may need to be aligned, **540**, especially in respect of regions of the images containing or suspected to contain eyes. Essentially, alignment means transforming at least one of the images, and in this embodiment the preview image P'(x,y), to obtain maximum correlation between the images, or relevant regions thereof, based on measurable characteristics such as color, texture, edge analysis. Those familiar in the art are aware of several algorithms to achieve such alignment; see, for example, U.S. Pat. No. 6,295,367 which is hereby incorporated by reference and which describes alignment of images due to object and camera movement, and U.S. Pat. No. 5,933,546, which is also hereby incorporated by reference and which addresses the use of multi-resolution data for pattern matching.

Further discussion on the alignment is presented in FIG. **5**-*c*. In this Figure, the inputs are the two images I'(x,y) and P'(x,y) as defined in FIG. **5**-*a*. The alignment may be global for the entire image or local for specific regions. For example, a simple linear alignment, such as a shift in the horizontal direction by H pixels, and/or in the vertical direction by V pixels, or a combination of the two. Mathematically, the shifted image, P''(x,y), can be described as:

$$P''(x,y)=P'(x-H,y-V)$$

However, simple translation operation may not suffice in the need to align the image. Therefore, there may be a need for X-Y shearing, which is a symmetrical shift of the object's points in the direction of the axis to correct for perspective changes: X-Y tapering where the object is pinched by shifting its coordinates towards the axis, the greater the magnitude of the coordinate the further the shift; or rotation around an arbitrary point.

In general, the alignment process may involve an affine transformation, defined as a special class of projective transformations that do not move any objects from the affine space R_3 to the plane at infinity or conversely, or any transformation that preserves collinearity (i.e. all points lying on a line initially still lie on a line after transformation) and ratios of distances (e.g., the midpoint of a line segment remains the midpoint after transformation). Geometric contraction, expansion, dilation, reflection, rotation, shear, similarity transformations, spiral similarities and translation are all affine transformations, as are their combinations. In general, the alignment **540** may be achieved via an affine transformation which is a composition of rotations, translations, dilations, and shears, all well-known to one familiar in the art of image processing.

If it is determined through a correlation process that a global transformation suffices, as determined in block **542**=YES, one of the images, and for simplicity the preview image, will undergo an affine transformation, **544**, to align itself with the final full resolution image. Mathematically, this transformation can be depicted as:

$$P''=AP'+q$$

where A is a linear transformation and q is a translation.

However, in some cases a global transformation may not work well, in particular for cases where the subject matter moved, as could happen when photographing animated objects. In such case, in particular in images with multiple human subjects, and when the subjects move in independent fashion, the process of alignment **540** may be broken down, **546**, to numerous local regions each with its own affine transformation. What is important is to align the eyes between the images. Therefore, according to this alternative, one or multiple local alignments may be performed, **548**, for regions in the vicinity surrounding the eyes, such as faces.

Only after the images are aligned can one compare the potential red-eye colors.

In the preferred embodiment of FIG. **5**-*a*, the preview image information is used as part of the falsing stage **96**. Blocks **92**, **94** and **98** correspond to the same blocks in FIG. **1**, being the stages of pixel locator, shape analyzer and pixel modification respectively. This embodiment can incorporate pixel locator **92**, shape analyzer **94** and pixel modifier **98** as

described in U.S. Pat. No. 6,407,777 (DeLuca), incorporated by reference above, the functions of the pixel locator **92** and shape analyzer **94** being performed on the image I'(x,y) and the pixel modifier **98** operating on the original acquired image I(x,y). Block **96**, which is the falsing stage, is improved in this embodiment as compared to the falsing stage of DeLuca.

Referring to block **96**, for each region of the image I'(x,y) suspected as red-eye, step **596-2**, as identified by steps **92** and **94**, the suspected region is tested by comparing the pixel values of the region with the pixel values of the corresponding region in the aligned preview image P"(x,y), **596-6**. However, prior to doing so, the regions need to be prepared and modified for such comparison, **596-4**.

Due to the fact that the regions may not match exactly, a pixel-by-pixel comparison may not suffice. The reason for the mismatch may occur due to the original size discrepancy. For example, in edges this phenomenon is graphically illustrated in FIG. **4**. Other reasons for a mismatch are potential movement of the object, or there may be some averaging that is done in the low resolution preview image that may loose high frequency color data. Such effects are referred to as smoothing and aliasing. In addition, even if the alignment is optimal, there may be sub-pixel alignment that can not be accounted for. Moreover, there may be color differences between the preview image, shot using available light and the acquired full resolution image which is shot using flash. In many cases, the color transformation between one image to another is not global and uniform. Therefore, the process of preparing the regions for comparison.

This process as illustrated in block **596-4** will be further described in FIG. **5**-*d*. The underlying concept behind step **596-4** is to distinguish between differences that are caused due to the acquisition process and the differences that are caused due to the existence of red-eye in the image. This problem is well known to one familiar in the art of statistical pattern matching and scene analysis and image recognition. An example of such an application taking into account differences due to resolution is described in U.S. Pat. No. 5,933,546, which is hereby incorporated by reference.

If a region in the aligned preview image P"(x,y) was red and the equivalent region is red in the image I'(x,y), **596-6**, that region will be eliminated from I'(x,y) as a red-eye artefact, **596-9**, and the corresponding region will be eliminated as a red-eye artefact from the original full resolution image I(x,y). Otherwise, the region will continue to remain suspected as red-eye, **596-8**. The process will continue, **596-3**, for all suspected regions.

The comparison of the regions for a color value is done as a global operation on the entire region, and the answer to the question of whether a region is red or not is made statistically for the entire region and not pixel by pixel, i.e. it does not depend on the value of any particular individual pixel. Such approach will account for inconsistencies on the pixel level that may be resolved statistically when analyzing a larger collection of pixels consisting of a region. For example, some regions of the eye may not be fully red, or display other artefacts such as a glint of high luminance. Other example for the need of a global statistical operation is the presence of noise in the image. Techniques are known in the art for such global comparison.

Based on the information above, the regions finally identified as red-eye artefacts can be modified, **98**, to eliminate the red-eye from the original full resolution image I(x,y). The modification can be done using any one of numerous available techniques such as luminance reduction, chrominance reduction, or subtraction of the artefact, as described in US Published Patent Application 2002/0150306 (Baron), which is hereby incorporated by reference.

FIG. **5**-*d* describes the preparation of regions suspected of red-eye for comparison as described in FIG. **5**-*a*, block **596-4**. As discussed above, a simple pixel level comparison may not be enough to determine whether the region is not of red-eye nature. The process of preparation may include a combination of several components such as creating color balance between the regions of the preview image and the final image, **1510**, analyzing the texture, or differences in high frequency patterns between the two regions that may have occurred due to the change in resolution, **1520**, and comparing the edges between the two regions, **1530**, where the differences may have occurred due to change in exposure, color balance, resolution or alignment, and in particular sub pixel alignment. The color balance step **1510** comprises marking each red-eye region in I'(x,y) and the corresponding region in P"(x,y), steps **1512** and **1514**, determining the difference in color balance between the region in I'(x,y) surrounding, but not including, the suspected red-eye region and the corresponding region of P"(x,y), step **1516**, and transforming the entire region, including the suspected red-eye region, based on the color balance difference so determined, step **1518**.

As an alternative embodiment of this invention, the preview image can be used as part of the pixel locator stage **92**, as illustrated in FIG. **5**-*b*, rather than as part of the falsing analyzer **96**. In FIG. **5**-*b*, blocks **510**, **520**, **522**, **530**, **532**, **534**, **540**, **94** and **98** are identical to those in FIG. **5**-*a*. According to this embodiment, the use of the preview image in order to detect red-eye artefacts is implemented as part of the red-eye identification process, otherwise described as the pixel locator **92** in FIG. **1** but here identified as Pixel Analyser and Region Segmenter **592**.

After the suspected red-eye regions are identified, the process continues via the shape analysis **94**, false detection elimination **96** and correction **98** as described in FIG. **1**. In this case, the falsing detector **96** may be performed according to DeLuca.

According to this embodiment, after the alignment step **540** the following steps **592-1***a* and **592-1***b* analyse both images I'(x,y) and P"(x,y) for the presence of pixels having a color indicative of red-eye (**592-1***a*), for example in the manner of DeLuca, and then identifies clusters of contiguous red pixels so detected (**592-1***b*). This is known as segmentation and is more fully described in US Pat. Appn. 2002/0176623, which is hereby incorporated by reference.

Now, each region (cluster) with red content in the acquired image I'(x,y), step **592-2**, is compared with the corresponding region in the aligned preview image P"(x,y). The regions will need to be prepared, **592-4**, as previously described in relation to block **596-4** of FIG. **5**-*a*. If the regions are red in both cases, **592-6**=YES, the region will not be marked as red-eye, no action will be taken and the process will continue to the next suspected region, **592-3**. If the region is red in the acquired image I'(x,y) while the corresponding region is not red in the preview image P"(x,y), **592-6**=NO, then the region will be marked as suspected red-eye, **592-8**.

FIG. **6**-*a* shows a modification of the embodiment of FIG. **5**-*b* in which Step **540** (Align Images) has been divided into two steps, Step **541** (If Possible Globally Align Images) and Step **592-3** (If Required Locally Align Images). Step **541** corresponds to Steps **542** and **544** of FIG. **5**-*c*. However, if a global alignment is not possible or practical, the local alignment is deferred until after red pixel identification and clustering has been performed, since the presence of such clusters

in the two images I'(x,y) and P'(x,y) will assist in the local alignment. FIG. **6**-*b* shows a similar modification applied to FIG. **5**-*a*.

In the embodiments of the invention, in the comparison stages, **592-6** and **596-6** the pixel values do not necessarily have to be compared with red but may alternatively or additionally be compared with other values such as yellow, white, pink, brown or other color indicative of a red-eye phenomenon, or to a range of values, to accommodate other flash related eye artefacts that are not purely red. Due to the fact that the eye surface is retro-reflective (due to the smoothness created by the tears, and the spherical shape of the eyeball), the technique as described in this specification can assist in the detection of the eyes in an image. Such existence of an eye can be found by comparison of the spectral reflection of the flash in the eye with the same region where no flash was used, and thus without spectral reflection. This comparison may assist in locating eyes in general and not just eyes with red-eye artefacts. This process may be implemented by finding the change of small specular reflections that occur in the eye region when flash illumination is used such as described in WO 03/026278 (Jarman). The specular reflections may be used as another indication of suspected regions as defined in blocks **592-2** and **596-2** by comparing the specular reflection of the flash image with no specular reflection of the preview image.

Alternatively to a binary decision of adding or eliminating a region, **596-8** and **596-9**, in the case of a continuous probability for each region, the process will be revised from a binary decision to changing a probability decision. The quantitative determination of such change in probability may be decided based on analysis of the confidence level of the comparison **592-4** and **596-4**.

The preferred embodiments described above may be modified by adding or changing operations, steps and/or components in many ways to produce advantageous alternative embodiments. For example, the reference image can be a post-view image rather than a preview image, i.e. an image taken without flash immediately after the flash picture is taken.

A red-eye correction procedure may begin as described by block **92** with detecting a human face in a digital image and, based on this detection, finding the eyes in the face (see, e.g., U.S. Pat. No. 6,252,976, U.S. Publ. Pat. App. No. 2003/0044070 and U.S. Pat. No. 6,278,491, which are hereby incorporated by reference). This procedure may also be used for creating the regional alignment **546** and color balance **1510**.

A range of alternative techniques may be employed to detect and verify the existence of red-eye defects in an image (see, e.g., U.S. Publ. Pat. Apps. No. 2003/0044177 and 2003/0044178, which are hereby incorporated by reference). These techniques may be incorporated into the pixel locator, shape analyzer, falsing analyzer and pixel modifier corresponding to blocks **92**, **94**, **96** and **98**. A camera may include software or firmware for automatically detecting a red-eye image using a variety of image characteristics such as image brightness, contrast, the presence of human skin and related colors. The analysis of these image characteristics may be utilized, based on certain pre-determined statistical thresholds, to decide if red-eye defects exist and if a flash was used to take the original image.

The preferred embodiments described herein may involve expanded digital acquisition technology that inherently involves digital cameras, but that may be integrated with other devices such as cell-phones equipped with an acquisition component, toy cameras etc. The digital camera or other image acquisition device of the preferred embodiment has the capability to record not only image data, but also additional data referred to as meta-data. The file header of an image file, such as JPEG, TIFF, JPEG-2000, etc., may include capture information including the preview image, for processing and red-eye detection at a later post processing stage, which may be performed in the acquisition device or in a separate device such as a personal computer. The preferred embodiments described herein serve to improve the detection of red-eyes in images, while eliminating or reducing the occurrence of false positives, and to improve the correction of the detected artefacts.

While an exemplary drawing and specific embodiments of the present invention have been described and illustrated, it is to be understood that that the scope of the present invention is not to be limited to the particular embodiments discussed. Thus, the embodiments shall be regarded as illustrative rather than restrictive, and it should be understood that variations may be made in those embodiments by workers skilled in the arts without departing from the scope of the present invention, as set forth in the claims below and structural and functional equivalents thereof.

In addition, in methods that may be performed according to preferred embodiments herein and that may have been described above, the operations have been described in selected typographical sequences. However, the sequences have been selected and so ordered for typographical convenience and are not intended to imply any particular order for performing the operations, unless expressly set forth or understood by those skilled in the art being necessary.

Thus, the preferred embodiments described herein provide an improved method and apparatus for detecting red-eye phenomenon within images taken by a digital camera having a flash while eliminating or reducing the occurrence of false positives by using preview information.

In addition to all of the references cited above that have been incorporated by reference, the sections entitled BACKGROUND, SUMMARY OF THE INVENTION, ABSTRACT and BRIEF DESCRIPTION OF THE DRAWINGS, are hereby incorporated by reference into the DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT.

What is claimed is:

1. A digital image acquisition system having no photographic film, comprising a portable apparatus for capturing digital images, a flash unit for providing illumination during image capture, and a red-eye filter for detecting a region within a captured image indicative of a red-eye phenomenon, said detection being based upon a comparison of said captured image and at least one reference eye color characteristic,

wherein said at least one reference eye color characteristic comprises an eye color characteristic of a reference image of nominally the same scene taken without flash, and wherein the reference image comprises a preview image of lower pixel resolution than the captured image, the filter including programming code for matching the pixel resolutions of the captured and reference images by at least one of up-sampling the preview image and sub-sampling the captured image.

2. A system according to claim **1**, the filter including further programming code for aligning at least portions of the captured image and reference image prior to said comparison.

3. A system according to claim **2**, wherein the filter also includes a shape analyser so that the filter is configured to identify a region in the captured image having both a shape

and color indicative of a red-eye phenomenon for subsequent comparison with the corresponding region in the reference image.

4. A system according to claim **2**, wherein the filter also includes a shape analyser to determine subsequent to said comparison whether a region designated as indicative of a red-eye phenomenon has a shape indicative of a red-eye phenomenon.

5. A system according to claim **1**, wherein said at least one reference eye color characteristic comprises an eye color characteristic of a reference image of nominally the same scene taken without flash, and the filter further including programming code for spatially aligning at least portions of the captured image and reference image prior to said comparison.

6. A system according to claim **5**, wherein the filter also includes a shape analyser so that the filter is configured to identify a region in the captured image having both a shape and color indicative of a red-eye phenomenon for subsequent comparison with the corresponding region in the reference image.

7. A system according to claim **5**, wherein the filter also includes a shape analyser to determine subsequent to said comparison whether a region designated as indicative of a red-eye phenomenon has a shape indicative of a red-eye phenomenon.

8. A system according to claim **1**, wherein the filter detects said region indicative of a red-eye phenomenon by identifying a region in the captured image at least having a color indicative of a red-eye phenomenon and comparing said identified region with the corresponding region in the reference image, the filter further designating said region as indicative of a red-eye phenomenon if said corresponding region does not have a color indicative of a red-eye phenomenon.

9. A system according to claim **8**, wherein the decision as to whether a region has a color indicative of a red-eye phenomenon is determined on a statistical basis as a global operation on the entire region.

10. A system according to claim **1**, wherein said digital image acquisition system is a camera is a combination of a digital camera and an external processing device.

11. A system as claimed in claim **10**, wherein said red-eye filter is located in said external processing device.

12. A system according to claim **1**, further including a pixel modifier for modifying the color of the pixels within a region indicative of a red-eye phenomenon.

13. A system according to claim **1**, further including a pixel modifier for modifying the color of the pixels within a region indicative of a red-eye phenomenon.

14. A digital image acquisition system having no photographic film, comprising a portable apparatus for capturing digital images, a flash unit for providing illumination during image capture, and a red-eye filter for detecting a region within a captured image indicative of a red-eye phenomenon, said detection being based upon a comparison of said captured image and at least one reference eye color characteristic,

wherein the filter also includes a shape analyser so that the filter is configured to identify a region in the captured image having both a shape and color indicative of a red-eye phenomenon for subsequent comparison with stored information of characteristics of red eye phenomenon, and

wherein the at least one reference eye color characteristic is determined from a reference image of lower pixel resolution than the captured image, the filter including programming code for matching the pixel resolutions of the captured and reference images by at least one of up-sampling the reference image and sub-sampling the captured image.

15. A digital image acquisition system having no photographic film, comprising a portable apparatus for capturing digital images, a flash unit for providing illumination during image capture, and a red-eye filter for detecting a region within a captured image indicative of a red-eye phenomenon, said detection being based upon a comparison of said captured image and at least one reference eye color characteristic, wherein the filter also includes a shape analyser to determine subsequent to said comparison whether a region designated as indicative of a red-eye phenomenon has a shape indicative of a red-eye phenomenon, and wherein the at least one reference eye color characteristic is determined from a reference image of lower pixel resolution than the captured image, the filter including programming code for matching the pixel resolutions of the captured and reference images by at least one of up-sampling the reference image and sub-sampling the captured image.

16. A system according to claim **15**, wherein said digital image acquisition system comprises a digital camera.

17. A digital image acquisition system having no photographic film, comprising a portable apparatus for capturing digital images, a flash unit for providing illumination during image capture, and a red-eye filter for detecting a region within a captured image indicative of a red-eye phenomenon, said detection being based upon a comparison of said captured image and at least one reference eye color characteristic, wherein the filter also includes a shape analyser so that the filter is configured to identify a region in the captured image having both a shape and color indicative of a red- eye phenomenon for subsequent comparison with a reference eye shape characteristic and the reference eye color characteristic, respectively, and

wherein the at least one reference eye color characteristic is determined from a reference image of lower pixel resolution than the captured image, the filter including programming code for matching the pixel resolutions of the captured and reference images by at least one of up-sampling the reference image and sub-sampling the captured image.

18. A system according to claim **17**, further including a pixel modifier for modifying the color of the pixels within a region indicative of a red-eye phenomenon.

19. A digital image acquisition system having no photographic film, comprising a portable apparatus for capturing digital images, a flash unit for providing illumination during image capture, and a red-eye filter for detecting red-eye phenomenon in a captured image based upon a comparison of said captured image and a reference image of nominally the same scene taken without flash, wherein the reference image is a preview image of lower pixel resolution than the captured image, the filter including means for matching the pixel resolutions of the captured and reference images by at least one of up-sampling the preview image and sub-sampling the captured image.

20. A system according to claim **19**, the filter further including means for aligning at least portions of the captured image and reference image prior to said comparison.

21. A system according to claim **20**, wherein the filter detects said red-eye phenomenon by identifying a region in the captured image having a color indicative of a red-eye phenomenon and comparing said identified region with the corresponding region in the reference image, the filter further designating said region as indicative of a red-eye phenom-

enon if said corresponding region does not have a color indicative of a red-eye phenomenon.

22. A system according to claim **19**, wherein the decision as to whether a region has a color indicative of a red-eye phenomenon is determined on a statistical basis as a global operation on the entire region.

23. A system according to claim **19**, wherein the filter detects said red-eye phenomenon by identifying a region in the captured image having a color indicative of a red-eye phenomenon and comparing said identified region with the corresponding region in the reference image, the filter further designating said region as indicative of a red-eye phenomenon if said corresponding region does not have a color indicative of a red-eye phenomenon.

24. A digital image acquisition system having no photographic film, comprising a portable apparatus for capturing digital images, a flash unit for providing illumination during image capture, and a red-eye filter for detecting a region within a captured image indicative of a red-eye phenomenon, said red eye filter comprising a falsing analyzer for processing the captured image around the region for details indicative of an image of an eye, and wherein the detecting is based upon a comparison of an eye grouping characteristic of said captured image and at least one reference eye grouping characteristic, and wherein the reference eye grouping characteristic is determined from a reference image of lower pixel resolution than the captured image, the filter including programming code for matching the pixel resolutions of the captured and reference images by at least one of up-sampling the reference image and sub-sampling the captured image.

25. A system according to claim **24**, wherein said at least one reference eye grouping characteristic comprises an eye grouping characteristic of a reference image of nominally the same scene taken without flash, and wherein the reference image is a preview image of lower pixel resolution than the captured image, the filter including programming code for matching the pixel resolutions of the captured and reference images by at least one of up-sampling the preview image and sub-sampling the captured image.

26. A system according to claim **25**, the filter including further programming code for aligning at least portions of the captured image and reference image prior to said comparison.

27. A system according to claim **26**, wherein the filter also includes a shape analyser so that the filter is configured to identify a region in the captured image having both a shape and grouping indicative of a red-eye phenomenon for subsequent comparison with the corresponding region in the reference image.

28. A system according to claim **26**, wherein the filter also includes a shape analyser to determine subsequent to said comparison whether a region designated as indicative of a red-eye phenomenon has a shape indicative of a red-eye phenomenon.

29. A method of detecting a red-eye phenomenon within a digital image acquired by a digital image acquisition device having no photographic film, the device comprising a portable apparatus for capturing digital images, and a flash unit for providing illumination during image capture, the method comprising identifying a region within a captured image indicative of a red-eye phenomenon including comparing said captured image and at least one reference eye grouping characteristic and processing the captured image around the region for details indicative of an image of an eye, and wherein the reference eye grouping characteristic is determined from a reference image of lower pixel resolution than the captured image, the filter including programming code for matching the pixel resolutions of the captured and reference images by at least one of up-sampling the reference image and sub-sampling the captured image.

30. A method according to claim **29**, wherein said at least one reference eye grouping characteristic comprises an eye grouping characteristic of a reference image of nominally the same scene taken without flash, and wherein the reference image is a preview image of lower pixel resolution than the captured image, the method further comprising matching the pixel resolutions of the captured and reference images including up-sampling the preview image or sub-sampling the captured image, or a combination thereof.

31. A method according to claim **30**, further comprising aligning at least portions of the captured image and reference image prior to said comparison.

32. A method according to claim **31**, further comprising analysing a shape so that the identifying comprises identifying a region in the captured image having both a shape and grouping indicative of a red-eye phenomenon for subsequent comparison with the corresponding region in the reference image.

33. A method according to claim **31**, further comprising analysing a shape to determine subsequent to said comparison whether a region designated as indicative of a red-eye phenomenon has a shape indicative of a red-eye phenomenon.

34. A method according to claim **29**, further comprising correcting the red eye phenomenon, comprising separating a red pupil color component from an iris color component of a pupil/iris pixel, and modifying the red pupil color component to a black component.

35. A digital image acquisition system having no photographic film, comprising a portable apparatus for capturing digital images, a flash unit for providing illumination during image capture, and a red-eye filter for detecting a region within a captured image indicative of a red-eye phenomenon, said detection being based upon a comparison of said captured image and at least one reference eye color characteristic,

wherein the filter also includes a grouping analyser so that the filter is configured to identify a region in the captured image having both a grouping characteristic and color indicative of a red-eye phenomenon for subsequent comparison with a reference eye grouping characteristic and the reference eye color characteristic, respectively, and

wherein the reference eye grouping or color characteristic, or both, is determined from a reference image of lower pixel resolution than the captured image, the filter including programming code for matching the pixel resolutions of the captured and reference images by at least one of up-sampling the reference image and sub-sampling the captured image.

* * * * *

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First Named Inventor/Applicant Name:	Neal Solomon
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Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		13691805_SIDS_01-16-2020.pdf	216516 cc1ad554ac6dfc1a1a58ed38d8bc9f80cacc38cd	yes	9
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2	Foreign Reference	0001_jp_2004343358_a.pdf	880812 644c07321894f1424d774ca3f8587400993c68e2	no	28
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3	Non Patent Literature	0002_20191107_361_canon_declaration_of_ryan_m_mott.pdf	478698 63b6b157df05d2ea202f0fdc0a59bca69e482683	no	5
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National Stage of an International Application under 35 U.S.C. 371

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New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Espacenet

JP2004343358A IMAGE PROCESSING SYSTEM, IMAGE PROCESSING CONTROL METHOD, AND PROGRAM

Applicants: OLYMPUS CORP
Inventors: KISHIDA HIRONORI

IPC ***H04N5/235; H04N9/04; H04N9/73;*** (IPC1-7): H04N5/235; H04N9/04; H04N9/73;

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Priority numbers: JP2003136509A 2003-05-14
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Priority date: 2003-05-14
Published as: JP2004343358A;**JP4309695B2**

Abstract: IMAGE PROCESSING SYSTEM, IMAGE PROCESSING CONTROL METHOD, AND PROGRAM
<P>PROBLEM TO BE SOLVED: To provide an appropriate image by making shading correction and exposure correction or white balance correction be compatible. <P>SOLUTION: An image processing part 103 performs an image processing of correcting the exposure or white balance of an observation image by a microscope 1 picked up by an image pickup part 102. An image processing part control part 104 controls the image processing by the image processing part 103 on the basis of a predicted result for shading predicted to be generated in an object image when the image processing is executed.
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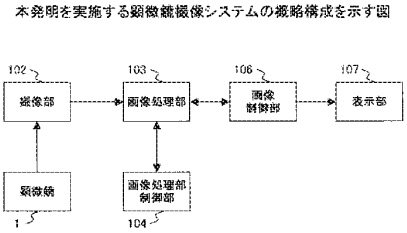
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5C066 AA01 CA05 EA14 KA12 KE02
KE07

(54)【発明の名称】画像処理システム、画像処理制御方法、及びプログラム

(57)【要約】
【課題】シェーディング補正と露出補正若しくはホワイトバランス補正とを両立させて適切な画像を提供できるようにする。
【解決手段】画像処理部１０３は、撮像部１０２によって撮像された顕微鏡１での観察画像の露出若しくはホワイトバランスを補正する画像処理を行う。画像処理部制御部１０４は、この画像処理が施されると被写体画像に発生することが予測されるシェーディングについての予測結果に基づいて画像処理部１０３によるこの画像処理を制御する。
【選択図】　図１



【特許請求の範囲】
【請求項１】
被写体が表されている被写体画像に処理を施して当該被写体画像の露出の補正若しくはホワイトバランスの補正を行う画像処理手段と、
前記被写体画像に発生することが予測されるシェーディングについての予測結果に基づいて当該処理を制御する画像処理制御手段と、
を有することを特徴とする画像処理システム。
【請求項２】
前記被写体画像は、前記被写体である観察標本についての顕微鏡での観察像を撮像して得られた画像であることを特徴とする請求項１に記載の画像処理システム。
【請求項３】
前記画像処理制御手段による前記制御の下で前記処理が施された後の前記被写体画像に発生しているシェーディングを補正するシェーディング補正手段を更に有することを特徴とする請求項１に記載の画像処理システム。
【請求項４】
前記画像処理制御手段は、前記被写体画像とは別に撮像された画像であって前記被写体が表されていない画像である背景画像から予測される前記予測結果に基づいて前記処理を制御することを特徴とする請求項１に記載の画像処理システム。
【請求項５】
前記画像処理制御手段は、前記背景画像内に定義されている複数の部分領域の各々に含まれている各画素に関するデータから予測される前記予測結果に基づいて、同一の部分領域に含まれる画素の各々に対し一定の前記処理を施させるように当該処理を制御することを特徴とする請求項４に記載の画像処理システム。
【請求項６】
前記画像処理制御手段は、前記背景画像内の中央部分に位置する部分領域に含まれている各画素の輝度値の平均値と、当該背景画像内の周辺部分に位置する部分領域に含まれている各画素の輝度値若しくは当該輝度値の平均値と、の差分値に基づいて前記処理を制御することを特徴とする請求項５に記載の画像処理システム。
【請求項７】
前記複数の部分領域は、前記背景画像の中心部分から同心円状に定義されていることを特徴とする請求項５に記載の画像処理システム。
【請求項８】
前記複数の部分領域は、前記背景画像を特定の方向で区切られてなる矩形領域として定義されていることを特徴とする請求項５に記載の画像処理システム。
【請求項９】
被写体が表されている被写体画像の露出若しくはホワイトバランスを補正する画像処理を、当該被写体画像に発生することが予測されるシェーディングについての予測結果に基づいて制御することを特徴とする画像処理制御方法。
【請求項１０】
被写体が表されている被写体画像を処理して露出の補正若しくはホワイトバランスの補正を当該被写体画像に対して施す画像処理と、
前記被写体画像に発生することが予測されるシェーディングについての予測結果に基づいて当該処理を制御する画像処理制御処理と、
をコンピュータに行わせるためのプログラム。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】
本発明は、画像処理技術に関し、特に、画像の露出若しくはホワイトバランスの補正処理の技術に関する。
【０００２】

【従来の技術】
撮像装置におけるレンズ等の結像光学系自体の特性等の影響により、シェーディングと一般的に称されている、撮像された画像の光量がその画像内で不均一にばらついてしまう現象が発生することがある。従来は、撮像後の画像に対し、経験的に得られている補正値や実測結果に基づいた画像処理を施すことによってシェーディングによる画像劣化の補正を行っている。
【０００３】
このシェーディングは結像光学系の特性や、電子カメラの場合にはＣＣＤ（Ｃｈａｒｇｅ Ｃｏｕｐｌｅｄ Ｄｅｖｉｃｅ）等の撮像素子の特性により撮像画像内で様々な形状となって現れる。このうち、光の三原色の色毎の輝度分布特性の違いに起因して撮像画像が不自然に着色してしまう現象は色シェーディングと称されている。
【０００４】
顕微鏡によって得られる標本像を専ら撮像する顕微鏡用撮像装置においては、シェーディングが標本の観察にとりわけ大きな影響を及ぼすが、対物レンズの種類、検鏡法、照明等の違いによって多種多様なシェーディングの発生が想定される。このようなシェーディングの補正を行えるようにする技術として、例えば特許文献１には、標本の存在しない背景のみの画像を対物レンズ毎に予め撮影しておき、この撮影によって得られた背景画像に基づいて生成される対物レンズ毎の補正データを用いて撮像画像に生じているシェーディングを補正する手法が開示されている。
【０００５】
【特許文献１】
特開２００１－２８１５５４号公報
【０００６】
【発明が解決しようとする課題】
多くの撮像装置では、撮像画像の明るさ・色彩の表現を適切なものとするために、操作者の指定する画像内の部分領域に対して露出やホワイトバランスの補正を自動的に行う機能が設けられている。しかしながら、光量低下や色変化といった前述したシェーディングが発生している画像部分に対してこのような露出やホワイトバランスの補正を施しても、適切な撮像画像が得られないことがある。
【０００７】
このような補正が施された後の撮像画像に対して前述したシェーディング補正を行っても、適切な画像が得られないことがある。例えば、シェーディングによって光量の低下している画像部分に対して露出補正を施し、その部分の明るさを適切なものとした後にシェーディング補正を単純に施すと、その画像部分を更に明るくしてしまって過補正の状態となってしまう。
【０００８】
ここで、未補正の撮像画像に対してシェーディング補正を先に行い、その後に露出やホワイトバランスの補正を行うようにすることも考えられる。しかし、画像に生じているシェーディングを補正する画像処理というものは一般的には処理量が膨大である。その一方で、標本の状態の観察等のためにリアルタイム若しくはそれに近いフレームレートでの表示が要求される観察画像としては、露出やホワイトバランスの補正が施されたものを表示する必要があるため、シェーディング補正を露出やホワイトバランスの補正前に行うと、観察画像表示のリアルタイム性が失われてしまうことがある。
【０００９】
本発明は上述した問題を鑑みてなされたものであり、その解決しようとする課題は、シェーディング補正と露出補正若しくはホワイトバランス補正とを両立させて適切な画像を提供できるようにすることである。
【００１０】
【課題を解決するための手段】
本発明の態様のひとつである画像処理システムは、被写体が表されている被写体画像に処

理を施して当該被写体画像の露出の補正若しくはホワイトバランスの補正を行う画像処理手段と、当該被写体画像に発生することが予測されるシェーディングについての予測結果に基づいて当該処理を制御する画像処理制御手段と、を有するように構成するというものであり、このシステムを使用することによって前述した課題が解決される。

【００１１】

この構成によれば、被写体画像に発生することが予測されるシェーディングについての予測結果に基づいて露出補正処理若しくはホワイトバランス補正処理が制御されるので、これらの処理の後に更にシェーディング補正を行ってもシェーディング補正後の被写体画像が不適切なものとならないようにこれらの処理を制御することにより、シェーディング補正と露出補正若しくはホワイトバランス補正とを両立させた適切な画像が提供できるようになる。

【００１２】

また、画像処理制御手段は、被写体画像に対してシェーディング補正を行う画像処理よりも処理量が遥かに少ない、被写体画像の露出の補正若しくはホワイトバランスの補正の処理の制御を行うので、観察画像表示のリアルタイム性が失われることがない。

【００１３】

なお、上述した本発明に係る画像処理システムにおいて、被写体画像を、例えば被写体である観察標本についての顕微鏡での観察像を撮像して得られた画像とすることができる。前述したように、顕微鏡での観察像の撮像画像に生じているシェーディングは標本の観察にとりわけ大きな影響を及ぼすので、こうすることにより、シェーディングが標本の観察に及ぼしている影響を排除することができる。

【００１４】

また、前述した本発明に係る画像処理システムにおいて、前述した画像処理制御手段による前述した制御の下で前述した処理が施された後の被写体画像に発生しているシェーディングを補正するシェーディング補正手段を更に有するように構成してもよい。

【００１５】

この構成によれば、この画像処理システムで被写体画像に対するシェーディング補正を施すこともできるようになる。

また、前述した本発明に係る画像処理システムにおいて、画像処理制御手段が、前述した被写体画像とは別に撮像された画像であって前述した被写体が表されていない画像である背景画像から予測される前述した予測結果に基づいて前述した処理を制御するようにしてもよい。

【００１６】

この構成は、被写体画像に露出の補正若しくはホワイトバランスの補正の処理が施されたときに発生するシェーディングの予測手法の一例として、背景画像に基づくシェーディング予測を行うというものである。

なお、このとき、画像処理制御手段が、前述した背景画像内に定義されている複数の部分領域の各々に含まれている各画素に関するデータから予測される前述した予測結果に基づいて、同一の部分領域に含まれる画素の各々に対し一定の前述した処理を施させるようにこの処理を制御するようにしてもよい。

【００１７】

こうすることにより、画像処理制御手段によって行われるシェーディング予測結果に基づいた制御のための処理負担が軽減される。

また、ここで、画像処理制御手段が、前述した背景画像内の中央部分に位置する部分領域に含まれている各画素の輝度値の平均値と、その背景画像内の周辺部分に位置する部分領域に含まれている各画素の輝度値若しくはこの輝度値の平均値と、の差分値に基づいて前述した処理を制御するようにしてもよい。

【００１８】

この構成は、画像処理制御手段の具体的な構成の一例として、上述した差分値に基づいて被写体画像の露出の補正若しくはホワイトバランスの補正の処理の制御を行うというもの

である。
ここで、上述した複数の部分領域は、例えば、前述した背景画像の中心部分から同心円状に定義されているものであってもよく、また、前述した背景画像を特定の方向で区切られてなる矩形領域として定義されているものであってもよい。
【００１９】
本発明の別の態様のひとつである画像処理方法は、被写体が表されている被写体画像の露出若しくはホワイトバランスを補正する画像処理を、当該被写体画像に発生することが予測されるシェーディングについての予測結果に基づいて制御するというものであり、この方法を使用することによって、前述した本発明に係る画像処理システムと同様の作用・効果が得られ、前述した課題が解決される。
【００２０】
また、被写体が表されている被写体画像を処理して露出の補正若しくはホワイトバランスの補正を当該被写体画像に対して施す画像処理と、この被写体画像に発生することが予測されるシェーディングについての予測結果に基づいてこの処理を制御する画像処理制御処理と、をコンピュータに行わせるためのプログラムについても本発明に係るものであり、このプログラムをコンピュータで実行させることにより、前述した本発明に係る画像処理システムと同様の作用・効果が得られる結果、前述した課題が解決される。
【００２１】
【発明の実施の形態】
以下、本発明の実施の形態を図面に基づいて説明する。なお、ここでは、顕微鏡によって得られる標本像を専ら撮像する顕微鏡用撮像システムにおいて本発明を実施する形態について説明する。
【００２２】
図１は本発明を実施する顕微鏡用撮像システムの概略構成を示している。
図１において、撮像部１０２によって撮像された顕微鏡１の観察像を表現している画像データ（画像を構成する全ての画素の輝度を示すデータ）が画像処理部１０３に入力されると、画像処理部１０３はその画像データを一旦画像処理部制御部１０４へ出力する。
【００２３】
画像処理部制御部１０４は、画像処理部１０３からの画像データの補正を行い、補正後の画像データを画像処理部１０３へ出力する。
画像処理部１０３は、画像処理部制御部１０４からの補正画像データに対して画像制御部１０６より指示された所定の画像処理を施し、その処理後の画像データを画像制御部１０６へ出力する。画像制御部１０６は画像処理部１０３によって処理された後の画像データを表示部１０７へ送付して顕微鏡１での観察画像の表示を表示部１０７に行わせると共に、撮影指示に応じて観察画像の記録を行う。
【００２４】
次に、本発明を実施する顕微鏡用撮像システムの各構成の詳細について、図２を用いて説明する。
顕微鏡１は透過観察用光学系３と落射観察用光学系４とを備えている。
透過観察用光学系３では、ハロゲンランプ等の透過観察用光源５から放射された光がコレクタレンズ６、透過用フィルタユニット７、透過視野絞り８、折り曲げミラー９、コンデンサ光学素子ユニット１０及び１１、トップレンズユニット１２を経て、ステージ１８上に載置されている図示しない標本に照射される。
【００２５】
一方、落射観察用光学系４では、落射照明用光源１３から放射される光が落射用フィルタユニット１４、落射シャッタ１５、落射視野絞り１６、落射開口絞り１７、キューブユニット２１、対物レンズ１９を経て上述した標本に照射される。ここで、キューブユニット２１では、明視野観察や蛍光観察などといった各種検鏡法に応じ、そこに設置されているダイクロイックミラーを切り換えることができる。
【００２６】

落射照明光学系４の光軸と透過照明光学系３の光軸とが重なっている観察光路Ｓ上には、対物レンズ１９を切り換えるためのレボルバ２０と、観察光路Ｓを接眼レンズ側と撮像装置側とに分岐するビームスプリッタ２２とが配置されている。

【００２７】

ビームスプリッタ２２及び観察光路Ｓを通過した光は撮像部１０２に入射する。

撮像部１０２は観察光路Ｓ上に配置されており、撮像素子３１、Ａ／Ｄ変換部４９、前置処理部３２、及びＣＣＤ駆動部４８から構成されている。撮像素子３１の出力はＡ／Ｄ変換部４９に、Ａ／Ｄ変換部４９の出力は前置処理部３２に、そしてＣＣＤ駆動部４８の出力は撮像素子３１に、各々導かれるように接続されている。

【００２８】

顕微鏡１から入射する、所定の倍率まで拡大された観察標本像が撮像素子３１上で結像すると、この観察標本像は撮像素子３１によって光電変換されてアナログ電気信号としてＡ／Ｄ変換部４９へ出力される。なお、本実施形態においては、撮像素子３１としてＣＣＤ（Ｃｈａｒｇｅ　Ｃｏｕｐｌｅｄ　Ｄｅｖｉｃｅ　）を使用している。

【００２９】

Ａ／Ｄ変換部４９はこのアナログ電気信号をデジタルデータである画像データへ変換する。その後、この画像データは前置処理部３２において光の三原色であるＲ（赤）、Ｇ（緑）、Ｂ（青）各色の画像データに分離されて画像処理部１０３へ出力される。この他に、前置処理部３２からはアドレス信号も出力される。これは、前置処理部３２から出力される画像データの各々が１フレームの画像内におけるどの位置の画素に対応するものであるかを２次元アドレス（ｘ，ｙ）で表したものである。

【００３０】

画像処理部１０３は、ＷＢ可変利得増幅器３３、ＷＢ利得設定部３４、ホワイトバランス検出部３５、ＡＥ可変利得増幅器３７、ＡＥ設定部３８、ＡＥ評価部３９、フレームメモリ４１、メモリコントローラ４２、及びＩ／Ｆ部４５から構成されている。

【００３１】

前置処理部３２から画像処理部１０３に入力されるＲＧＢ各色の画像データに対し、ＡＥ（Ａｕｔｏ　Ｅｘｐｏｓｕｒｅ　：自動露出）可変利得増幅器３７はＡＥ設定部３８によって設定された各色一様の係数値を乗じて露出補正を施し、補正後の画像データをＷＢ可変利得増幅器３３へ出力する。

【００３２】

ＷＢ（Ｗｈｉｔｅ　Ｂａｌａｎｃｅ　）可変利得増幅器３３は、可変利得増幅器３７から送られてきた画像データに対してＷＢ利得設定部３４によって設定されるＲＧＢ各色別の係数値を乗じてホワイトバランスの補正を施し、補正後の画像データをフレームメモリ４１へ出力する。

【００３３】

フレームメモリ４１は、撮像部１０２において撮像された観察標本像の１フレーム分の画像データを一時的に記憶するものである。

画像制御部１０６は、パーソナルコンピュータ本体（以下ＰＣと略す）４６とキーボードやマウス等の入力装置４７とから構成される。なお、ＰＣ４６は、制御プログラムを実行することで各構成要素を制御するＣＰＵ（Ｃｅｎｔｒａｌ　Ｐｒｏｃｅｓｓｉｎｇ　Ｕｎｉｔ　：中央演算装置）と、ＲＯＭやＲＡＭ及び磁気記憶装置などからなり、ＣＰＵに各構成要素を制御させる制御プログラムの記憶やＣＰＵが制御プログラムを実行する際のワークエリアあるいは各種データの記憶領域として使用される記憶部と、図２に示したシステム（以下、「本システム」ともいう）の使用者による操作に対応付けられている各種のデータが取得される入力部と、表示部１０７等の出力装置に各種のデータを提示して使用者に通知する出力部と、画像制御部１０６等の他の機器に接続して各種のデータの授受を可能とするためのインタフェース機能を提供するＩ／Ｆ部とを備える、ごく標準的な構成を有するものでよい。

【００３４】

ＰＣ４６は、入力装置４７に対してなされた本システムの使用者による操作に対応付けられている入力に応じた画像処理の実行を画像処理部１０３に指示する一方で、画像処理がされた後の画像データを画像処理部１０３から取り込んでその画像データで表現されている観察画像を表示部１０７に表示させると共に、図３に示すような矩形の指定領域３０５をその観察画像内に表示させる。

【００３５】

図３に示す観察画像の表示例において、標本像３０６と共に表示されている指定領域３０５は移動可能であり、またその形状や大きさを観察画像内で任意に変えることができる。本システムの使用者は、この指定領域３０５を自動露出補正若しくはホワイトバランス補正を施す領域として指定する。使用者がマウス等の入力装置４７を操作して図３では不図示であるポインタで自動露出補正ボタン３０３上のいずれかの位置をクリックさせる指示を行うことにより、指定領域３０５に対する測光及び露出補正の処理が実行される。同様にして自動ホワイトバランス補正ボタン３０４上のいずれかの位置をクリックさせる指示を使用者が行えばホワイトバランス補正処理が実行される。

【００３６】

なお、背景撮影ボタン３０１及び本撮影ボタン３０２については後述する。

図２の説明へ戻る。

メモリコントローラ４２は、ＰＣ４６によってＩ／Ｆ部４５を介して指定された観察画像上の任意領域内の画像データとアドレスデータとをフレームメモリ４１から読み出し、これらのデータを、画像処理部制御部１０４を構成している輝度分布検出部４３及び画像データ修正部４４へ出力する。

【００３７】

輝度分布検出部４３は、メモリコントローラ４２から送られてきたこれらのデータに基づいて露出補正制御及びホワイトバランス補正制御のための制御データを生成し、生成された制御データを画像データ修正部４４へ出力する。

画像データ修正部４４は，メモリコントローラ４２から送られてきた画像データに対し、輝度分布検出部４３から送られてきた制御データを用いて修正処理を施し、修正された画像データをホワイトバランス検出部３５とＡＥ評価部３９とへ出力する。なお、画像データ修正部４４による修正処理の動作はメモリコントローラ４２からの指示によってＯＮ／ＯＦＦ（補正／スルー）の切り替えがなされる。

【００３８】

ＡＥ評価部３９は、画像データ修正部４４から送られてきた修正後の画像データに基づき、指定領域３０５内に含まれている画素についての輝度積算値を算出してＡＥ設定部３８へ出力する。

ＡＥ設定部３８は、ＡＥ評価部３９から受け取った輝度積算値から指定領域３０５内の輝度平均値を算出し、指定領域３０５内の輝度値が適切なものとするために、この算出結果を用いて下記の式

利得＝最適輝度値（目標値）／指定領域３０５内の輝度平均値……（１）

によって算出される利得値をＡＥ可変利得増幅器３７に設定する。

【００３９】

また、画像記録の際の撮像時の露出が適切となるように、下記の式

画像記録時露出時間＝利得×現在の露出時間……（２）

によって算出される画像記録時露出時間の値をＣＣＤ駆動部４８へ出力する。この値を受け取ったＣＣＤ駆動部４８は、画像記録の際の撮像時には、この画像記録時露出時間に従って撮像されるように撮像素子３１を駆動させる。

【００４０】

ホワイトバランス検出部３５は、画像データ修正部４４から送られてきた修正後の画像データに基づいて指定領域３０５内のホワイトバランスを算出する。この算出結果からホワイトバランスが崩れていると判定される場合には、ホワイトバランスを適正化させる補正のためにＷＢ可変利得増幅器３３に設定すべき利得値をこの算出結果から求めてＷＢ利得

設定部３４へ出力する。ＷＢ利得設定部３４はこの利得値をＷＢ可変利得増幅器３３に設定する。

【００４１】

ホワイトバランスが適正である場合には、画像データ修正部４４から送られてきた画像データで表現されている画像の輝度積算値の各色の比（Ｒ：Ｇ：Ｂの比）は１：１：１であるとすることができる。そこで、ホワイトバランス検出部３５は、ＷＢ可変利得増幅器３３に設定すべき利得値として、この比が得られるような値を求めてＷＢ利得設定部３４へ出力する。

【００４２】

ＡＥ可変利得増幅器３７とＷＢ可変利得増幅器３３とに対して上述した設定がなされた後は、ＡＥ可変利得増幅器３７とＷＢ可変利得増幅器３３とは、前置処理部３２から画像処理部１０３に入力される画像データに対し、その設定に基づく露出補正とホワイトバランス補正とをそれぞれ施す。

【００４３】

ＡＥ可変利得増幅器３７とＷＢ可変利得増幅器３３とによって露出調整及びホワイトバランスの補正がなされた画像データは、フレームメモリ４１で一旦保持された後、Ｉ／Ｆ部４８を介してＰＣ４６へ出力される。

ＰＣ４６では、フレームメモリ４１からＩ／Ｆ部４８を介して受け取ったこの画像データで表現されている観察画像を表示部１０７で表示させる。また、本システムの使用者から撮影指示がなされたときには、この画像データに対し、ＰＣ４６自身の有している不図示の記憶部に格納されている、予め撮像しておいた画像であって標本が視野内に表されていない画像である背景画像についての画像データに基づいてシェーディング補正を施した後、その補正後の画像データをＰＣ４６の有する記憶部に記録して保存する。

【００４４】

図２に示す顕微鏡用撮像システムは以上のように構成されている。

次に、この顕微鏡撮像システムの動作について説明する。図４は、この顕微鏡撮像システムによって実行される観察画像の撮影・記録動作の手順をフローチャートで示したものである。なお、以下の説明において、ＰＣ４６によって行われる処理は、ＰＣ４６の記憶部に予め格納されている制御プログラムをＰＣ４６の有するＣＰＵが読み込んで実行することによって実現される。

【００４５】

まず、シェーディング予測に基づいた露出補正制御について説明する。

本システムの使用者は、まず、ステージ１８上の観察標本を観察画像の視野から外しておく。ここでマウス等の入力装置４７を操作し、表示部１０７の撮像画面（図３）に表示されている背景撮影ボタン３０１上のいずれかの位置を図３では不図示であるポインタでクリックさせる指示を行う。この指示をＰＣ４６が取得すると、図４に示されている手順の実行が開始される（Ｓ５０１）。

【００４６】

すると、ＰＣ４６は、ホワイトバランス補正値及び露出補正値の初期値をメモリコントローラ４２へＩ／Ｆ部４５を介して送付する処理、及び画像データ修正部４４をＯＦＦする指示を送付する処理を実行する。

【００４７】

また、ＰＣ４６は、表示部１０７に表示されている撮像画面における本撮影ボタン３０２、自動露出補正ボタン３０３、及び自動ホワイトバランス補正ボタン３０４に対するクリック操作を禁止状態とする処理を実行する。

ＰＣ４６から上述した値を受け取ったメモリコントローラ４２は、ＡＥ設定部３８及びＷＢ利得設定部３４へこれらの値を送付し、ＡＥ可変利得増幅器３７及びＷＢ可変利得増幅器３３に利得の初期値である「１」を設定させる。この設定の下でフレームメモリ４１に格納される画像データは、撮像部１０２から受け取ったままで何らの画像処理もされていない生データとなる。

【００４８】
この後、メモリコントローラ４２は、観察標本が表されていない背景画像の撮像動作を画像処理部１０３に行わせる（Ｓ５０２）。なお、この背景画像の撮像時における撮影環境（照射光量や焦点位置など）は、後に行う観察標本画像の撮像時におけるものと同一にしておくことが望ましい。
【００４９】
その後、メモリコントローラ４２は、この撮像動作によってフレームメモリ４１に格納された背景画像である１フレーム分の画像データとアドレスデータとをＰＣ４６へＩ／Ｆ部４５を介して送付すると共に、これらのデータを輝度分布検出部４３と画像データ修正部４４とにも出力する（Ｓ５０３）。
【００５０】
ＰＣ４６では、送られてきたこれらのデータをＰＣ４６内の記憶部に格納する処理が実行される。
一方、輝度分布検出部４３では、送られてきたこれらのデータに基づいて露出補正制御のための制御値の算出が行われる（Ｓ５０４）。
【００５１】
以下、シェーディング予測結果に基づいた露出補正制御のための制御値の算出について図５から図９までの各図を用いて説明する。
輝度分布検出部４３は、受け取った画像データ及びアドレスデータに基づいて、図５に示すような背景画像の画像中心Ｏを通る直線に沿う複数の矩形領域、図５の例では５つの矩形領域（ｓ１～ｓ５）の各々の輝度平均値を算出する。算出されたこれらの画像輝度平均値は画像データ修正部４４の有する不図示のメモリに格納される。
【００５２】
続いて、画像データ修正部４４は、上述した矩形領域のうちの中心Ｏに最も近いものを除いた矩形領域（ｓ２～ｓ５）について、中心Ｏに最も近い矩形領域ｓ１との輝度平均値の差分値を算出し、算出された差分値を画像データ修正部４４の有するメモリに同様に格納する（Ｓ５０５）。この差分値がシェーディング予測結果に基づいた露出補正制御のための制御値として使用される。
【００５３】
以上のデータ処理によって、画像データ修正部４４のメモリには図６に示すテーブル内のデータが格納されることとなる。なお、同図において、「中心からの距離」の列は、矩形領域ｓｉが存在する範囲を中心Ｏからの距離の範囲として示したものであり、例えば矩形領域ｓ３は中心Ｏからの距離がｒ２からｒ３までの範囲に存在していることを示している。
【００５４】
この後、メモリコントローラ４２は、背景画像の撮影が終了したことをＰＣ４６へＩ／Ｆ部４５を介して通知する（Ｓ５０６）。
この通知を受け取ったＰＣ４６は、表示部１０７に表示されている撮像画面におけるクリック操作を禁止状態としていた本撮影ボタン３０２、自動露出補正ボタン３０３、及び自動ホワイトバランス補正ボタン３０４を操作可能状態に戻す処理が実行される。
【００５５】
次に、本システムの使用者が観察標本を観察画像の視野内へ戻し、露出補正を行わせるべく、マウス等の入力装置４７を操作して自動露出補正ボタン３０３上のいずれかの位置を不図示のポインタでクリックさせる指示を行うと、ＰＣ４６はＩ／Ｆ部４５を介してメモリコントローラ４２に指示を与え、指定領域３０５内の画像データとその画像データを示すアドレスとをフレームメモリ４１から画像データ修正部４４へ送付させる処理を実行する。
【００５６】
画像データ修正部４４は、図７に示すように、入力されるアドレス（Ｘ，Ｙ）と画像中心Ｏの位置を示すアドレス（Ｘ’，Ｙ’）の差分値の絶対値（｜Ｘ－Ｘ’｜，｜Ｙ－Ｙ’｜

）、すなわち入力画像の各画素の位置と画像中心Ｏとの間の距離Ｒを算出する。

【００５７】

ここで、この距離Ｒがｓｉ（ｉ＝１，２…）の領域に含まれていたとすると、ＡＥ評価部３９に出力される、アドレス（Ｘ，Ｙ）に位置する画素の輝度値（出力輝度値）は、入力画像においてそのアドレスに位置する画素の輝度値を入力輝度値とすると、

出力輝度値＝入力輝度値＋Δ差分（平均値１－平均値ｉ）……（３）

と算出される。具体例で説明すると、アドレス（Ｘ，Ｙ）に位置する画素の輝度値は、その画素についての中心Ｏからの距離Ｒが領域ｓ３に含まれている場合には、下式に従い、

出力輝度値＝入力輝度値＋Δ差分（平均値１－平均値３）……（４）

と算出される。つまり、中心Ｏからの距離Ｒが領域ｓ３に含まれる画素については、いずれの画素に対してもこの（４）の式の演算を実行する。このように、同一の領域に含まれる画素の各々に対しては一定の処理を施すようにすることにより、このシェーディング予測結果に基づいた修正のための処理負担が軽減される。

【００５８】

以上のように、上記の（３）式を指定領域３０５内の全ての画素に対して演算することによって露出補正における補正量の決定のためのデータに対し、シェーディング予測結果に基づいた修正が行われる。

ＡＥ評価部３９は、画像データ修正部４４から受け取った上述した修正後の画像データに基づいて指定領域３０５内の輝度積算値を算出してＡＥ設定部３８へ出力する。

【００５９】

ＡＥ設定部３８は受け取った輝度積算値から指定領域３０５内の輝度平均値を算出し、その輝度平均値に基づいて行われる前述した（１）式の演算によって算出される露出補正のための利得値をＡＥ可変利得増幅器３７に設定する。更に、ＡＥ設定部３８は、（２）式の演算によって算出される露出時間をＣＣＤ駆動部４８へそれぞれ出力する。この露出時間を受け取ったＣＣＤ駆動部４８は、この画像記録時露出時間に従って撮像されるように撮像素子３１を駆動する。以降、この撮像素子３１によって撮像される画像は前述したようにしてシェーディング予測結果に基づいて制御されている露出補正がされた画像データとしてフレームメモリ４１に格納される。

【００６０】

以上のようにして、シェーディング予測結果に基づいて制御されている露出補正処理が行われ、露出補正された観察画像がフレームメモリ４１を経てＰＣ４６に入力されるようになる（Ｓ５０７）。

ここで本システムの使用者が観察画像の撮像・記録を行わせるべく、マウス等の入力装置４７を操作して本撮影ボタン３０２上のいずれかの位置を不図示のポインタでクリックさせる指示を行うと、ＰＣ４６は、Ｉ／Ｆ部４５を介し、そのときにフレームメモリ４１に格納されている画像データを取得し、取得した画像データの全画素の各々に対して記憶部内の背景画像データに基づいて次式を演算する処理を実行する。

【００６１】

出力画素輝度値＝入力画素輝度値＋（背景画像中央部輝度平均値

－背景画像の対応画素における輝度値）……（５）

なお、上式において、「背景画像の対応画素における輝度値」とは、演算対象である画素の観察画像上における位置と同様の関係の位置にある背景画像上の画素の輝度値である。

【００６２】

この（５）式の演算を実行することにより、図８に示すように、観察画像の輝度分布（図８（ｂ）の▲２▼）に背景画像の中央部輝度平均値と背景画像の輝度分布との差分値（図８（ａ）の▲１▼）が画素毎に加算される結果、観察画像の周辺部の画素の輝度レベルが観察画像の中央部に対してもちあげられ、シェーディングが適正に補正される（図８（ｃ）の▲１▼＋▲２▼）。

【００６３】

ＰＣ４６は、このようにして露出補正とシェーディング補正とが適正に行われた後の画像データをＰＣ４６内の記憶部に保存する処理を実行し（Ｓ５０８）、撮像動作を終了する（Ｓ５０９）。
次に本発明に係るシェーディング予測結果に基づく露出補正制御の効果について図９及び図１０を用いて説明する。
【００６４】
図９は、本発明に係るシェーディング予測結果に基づく露出補正制御を行わない顕微鏡用撮像システムの構成を示している。
図９のシステムを図２に示したものと比較すると分かるように、図９のシステムでは画像処理部制御部１０４を有しておらず、観察画像内の指定領域３０５の画像データが、メモリコントローラ４２から直接ホワイトバランス検出部３５とＡＥ評価部３９とに入力されている。
【００６５】
このような図９のシステムによって露出補正がされた観察画像に対して、同心円状に輝度分布が変化している典型的なシェーディングの補正を行ったときの輝度変化の様子を模式的に表したのが図１０（ｂ）である。
観察画像について図１０（ａ）に示すようなシェーディングが発生している画像の全領域に対して自動露出補正を行うと、ＡＥ評価部３９は、（２）として示す入力画像の中央部の輝度平均値よりも低い値である、（１）として示す輝度平均値を基準にし、この輝度平均値を図１０（ｂ）に（３）として示す目標値とするように露出補正を行う。そのため、この露出補正の時点で既に観察画像の中央部の輝度は（３）の目標値を超えて（４）として示す出力レベルに達してしまっており、観察画像の中心付近が不自然に明るくなってしまっている。
【００６６】
また、例えば図１０（ｂ）に示す位置（ｉｉｉ）付近の領域を使用者が指定してスポット測光を行うと、露出補正によってこの位置の輝度を（３）目標値付近に調節することができる。しかし、その後にシェーディング補正を行えば、この位置付近の輝度値が更に大きくされるので、結局（４）の出力レベル付近にまで引き上げられてしまい、指定領域さえもが露出オーバーとなってしまう。
【００６７】
一方、本発明に係るシェーディング予測結果に基づく露出補正制御が行われる図２のシステムによって露出補正がされた観察画像に対して、同心円状に輝度分布が変化している典型的なシェーディングの補正を行ったときの輝度変化の様子を模式的に表したものが図１０（ｃ）である。
【００６８】
図２のシステムでは、使用者がまず背景画像の撮影を指示すると、撮像された背景画像についての画像データが輝度分布検出部４３へ渡され、図５に示す画像中心Ｏからの距離に応じた矩形領域毎の輝度平均値と中央領域の輝度平均値との差分値（図６）が算出されて、その差分値が画像データ修正部４４内のメモリに格納される。
【００６９】
その後、使用者が露出補正を指示すると、画像データ修正部４４が、メモリコントローラ４２から入力される観察画像に対し、前掲した（３）式に従って図６に示す差分値が加算されて得られる画像データがＡＥ評価部３９に渡される。この画像データは、図７に示したような、中心からの距離に応じて同心円状に一定の差分値が加算されたものとなっている。
【００７０】
画像データ修正部４４の機能を図１０（ｃ）に従って説明すると、画像データ修正部４４は、差分値の加算によって同図に▲１▼として示すシェーディング予測結果による修正を行い、観察画像の光量を近似的に補正したものである同図に（６）として示す輝度補正値をＡＥ評価部３９へ出力するということになる。この結果、ＡＥ評価部３９は、観察画像

の周辺部分の光量の低下の影響で目標値を大きく越えてしまうような利得や露出時間の設定、すなわち露出補正の誤設定を生じさせることなく、同図に（５）として示す目標値近辺に観察画像の輝度分布を適切にシフトさせるので、露出補正された観察画像に対して同図に▲３▼として示すシェーディング補正を施しても、測光領域の輝度の上昇によりシェーディング補正後の観察画像が（５）の目標値を大きく上回って露出オーバーとなってしまうことが防止される。

【００７１】

次に、シェーディング予測に基づいたホワイトバランス補正制御について、図４に従って説明する。

図４において、本システムの使用者が入力装置４７を操作して背景画像の撮影を指示してから、背景画像の輝度分布をＰＣ４６へ送付してＰＣ４６内部の記憶部に保存するまでの処理手順（Ｓ５０１～Ｓ５０３）は前述した露出補正制御のときと同様であるが、画像データはＲＧＢの各色別にＰＣ４６の記憶部に格納される。

【００７２】

輝度分布検出部４３は、露出補正制御のときと同様に、画像中心Ｏから周辺部方向への直線に沿う複数の領域（図５参照）に対して制御値である差分値を算出し（Ｓ５０４）、図１１に示すように、ＲＧＢの各色別のテーブルデータとして画像データ修正部４４のメモリに格納する（Ｓ５０５）。

【００７３】

この後、背景撮影が終了したことがメモリコントローラ４２からＩ／Ｆ部４５を介して通知される（Ｓ５０６）と、この通知を受け取ったＰＣ４６は、表示部１０７に表示されている撮像画面におけるクリック操作を禁止状態としていた本撮影ボタン３０２、自動露出補正ボタン３０３、及び自動ホワイトバランス補正ボタン３０４を操作可能状態に戻す処理が実行される。

【００７４】

次に、使用者が観察標本を観察画像の視野内へ戻し、ホワイトバランス補正を行わせるべく、マウス等の入力装置４７を操作して自動ホワイトバランス補正ボタン３０４上のいずれかの位置を不図示のポインタでクリックさせる指示を行うと、ＰＣ４６はＩ／Ｆ部４５を介してメモリコントローラ４２に指示を与え、指定領域３０５内の画像データとその画像データを示すアドレスとをフレームメモリ４１から画像データ修正部４４へ送付させる処理を実行する。

【００７５】

画像データ修正部４４は、露出補正制御のときと同様に前掲した（３）式を用い、自身の有するメモリに格納されているテーブルデータ（図１１）の差分値を、観察画像を構成する画素の画像上の位置を示すアドレスに応じてその画素の輝度値（入力輝度値）にＲＧＢ別に加算し、その加算結果（出力輝度値）をホワイトバランス検出部３５に出力する。

【００７６】

ホワイトバランス検出部３５は、画像データ修正部４４から送られてきた指定領域３０５内の画像データの輝度値をＲＧＢの各色別に積算し、各色別の平均輝度値を求める。そして、この輝度平均値についてのＲ：Ｇ：Ｂの比を算出する。ここで、平均輝度値についてＲ：Ｇ：Ｂ＝１：１：１の関係が成り立っておらず、ホワイトバランスが崩れていると判定された場合には、この比をＲ：Ｇ：Ｂ＝１：１：１とすべく、ホワイトバランス検出部３５はＷＢ可変利得増幅器３３に設定すべき利得値をＷＢ利得設定部３４へ出力する。

【００７７】

例えば、上述した輝度平均値が（Ｒ，Ｇ，Ｂ）＝（２００，１８０，１８０）であったならば、ホワイトバランス検出部３５は（Ｒ利得，Ｂ利得，Ｇ利得）＝（１，２００／１８０，２００／１８０）≒（１．０，１．１，１．１）をＷＢ利得設定部３４へ出力する。

【００７８】

ＷＢ利得設定部３４は、ホワイトバランス検出部３５から受け取った利得値をＷＢ可変利得増幅器３３に設定する。

以上のようにして、シェーディング予測結果に基づいて制御されているホワイトバランス補正処理が行われ、ホワイトバランス補正された観察画像がフレームメモリ４１を経てＰＣ４６に入力されるようになる（Ｓ５０７）。

【００７９】

ここで本システムの使用者が観察画像の撮像・記録を行わせるべく、マウス等の入力装置４７を操作して本撮影ボタン３０２上のいずれかの位置を不図示のポインタでクリックさせる指示を行うと、ＰＣ４６は、Ｉ／Ｆ部４５を介し、そのときにフレームメモリ４１に格納されている画像データを取得し、取得した画像データの全画素の各々に対して記憶部内の背景画像データに基づいて前述の（５）式の演算を各色別に実行する処理を行ってシェーディングの補正を行う。

【００８０】

この（５）式の演算を実行することにより、図９に示すように、観察画像の各色別の輝度分布（図８（ｂ）の▲２▼）に背景画像の中央部輝度平均値と背景画像の各色別の輝度分布との差分値（図８（ａ）の▲１▼）が画素毎に加算される結果、観察画像の周辺部の画素の輝度レベルが観察画像の中央部に対してもちあげられ、シェーディングが適正に補正される（図８（ｃ）の▲１▼＋▲２▼）。

【００８１】

ＰＣ４６は、このようにしてホワイトバランス補正とシェーディング補正とが適正に行われた後の画像データをＰＣ４６内の記憶部に保存する処理を実行し（Ｓ５０８）、撮像動作を終了する（Ｓ５０９）。

次に、本発明に係るシェーディング予測結果に基づく露出補正制御の効果について図１２、図１３及び図１４を用いて説明する。

【００８２】

図１２は、色シェーディングが発生している背景画像の輝度分布例を示している。同図を参照すると分かるように、Ｇ色及びＢ色は同様な輝度分布であるのに対し、Ｒ色は背景画像の周辺部分の光量の落ち方がＧＢに比べて大きくなっている。

【００８３】

図１３は、前掲した図９のシステムによってホワイトバランス補正がされた観察画像に対して、図１２に示したシェーディングを補正する処理を行ったときの輝度変化の様子を模式的に表したものである。

前述したように、図９のシステムでは、図２に示すシステムには設けられている画像処理部制御部１０４を有しておらず、観察画像内の指定領域３０５の画像データが、メモリコントローラ４２から直接ホワイトバランス検出部３５とＡＥ評価部３９とに入力されている。従って、図９のシステムでは、本発明に係るシェーディング予測結果に基づくホワイトバランス補正制御が行われない。

【００８４】

まず、システム使用者が、観察画像の中心付近（図１２の（ｂ）位置）の領域に対してホワイトバランス補正を指定した場合を考えてみる。この位置ではホワイトバランスがほぼ取れているので、ＷＢ利得設定部３４がＷＢ可変利得増幅器３３へ設定する利得値は、（Ｒ利得，Ｇ利得，Ｂ利得）≒（１，１，１）となる。

【００８５】

次に、システム使用者が、観察画像の周辺領域（図１２の例えば（ａ）位置）に対してホワイトバランス補正を指定した場合を考える。この位置の輝度平均値が（Ｒ，Ｇ，Ｂ）＝（１８０，２００，２００）であったとすると、ＷＢ利得設定部３４がＷＢ可変利得増幅器３３へ設定する利得値は、（Ｒ利得，Ｇ利得，Ｂ利得）＝（２００／１８０，１，１）≒（１．１，１．０，１．０）となる。この設定では観察画像の中心付近（図１２の（ｂ）位置）の領域は赤色に着色されてしまうこととなる（図１３の▲１▼参照）。

【００８６】

さらに、この撮像画像に対してシェーディング補正を行うとＲの周辺画素の輝度値を上昇させてしまうため、中心付近だけでなく観察画像全体が赤く着色されてしまう（図１３の

▲２▼参照）。
これに対し、本発明に係るシェーディング予測結果に基づくホワイトバランス補正制御が行われる図２のシステムによってホワイトバランス補正がされた観察画像に対して、図１２に示したシェーディングを補正する処理を行ったときの輝度変化の様子を模式的に表したものが図１４である。
【００８７】
図２のシステムでは、使用者がまず背景画像の撮影を指示すると、撮像された背景画像についての画像データが輝度分布検出部４３へ渡され、露出補正制御のときと同様に、図１１に示す画像中心Ｏからの距離に応じた矩形領域毎の輝度平均値と中央領域の輝度平均値との差分値（図６）がＲＧＢ各色別に算出されて、その差分値が画像データ修正部４４内のメモリに格納される。
【００８８】
その後、使用者がホワイトバランス補正を指示すると、画像データ修正部４４が、メモリコントローラ４２から入力される観察画像に対し、前掲した（３）式に従って図１１に示す差分値がＲＧＢ各色別に加算されて得られる画像データがＡＥ評価部３９に渡される。この画像データは、図７に示したような、中心からの距離に応じて同心円状に一定の差分値がＲＧＢ各色別に加算されたものとなっている。
【００８９】
つまり、画像データ修正部４４は、差分値をＲＧＢ各色別に加算することで、図１２に示したような色シェーディングによる周辺部分の光量落ちを近似的に補正した、図１４に示すような輝度分布を呈している画像データをホワイトバランス検出部３５へ出力する。
【００９０】
従って、本システムの使用者がどのような領域を指定してホワイトバランス補正を指示しても、観察画像データの背景画像の色バランスが部位によらず一定に補正されているため、色シェーディングの影響で観察画像が所望していないような色彩に着色してしまうことが防止される。
【００９１】
以上までで説明した実施例を纏めると、本実施例によれば、シェーディングの発生の予測結果に基づいて露出補正とホワイトバランス補正とが制御されるので、シェーディング自体によりあるいはシェーディング補正により、露出オーバーやシステム使用者の所望していない色彩の着色が観察画像に生じることが防止される。
【００９２】
以下、本発明を実施する他の実施例について説明する。なお、以下の実施例と区別するために、ここまでで説明した本発明の実施例を「第一実施例」と称することとする。
まず、本発明の第二実施例について説明する。この実施例の特徴は、発生することが予想されるシェーディングのパターンを予め複数用意しておき、それらをシステム使用者が選択可能とした点にある。
【００９３】
本発明の第二実施例に係る顕微鏡撮像システムの構成は図１及び図２に示した第一実施例に係るものと同様であるが、表示部１０７に表示される表示画面に、予想パターン切り換えボタン１７０１とパターン表示部１７０２とが設けられている点が異なっている。この表示画面例を図１５に示す。
【００９４】
本システムの使用者が入力装置４７を操作して表示部１０７の表示画面に表示されている予想パターン切り換えボタン１７０１上のいずれかの位置を図１５では不図示であるポインタでクリックさせる指示を行う度に、ＰＣ４６は例えば図１６に示す順序の繰り返しでパターン表示部１７０２に表示されるシェーディングの予想パターンを切り換える（Ｓ１８０１～Ｓ１８０４）処理を実行する。
【００９５】
次に、第二実施例におけるこの顕微鏡撮像システムの動作について説明する。図１７は、

第二実施例におけるこの顕微鏡撮像システムによって実行される観察画像の撮影・記録動作の手順をフローチャートで示したものである。なお、以下の説明において、ＰＣ４６によって行われる処理は、ＰＣ４６の記憶部に予め格納されている制御プログラムをＰＣ４６の有するＣＰＵが読み込んで実行することによって実現される。

【００９６】

まず、シェーディング予測に基づいた露出補正制御について説明する。

観察標本を観察画像の視野から外しておいた状態で、本システムの使用者が入力装置４７を操作して表示部１０７の表示画面（図１５）に表示されている背景撮影ボタン３０１上のいずれかの位置を不図示のポインタでクリックさせる指示を行うと、図１７に示されている手順の実行が開始され、ＡＥ可変利得増幅器３７及びＷＢ可変利得増幅器３３に利得の初期値である「１」が設定されて背景画像の撮像動作が行われ、背景画像である１フレーム分の画像データとアドレスデータがＰＣ４６の記憶部で格納される一方で、これらのデータが輝度分布検出部４３と画像データ修正部４４とへ出力されるまでの動作（Ｓ１５０１からＳ１５０３にかけての動作）は、第一実施例における動作（図４のＳ５０１からＳ５０３にかけての動作）と同様である。

【００９７】

輝度分布検出部４３は、受け取った画像データ及びアドレスデータに基づいて、図１８に示すような背景画像の中央の矩形領域（ｓ１）及びその領域を通る水平線若しくは垂直線に沿う複数の矩形領域、図１８の例では１７個の矩形領域（ｓ１～ｓ１７）の各々の輝度平均値を算出する。算出されたこれらの画像輝度平均値は画像データ修正部４４の有する不図示のメモリに格納される。

【００９８】

続いて、画像データ修正部４４は、上述した矩形領域のうちの矩形領域ｓ１を除いた矩形領域（ｓ２～ｓ１７）について、矩形領域ｓ１との輝度平均値の差分値を算出し（Ｓ１５０４）、算出された差分値を画像データ修正部４４の有するメモリに同様に格納する（Ｓ１５０５）。この差分値がシェーディング予測結果に基づいた露出補正制御のための制御値として使用される。

【００９９】

以上のデータ処理によって、画像データ修正部４４のメモリには、第一実施例と同様、図６に示すテーブル内のデータが格納されることとなる。

この後、メモリコントローラ４２は、背景画像の撮影が終了したことをＰＣ４６へＩ／Ｆ部４５を介して通知する（Ｓ１５０６）。

この通知を受け取ったＰＣ４６では、表示部１０７に表示されている撮像画面におけるクリック操作を禁止状態としていた本撮影ボタン３０２、自動露出補正ボタン３０３、及び自動ホワイトバランス補正ボタン３０４を操作可能状態に戻す処理が実行される。

【０１００】

次に、本システムの使用者が観察標本を観察画像の視野内へ戻し、露出補正を行わせるべく、マウス等の入力装置４７を操作して自動露出補正ボタン３０３上のいずれかの位置を不図示のポインタでクリックさせる指示を行うと、ＰＣ４６はＩ／Ｆ部４５を介してメモリコントローラ４２に指示を与え、指定領域３０５内の画像データとその画像データを示すアドレスとをフレームメモリ４１から画像データ修正部４４へ送付させる処理を実行する。なお、このとき、ＰＣ４６は、表示部１０７のパターン表示部１７０２におけるシェーディングの予想パターンの現在の表示内容（図１６に示した切り替え手順によって切り換えられた現在の表示内容）を示している情報を画像データ修正部４４へ送付する処理を併せて実行する。

【０１０１】

画像データ修正部４４は、ＰＣ４６から送られてきたシェーディング予想パターンの情報を読み出し（Ｓ１５０７）、この情報に応じた修正を行った画像データをＡＥ評価部３９へ送付する。

例えば、シェーディング予想パターンの情報がＯＦＦ（図１６のＳ１８０１）を示してい

たときには、画像データ修正部４４は、入力された画像データに対して何らの修正を行うことなくそのままその画像データをＡＥ評価部３９へ出力する。

【０１０２】

また、この予想パターン情報がパターン１（図１６のＳ１８０２）のときには、既に説明した第一実施例と同様のパターン（図７に示したシェーディング予想パターン）が選択されているものとし、画像データ修正部４４は、前掲した（３）式の演算、すなわち、入力された画像データで表現されている画像の各画素の位置と中心位置との距離に基づいた前述した差分値を入力輝度値に加算する演算を行い、得られた出力輝度値をＡＥ評価部３９へ出力する。

【０１０３】

また、この予想パターン情報がパターン２（図１６のＳ１８０３）のときには、画像データ修正部４４は、入力された画像データで表現されている画像の各画素の水平方向の位置が、その画面全体を水平方向に区切った複数の領域（図１９（ａ）のｈ１～ｈ９の各領域）のうちのいずれに属するかを各画素の位置を示すアドレスに基づいて判別する。

【０１０４】

ここで、画素の位置を示すアドレスがｈｉ（ｉ＝１，２，３，…，９）のいずれかに含まれていることを示していたならば、画像データ修正部４４は、図６に示した画像データ修正部４４のメモリに格納されている差分値のうちｓｉで示される位置に格納されているものを、その画素についての入力画像輝度値に加算する演算を行い、得られた出力輝度値をＡＥ評価部３９へ出力する。

【０１０５】

また、この予想パターン情報がパターン３（図１６のＳ１８０４）のときには、画像データ修正部４４は、入力された画像データで表現されている画像の各画素の垂直方向の位置が、その画面全体を垂直方向に区切った複数の領域（図１９（ｖ）のｖ１及びｖ１０～ｖ１７の各領域）のうちのいずれに属するかを各画素の位置を示すアドレスに基づいて判別する。

【０１０６】

ここで、画素の位置を示すアドレスがｖｉ（ｉ＝１，１０，１１，…，１７）のいずれかに含まれていることを示していたならば、画像データ修正部４４は、図６に示した画像データ修正部４４のメモリに格納されている差分値のうちｓｉで示される位置に格納されているものを、その画素についての入力画像輝度値に加算する演算を行い、得られた出力輝度値をＡＥ評価部３９へ出力する。

【０１０７】

つまり、パターン１～３を操作者が切り換えて選択すると、画像データ修正部４４は画像データを異なった方法で修正し、また、ＯＦＦの選択を行ったときには画像データ修正部４４は画像データの修正を行わない。

この後、画像データ修正部４４からＡＥ評価部３９へ送られてきた画像データに基づいてＡＥ設定３８が指定領域３０５の画像データに対する露出時間と利得値との補正のための設定を行った後、本システムの使用者が入力装置４７を操作して本撮影ボタン３０２上のいずれかの位置を不図示のポインタでクリックさせる指示を行うことにより、露出補正が適正になされている画像データがフレームメモリ４１からＰＣ４６に取り込まれてシェーディング補正がされ、補正後の画像データがＰＣ４６内の記憶部に保存され撮像が終了するまでの処理の手順（Ｓ１５０８～Ｓ１５１０）は、第一実施例におけるもの（Ｓ５０７～Ｓ５０９）と同様である。

【０１０８】

以上のようにして実現される、第二実施例に係るシェーディング予測結果に基づく露出補正制御の効果について図２０を用いて説明する。

シェーディングの発生は、撮像レンズ等の光学的な要因によるものと、入射方向に対する撮像素子の感度ムラなど撮像デバイス自体に起因するものとに大別される。前者の要因によって生じるシェーディングのパターンの典型的な例としては、画像の中心部から周辺部

にかけて同心円状に光量が落ちているものが知られている。前述したもののうち図７や図８（ａ）に示したシェーディングのパターンがまさにこのパターンであるといえる。

【０１０９】

一方、後者の要因によって生じるシェーディングのパターンの典型的な例としては、画像の水平方向や垂直方向などある一定の方向に沿って輝度分布が変化し、画面端の光量が落ちているものが知られている。図１９や図２０に示したシェーディングのパターンがこのパターンである。

【０１１０】

第一実施例においては、光量落ちが同心円状に発生していた場合、画像データ修正部４４は同心円状のパターンに応じて周辺部の輝度値を修正した値をＡＥ評価部３９へ出力する。この結果、ＡＥ設定部３８は近似的に画面全体で一様な輝度値を基にして露出補正のための設定値を求めるようになるので、撮像画像の中心付近が明る過ぎとなってしまうことや、その後のシェーディング補正によってシステム使用者による測光指定部位が明る過ぎとなってしまうことが回避される。

【０１１１】

しかし、光量落ちが水平方向に発生していた場合、例えば観察画面の左方が暗くなっている場合、第一実施例の手法でＡＥ評価部３９に入力される画像データの修正を行うと、画面右方の輝度値までも高めてしまうために輝度平均値が大きくなってしまう。こうなると、露出補正の設定は逆に光量を下げる方向とされる結果、観察画像が暗くなってしまうおそれがある。

【０１１２】

第二実施例では、光量落ちが水平方向に発生している場合に使用者がパターン１を選択した状態で露出補正を指示すると、第一実施例と同様に、同心円状のパターンに応じて周辺部の輝度値を修正した値で露出補正のための設定値を求めることとなるため、観察画像が暗くなってしまう。

【０１１３】

しかし、このような場合であっても、第二実施例では、使用者がパターン２の選択に切り換えた後に本システムに対して露出補正を指示すれば、画像の輝度が水平方向に落ちていたとしても（図２０（ａ）のＡ）、画像の中心付近の輝度に近似的に補正した輝度分布（同図Ｂ）に基づいてＡＥ設定部３８が露出補正のための設定値を求めるので、撮影・記録された観察画像が暗くなることが防止される。

【０１１４】

また、光量落ちが垂直方向に発生している場合に使用者がパターン１を選択した状態で露出補正を指示すると、第一実施例と同様に、同心円状のパターンに応じて周辺部の輝度値を修正した値で露出補正のための設定値を求めることとなるため、観察画像が暗くなってしまう。

【０１１５】

しかし、このような場合であっても、第二実施例では、使用者がパターン３の選択に切り換えた後に本システムに対して露出補正を指示すれば、画像の輝度が垂直方向に落ちていたとしても（図２０（ｂ）のＣ）、画像の中心付近の輝度に近似的に補正した輝度分布（同図Ｄ）に基づいてＡＥ設定部３８が露出補正のための設定値を求めるので、撮影・記録された観察画像が暗くなることが防止される。

【０１１６】

次に、第二実施例におけるシェーディング予測に基づいたホワイトバランス補正の制御について説明する。

ホワイトバランス補正の制御の処理手順は、上記の露出補正の制御（図１７）と同様であるため詳細な説明は省略するが、画像データにおける各画素の輝度値をすべてＲＧＢ各色別に取得してその各々について輝度分布を修正した値が画像データ修正部４４からホワイトバランス検出部３５へ送付する点が異なっている。

【０１１７】

第二実施例に係るシェーディング予測結果に基づくホワイトバランス補正制御の効果について図２１を用いて説明する。
背景画像が図２１に示すような輝度分布、すなわちＲ色の輝度分布がＧＢ色よりも落ちており、更にＲ色の輝度分布においてもその水平方向の右方が落ちている輝度分布を有している場合、第一実施例に係る手法でＲＧＢ各色別の輝度分布の修正を行うと、同心円状に等しく周辺部の輝度を上昇させるため、Ｒの輝度分布Ａ’はＣ’へと修正されてしまう。この状態において例えば画像の左端寄りのＳ５の領域を指定してホワイトバランス補正を指示した場合には、ＲＧＢの各色の輝度値はその領域内ではほぼ等しいためＲＧＢの利得値はほぼ同一の値となってしまう。従って、ＧＢに比べてＲが小さいシアン色の背景色を白とするように設定してもホワイトバランスの補正が適切になされない。

【０１１８】
一方、第二実施例においては、使用者がパターン１を選択した状態でホワイトバランス補正を指示すると、第一実施例と同様にホワイトバランスの補正が適切になされない。しかし、使用者がパターン２を選択した状態でホワイトバランス補正を指示すれば、ホワイトバランスを検出するための画像データの輝度分布が水平方向に対してほぼ一様に修正される（図２１のＢ’）ので、Ｒ色の輝度を上昇させるように利得の設定がなされることとなり、背景色が適切に白色に補正される。

【０１１９】
また、輝度分布が垂直方向に変化しているのであれば、使用者がパターン３を選択した状態でホワイトバランス補正を指示すれば、同様に背景色が白色に適切に補正される。
このように、第二実施例によれば、使用者によって選択されるシェーディング予想パターンで近似的に周辺光量不足を修正した画像データに基づいて露出補正やホワイトバランス補正を行うため、観察状態によってシェーディングの状態が異なっていても適切な明るさ・色彩バランスの観察画像が得られるようになる。

【０１２０】
次に本発明の第三実施例について説明する。この実施例の特徴は、背景画像についての画像データから得られる全ての画素について、制御値である各画素の輝度修正値とその画像上の位置を示すアドレスとを予めシステム内のメモリに格納しておき、画素単位で修正した画像データに対して露出補正、ホワイトバランス補正を行うことにある。

【０１２１】
本発明の第三実施例に係る顕微鏡撮像システムの構成は図１及び図２に示した第一実施例に係るものと同様であるため詳細な説明は省略するが、第三実施例に係る顕微鏡撮像システムでは、画像処理部制御部１０４の動作が第一実施例に係るものと異なっている。

【０１２２】
観察標本を観察画像の視野から外しておいた状態で、本システムの使用者が入力装置４７を操作して表示部１０７の表示画面に表示されている背景撮影ボタン３０１上のいずれかの位置をポインタでクリックさせる指示を行うと、ＡＥ可変利得増幅器３７及びＷＢ可変利得増幅器３３に利得の初期値である「１」が設定されて背景画像の撮像動作が行われ、背景画像である１フレーム分の画像データとアドレスデータがＰＣ４６の記憶部で格納される一方で、これらのデータが輝度分布検出部４３と画像データ修正部４４とへ出力されるまでの動作は、第一実施例における動作（図４のＳ５０１からＳ５０３にかけての動作）と同様である。

【０１２３】
輝度分布検出部４３は、受け取った画像データ及びアドレスデータに基づいて、図２２に示すような背景画像の中央の矩形領域Ｓの輝度平均値を算出し、更に、アドレスデータを参照して各画素の輝度値と中心領域Ｓの輝度値との差分値を算出する（図４のＳ５０４に相当）。算出された全画素分の差分データは画像データ修正部４４の有する不図示のメモリに格納される（図４のＳ５０５に相当）。この差分値がシェーディング予測結果に基づいた露出補正制御及びホワイトバランス補正制御のための制御値として使用される。

【０１２４】

以上のデータ処理によって、画像データ修正部４４のメモリには、図２３に示すような、各画素に対応する差分データが画像データの全画素分格納されることとなる。
この後、メモリコントローラ４２は、背景画像の撮影が終了したことをＰＣ４６へＩ／Ｆ部４５を介して通知する（図４のＳ５０６に相当）。
この通知を受け取ったＰＣ４６では、表示部１０７に表示されている撮像画面におけるクリック操作を禁止状態としていた本撮影ボタン３０２、自動露出補正ボタン３０３、及び自動ホワイトバランス補正ボタン３０４を操作可能状態に戻す処理が実行される。

【０１２５】

次に、本システムの使用者が観察標本を観察画像の視野内へ戻し、露出補正を行わせるべく、マウス等の入力装置４７を操作して自動露出補正ボタン３０３上のいずれかの位置をポインタでクリックさせる指示を行うと、ＰＣ４６はＩ／Ｆ部４５を介してメモリコントローラ４２に指示を与え、指定領域３０５内の画像データとその画像データを示すアドレスとをフレームメモリ４１から画像データ修正部４４へ送付させる処理を実行する。

【０１２６】

画像データ修正部４４は、メモリコントローラ４２から送られてきたアドレス（ｘ，ｙ）と自身のメモリに格納されているアドレスとを比較し、一致したアドレスに保存されている差分値をそのアドレスに対応する画素の輝度値に加算し、加算結果をＡＥ評価部３９へ出力する。

【０１２７】

この後、ＡＥ評価部３９から指定領域３０５の輝度積算値を受け取ったＡＥ設定部３８が露出利得と露出時間とを求め、ＡＥ可変利得増幅器３７及びＣＣＤ駆動部４８に設定した後、システム使用者が撮影を指示し、画像撮影及び画像データの記録が完了するまでの手順は第一実施例と同様である。

【０１２８】

また、本システムの使用者がホワイトバランス補正を指示したときの各部動作は、上述した露出補正の指示がなされたときの動作とほぼ同様であるため詳細は省略するが、輝度分布検出部４３が画像データの輝度分布をすべてＲＧＢ各色別に取得して処理し、その各々について輝度分布を修正した画像データをホワイトバランス検出部３５に入力する点が異なっている。

【０１２９】

以上のようにして実現される、第三実施例に係るシェーディング予測結果に基づく露出補正制御及びホワイトバランス補正制御の効果について図２４を用いて説明する。
背景画像が図２４に示すようなランダムな輝度分布を有する場合、第一実施例のように同心円状に画像データの輝度分布を修正したり、第二実施例のように一定方向に変化する輝度分布を仮定して輝度値を修正したりしても、修正後の輝度値は部位ごとにまちまちになってしまう。

【０１３０】

これに対し、第三実施例に係るシステムでは、画像を構成する全ての画素について、画像の中央近辺の輝度平均値との差分を画素単位で加算して得られる、背景画像の輝度値を全体で一様になるように修正した画像データに基づいて露出補正やホワイトバランス補正が行われる。

【０１３１】

従って、背景画像の輝度分布に規則性が見られない、全くのランダムな分布を呈しているものであっても、露出補正を適切に行うことができる。
また、背景画像がＲＧＢ各色別にランダムな輝度分布を有する場合も、画像全体で一様な輝度分布に修正した画像データに基づいたホワイトバランスの補正がなされるため、観察画像に対するシステム使用者の指定部位によって色バランスが変化してしまうことなく、一様にホワイトバランスを補正することができる。

【０１３２】

なお、以上までに説明した第一、第二、及び第三の各実施例において図１及び図２に示し

た顕微鏡撮像システムの画像処理部１０３及び画像処理部制御部１０４における各構成要素に行わせていた各種の処理を前述したような標準的な構成を有するコンピュータのＣＰＵに行わせるための制御プログラムを作成し、この作成された制御プログラムをこのコンピュータで読み取り可能な記録媒体に記録させておき、その制御プログラムを記録媒体からこのコンピュータに読み込ませてＣＰＵで実行させるようにすれば、本発明に係るシェーディング予測に基づいた露出補正制御若しくはホワイトバランス補正制御をこのコンピュータに行わせることもできる。

【０１３３】

記録させた制御プログラムをコンピュータで読み取ることの可能な記録媒体としては、例えば、コンピュータに内蔵若しくは外付けの付属装置として備えられるＲＯＭやハードディスク装置などの記憶装置、フレキシブルディスク、ＭＯ（光磁気ディスク）、ＣＤ－ＲＯＭ、ＤＶＤ－ＲＯＭなどといった携帯可能記録媒体等が利用できる。

【０１３４】

また、記録媒体は通信回線を介してコンピュータシステムと接続される、プログラムサーバとして機能するコンピュータが備えている記憶装置であってもよい。この場合には、制御プログラムを表現するデータ信号で搬送波を変調して得られる伝送信号を、プログラムサーバから伝送媒体である通信回線を通じてコンピュータシステムへ伝送するようにし、コンピュータシステムでは受信した伝送信号を復調して制御プログラムを再生することでこの制御プログラムをＣＰＵで実行できるようになる。

【０１３５】

なお、本発明は、上述した実施形態に限定されることなく、本発明の要旨を逸脱しない範囲内で種々の改良・変更が可能である。

例えば、前述した第一実施例において、制御値である輝度の差分値を算出する際の同心円パターンの中心位置を移動可能としてもよく、そのためには画像を構成する各画素の位置を示すアドレスに適当なオフセット値を加算するようにすればよい。また、前述した第一及び第二実施例において、制御値である輝度の差分値を算出する際の領域の形状は矩形に限定されるものではなく、任意の形状に変形可能である。また、その大きさも任意に変更可能である。こうすることにより、多種多様なシェーディングに対して本発明に係る手法を適用可能とするだけでなく，露出補正の精度を高め、システム使用者の意図に対してより忠実な露出補正処理やホワイトバランス補正処理を提供することが可能となる。

【０１３６】

【発明の効果】

以上詳細に説明したように、本発明は、被写体が表されている被写体画像の露出若しくはホワイトバランスを補正する画像処理を、この画像処理が施されると被写体画像に発生することが予測されるシェーディングについての予測結果に基づいて制御するようにする。

【０１３７】

こうすることにより、シェーディング補正と露出補正若しくはホワイトバランス補正とを両立させた適切な画像が提供できるようになるという効果を本発明は奏する。

【図面の簡単な説明】

【図１】本発明を実施する顕微鏡撮像システムの概略構成を示す図である。

【図２】本発明を実施する顕微鏡撮像システムの詳細構成を示す図である。

【図３】観察画像の表示例を示す図である。

【図４】観察画像の撮影・記録動作の処理手順を示す図である。

【図５】背景画像に設定される部分領域を示す図である。

【図６】画像データ修正部内のメモリに格納されるデータを示す図（その１）である。

【図７】シェーディングの発生パターンの例を示す図である。

【図８】シェーディング補正の様子を示す図である。

【図９】シェーディング予測結果に基づく露出補正制御を行わない顕微鏡用撮像システムの構成を示す図である。

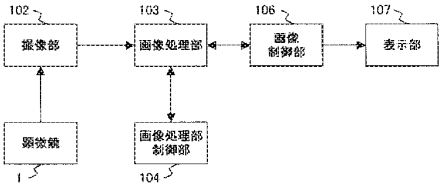
【図１０】本発明に係るシェーディングの予測結果に基づいた露出補正制御の効果を示す

図である。
【図１１】画像データ修正部内のメモリに格納されるデータを示す図（その２）である。
【図１２】色シェーディングが発生している背景画像の輝度分布例を示す図である。
【図１３】シェーディング予測結果に基づく制御のされていないホワイトバランス補正を行ったときの輝度分布を示す図である。
【図１４】シェーディング予測結果に基づく制御がされているホワイトバランス補正を行ったときの輝度分布を示す図である。
【図１５】第二実施例における観察画像の表示例を示す図である。
【図１６】シェーディング予想パターンの切換手順を示す図である。
【図１７】第二実施例における観察画像の撮影・記録動作の処理手順を示す図である。
【図１８】第二実施例において背景画像に設定される部分領域を示す図である。
【図１９】シェーディングの発生予想パターンの例を示す図である。
【図２０】第二実施例に係るシェーディング予想結果に基づいた露出補正制御の効果を説明する図である。
【図２１】第二実施例に係るシェーディング予想結果に基づいたホワイトバランス補正制御の効果を説明する図である。
【図２２】第三実施例において背景画像に設定される部分領域を示す図である。
【図２３】画像データ修正部内のメモリに格納されるデータを示す図（その３）である。
【図２４】第三実施例に係る制御の効果を説明する図である。
【符号の説明】
１　顕微鏡
３　透過観察用光学系
４　落射観察用光学系
５　透過照明用光源
６　コレクタレンズ
７　透過用フィルタユニット
８　透過視野絞り
９　折曲げミラー
１０、１１　コンデンサ光学素子ユニット
１２　トップレンズユニット
１３　落射照明用光源
１４　落射用フィルタユニット
１５　落射シャッタ
１６　落射視野絞り
１７　落射開口絞り
１８　ステージ
１９　対物レンズ
２０　レボルバ
２１　キューブユニット
２２　ビームスプリッタ
３１　撮像素子
３２　前置処理部
３３　ＷＢ可変利得増幅器
３４　ＷＢ利得設定部
３５　ホワイトバランス検出部
３７　ＡＥ可変利得増幅器
３８　ＡＥ設定部
３９　ＡＥ評価部
４１　フレームメモリ
４２　メモリコントローラ

４３　輝度分布検出部
４４　画像データ修正部
４５　Ｉ／Ｆ部
４６　ＰＣ
４７　入力装置
４８　ＣＣＤ駆動部
４９　Ａ／Ｄ変換部
１０２　撮像部
１０３　画像処理部
１０４　画像処理部制御部
１０６　画像制御部
１０７　表示部
３０１　背景撮影ボタン
３０２　本撮影ボタン
３０３　自動露出補正ボタン
３０４　自動ホワイトバランス補正ボタン
３０５　指定領域
３０６　標本像
１７０１　予想パターン切り換えボタン
１７０２　パターン表示部

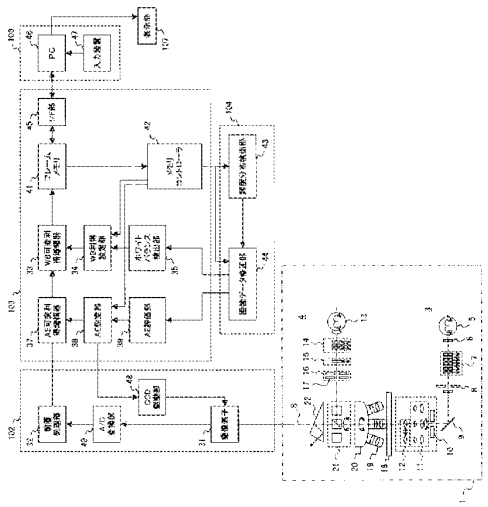
【図１】

本発明を実施する顕微鏡撮像システムの概略構成を示す図



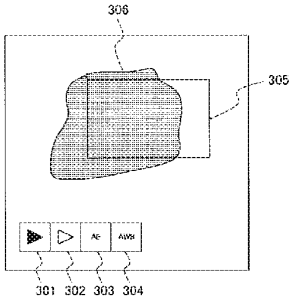
【図２】

本発明を実施する顕微鏡撮像システムの詳細構成を示す図



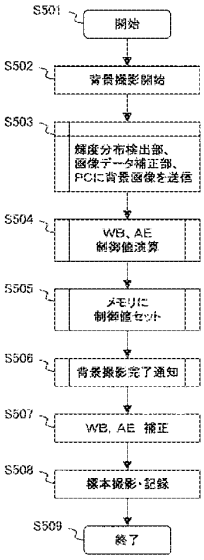
【図３】

観察画像の表示例を示す図



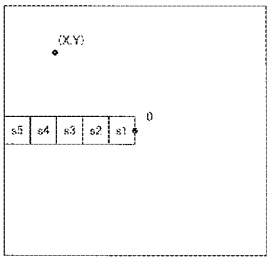
【図４】

観察画像の撮影・記録動作の処理手順を示す図



【図５】

背景画像に設定される部分領域を示す図



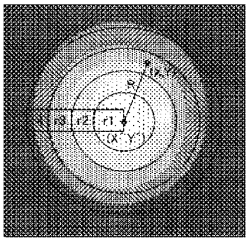
【図６】

画像データ修正部内のメモリに格納される
データを示す図（その１）

領域	中心からの距離	平均値	⊿差分（制御値）
s1	0～r1	平均値1	0
s2	r1～r2	平均値2	平均値1－平均値2
s3	r2～r3	平均値3	平均値1－平均値3
s4	r3～r4	平均値4	平均値1－平均値4
s5	r4～r5	平均値5	平均値1－平均値5
・・・	・・・	・・・	・・・

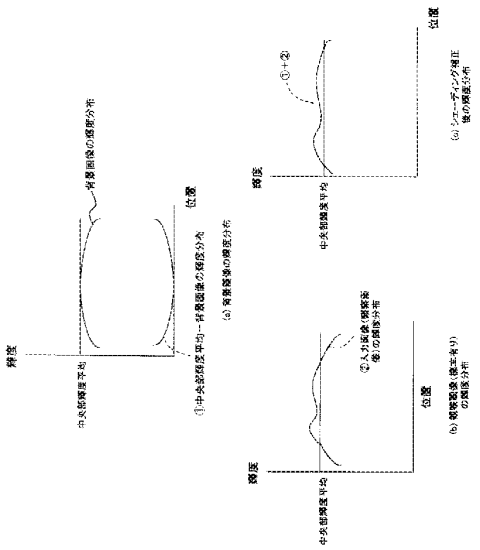
【図７】

シェーディングの発生パターンの例を示す図



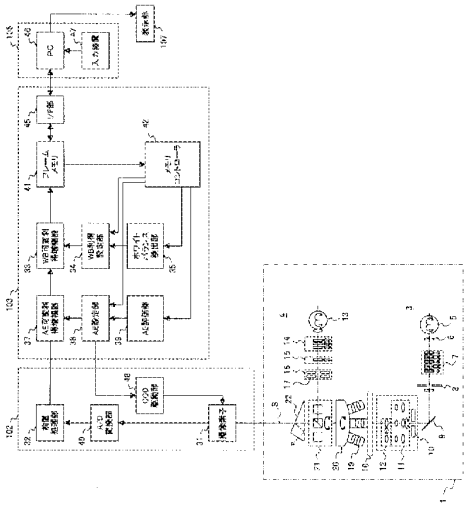
【図８】

シェーディング補正の様子を示す図



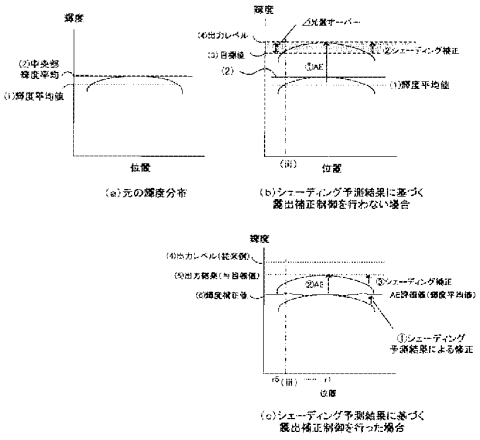
【図９】

シェーディング予測結果に基づく露出補正制御を行わない顕微鏡用撮像システムの詳細構成を示す図



【図１０】

本発明に係るシェーディング予測結果に基づいた露出補正制御の効果を説明する図



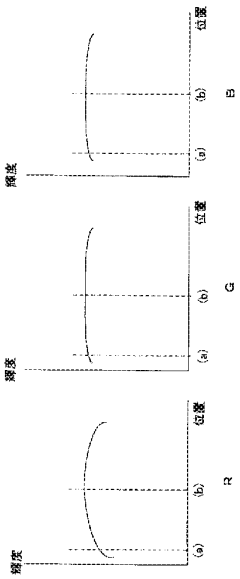
【図１１】

画像データ修正部内のメモリに格納されるデータを示す図(その2)

領域	中心からの距離	R					G					B				
		平均値	Δ差分				平均値	Δ差分				平均値	Δ差分			
s1	0～r1	平均値1	0				平均値1	0				平均値1	0			
s2	r1～r2	平均値2	平均値1－平均値2				平均値2	平均値1－平均値2				平均値2	平均値1－平均値2			
s3	r2～r3	平均値3	平均値1－平均値3				平均値3	平均値1－平均値3				平均値3	平均値1－平均値3			
s4	r3～r4	平均値4	平均値1－平均値4				平均値4	平均値1－平均値4				平均値4	平均値1－平均値4			
s5	r4～r5	平均値5	平均値1－平均値5				平均値5	平均値1－平均値5				平均値5	平均値1－平均値5			
・・・	・・・	・・・	・・・	・・・	・・・	・・・	・・・	・・・	・・・	・・・	・・・	・・・	・・・	・・・	・・・	・・・

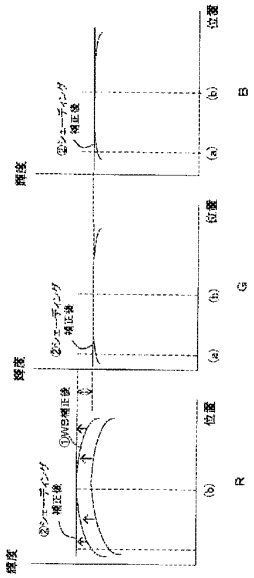
【図１２】

色シェーディングが発生している背景画像の
輝度分布例を示す図



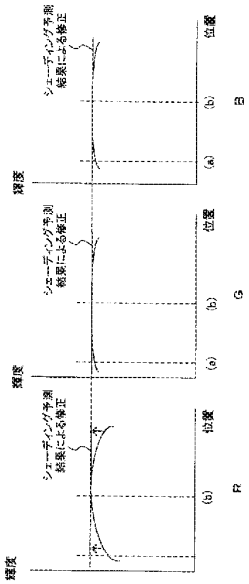
【図１３】

シェーディング予測結果に基づく制御のされていない
ホワイトバランス補正を行ったときの輝度分布を示す図



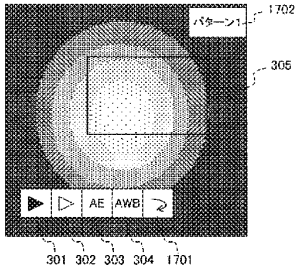
【図１４】

シェーディング予測結果に基づく制御がされている
ホワイトバランス補正を行ったときの輝度分布を示す図



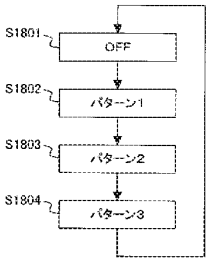
【図１５】

第二実施例における観察画像の表示例を示す図



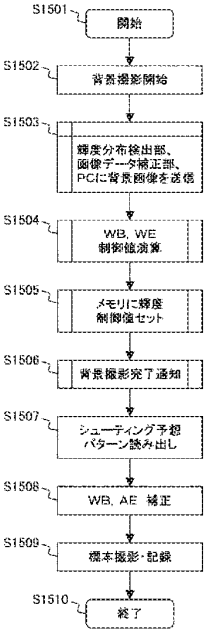
【図１６】

シェーディング予想パターンの
切換手順を示す図



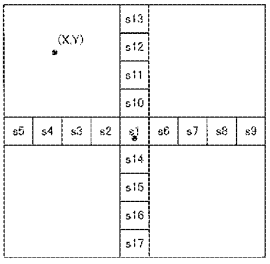
【図１７】

第二実施例における観察画像の
撮影・記録動作の処理手順を示す図



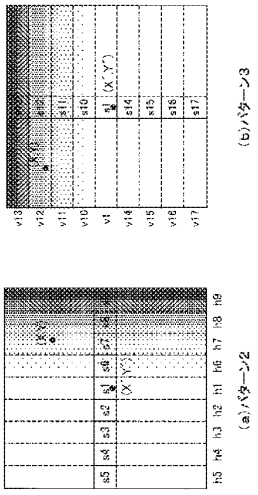
【図１８】

第二実施例において、背景画像に設定される
部分領域を示す図



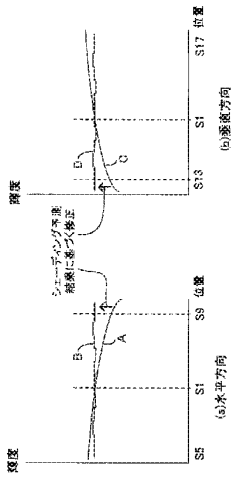
【図１９】

シェーディングの発生予想パターンの例を示す図



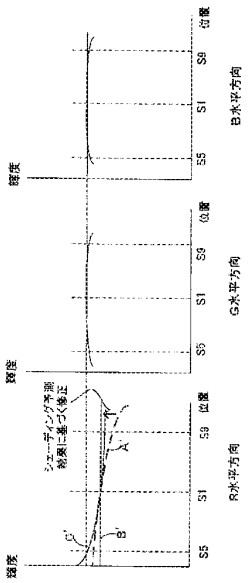
【図２０】

第二実施例に係るシェーディング予測結果に基づいた露出補正制御の効果を説明する図



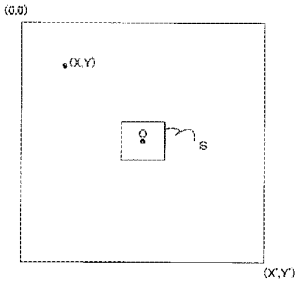
【図２１】

第二実施例に係るシェーディング予測結果に基づいたホワイトバランス補正制御の効果を説明する図



【図２２】

第三実施例において背景画像に設定される部分領域を示す図



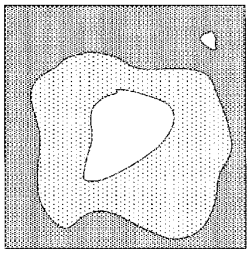
【図２３】

画像データ修正部内のメモリに格納されるデータを示す図(その3)

位置(X,Y)	領域S平均値との⊿値分
(0, 0)	0
(1, 0)	5
(2, 0)	3
(3, 0)	1
(4, 0)	0
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【図２４】

第三実施例に係る制御の効果を説明する図



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s):	Neal Solomon	Examiner:	Marly Camargo
Serial No.:	13/691,805	Group Art Unit:	2699
Filed:	December 2, 2012	Docket:	5311.001US3
Customer No.:	21186	Confirmation No.:	6244
Title:	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS		

COMMUNICATION CONCERNING PRIOR OR COPENDING APPLICATION(S)

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Pursuant to the guidance of MPEP §§ 2001.06(b) and 2004(9), Applicant would like to bring the following additional application(s) to the Examiner's attention. The identification of these applications is not intended to suggest that the subject matter claimed in any listed application is, or has been, substantially similar to any claim or claims in the present application.

Serial No./ Patent No.	Filing Date	Attorney Docket	Title
11/825,521 7,612,805	July 6, 2007	5311.001US1	DIGITAL IMAGING SYSTEM AND METHODS FOR SELECTIVE IMAGE FILTRATION
12/586,221 8,451,339	September 18, 2009	5311.001US2	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS
16/692,939	November 22, 2019	5311.001US4	DIGITAL CAMERA WITH IN-CAMERA SOFTWARE FOR IMAGE CORRECTION
16/692,972	November 22, 2019	5311.001US5	DIGITAL CAMERA WITH WIRELESS IMAGE TRANSFER
16/694,838	November 25, 2019	5311.001US6	DIGITAL CAMERA WITH IN-CAMERA SOFTWARE FOR DIGITAL IMAGE CORRECTION OF PIXEL INFORMATION

16/694,850	November 25, 2019	5311.001US7	WIRELESS DEVICE WITH BUILT-IN CAMERA AND UPDATABLE CAMERA SOFTWARE FOR IMAGE CORRECTION

Respectfully submitted,

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. Box 2938
Minneapolis, MN 55402
(612) 373-6912

Date 1/16/2020 By /Timothy E. Bianchi/
Timothy E. Bianchi
Reg. No. 39,610

Electronic Patent Application Fee Transmittal

Application Number:	13691805
Filing Date:	02-Dec-2012
Title of Invention:	Digital imaging system for correcting video image aberrations
First Named Inventor/Applicant Name:	Neal Solomon
Filer:	Garrett M. Hall/Jamie Johnson
Attorney Docket Number:	5311.001US3

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
SUBMISSION- INFORMATION DISCLOSURE STMT	2806	1	120	120
		Total in USD ($)		**120**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s): Neal Solomon
Title: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

Docket No.:	5311.001US3	Serial No.:	13/691,805
Filed:	December 2, 2012	Due Date:	N/A
Examiner:	Marly Camargo	Group Art Unit:	2699
Customer No.:	21186	Confirmation No.:	6244

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

We are transmitting herewith the following attached items (as indicated with an "X"):

X Communication Concerning Prior and Copending Applications (2 pgs.)
X Supplemental Information Disclosure Statement (2 pgs.), Form 1449 (4 pgs.) Copies of Cited References (72).
X Authorization to charge Deposit Account 19-0743 in the amount of $120.00 to cover the fee for consideration of Information Disclosure Statement under 37 C.F.R. § 1.97(c).

If not provided for in a separate paper filed herewith, please consider this a PETITION FOR EXTENSION OF TIME for sufficient number of months to enter these papers and please charge any additional fees or credit overpayment to Deposit Account No. 19-0743. If applicable, any papers or fees supplied herewith are considered to be timely filed pursuant to 37 C.F.R. § 1.7(a), the response period falling on a Federal Holiday, Saturday or Sunday being extended to the next succeeding business day.

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
Customer No.: 21186

By: /Timothy E. Bianchi/
Timothy E. Bianchi
Reg. No. 39,610

Modified form PTO/SB/08A(04-07) OMB 651-0031
US Patent & Trademark Office: U.S. DEPARTMENT OF COMMERCE
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Substitute for form 1449A/PTO **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** (Use as many sheets as necessary)	*Complete if Known*	
	Application Number	13/691,805
	Filing Date	December 2, 2012
	First Named Inventor	Neal Solomon
	Group Art Unit	2699
	Examiner Name	Marly Camargo
Sheet 1 of 4	Attorney Docket No: 5311.001US3	

US PATENT DOCUMENTS

Examiner Initial *	USP Document Number	Publication Date	Name of Patentee or Applicant of cited Document
	US-6,023,977	2/15/2000	Langdon, Donald R, et al.
	US-6,055,330	4/25/2000	Eleftheriadis, Alexandros, et al.
	US-6,508,764	1/21/2003	Thiele, Karl E, et al.
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	US-7,551,205	6/23/2009	Kubo, Masahiro, et al.
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	US-7,619,663	11/17/2009	Sakurai, Keiichi, et al.
	US-7,636,111	12/22/2009	Oota, Makoto
	US-7,701,484	4/20/2010	Habe, Masaru
	US-7,764,874	7/27/2010	Awazu, Kouhei, et al.
	US-8,106,976	1/31/2012	Kawasaka, Yasuki
	US-8,451,339	5/28/2013	Solomon, Neal
	US-20020163586A1	11/7/2002	Noguchi, Takafumi
	US-20030210343A1	11/13/2003	Okada, Hiroyuki
	US-20040071318A1	4/15/2004	Cheung, Humphrey, et al.
	US-20050099507A1	5/12/2005	Lee, Hoseong
	US-20050200722A1	9/15/2005	Ono, Shuji
	US-20050219391A1	10/6/2005	Sun, Jian, et al.
	US-20060285761A1	12/21/2006	Kasperkiewicz, Tomasz S, et al.
	US-20070002158A1	1/4/2007	Robinson, Dirk M
	US-20070080280A1	4/12/2007	Havens, William H
	US-20070236574A1	10/11/2007	Alon, Alex, et al.
	US-20070247672A1	10/25/2007	Nguyen, Hugh P
	US-20080151069A1	6/26/2008	Koizumi, Takahiko, et al.
	US-20080174678A1	7/24/2008	Solomon, Neal
	US-20100033604A1	2/11/2010	Solomon, Neal
	US-20100073508A1	3/25/2010	Okamoto, Satoshi
	US-20110096176A1	4/28/2011	Nakami, Yoshihiro, et al.

FOREIGN PATENT DOCUMENTS

Examiner Initial *	Foreign Document Number	Publication Date	Name of Patentee or Applicant of cited Document	T 1
	JP-2004343358A	12/2/2004	Kishida, Hironori	

EXAMINER DATE CONSIDERED

* EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant is to place a check mark here if English language Translation is attached

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	Filing Date	December 2, 2012
	First Named Inventor	Neal Solomon
	Group Art Unit	2699
	Examiner Name	Marly Camargo
Sheet 2 of 4	Attorney Docket No: 5311.001US3	

OTHER DOCUMENTS – NON PATENT LITERATURE DOCUMENTS

Examiner Initial *	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T 1
	"36-1 Canon Declaration of Ryan M. Mott 11/7/2019", 5 pgs	
	"36-13 Canon Exhibit L to Declaration of Ryan M. Mott 11/7/2019", 9 pgs	
	"36-15 Canon Exhibit N to Declaration of Ryan M. Mott 11/7/2019", 8 pgs	
	"36-17 Canon Exhibit P to Declaration of Ryan M. Mott 11/7/2019", 9 pgs	
	"36-20 Canon Exhibit S to Declaration of Ryan M. Mott 11/7/2019", 9 pgs	
	"36-22 Canon Declaration of Ana C. Tavares 11/7/2019", 6 pgs	
	"36-23 Canon Declaration of Hironori Aokage 11/7/2019", 3 pgs	
	"36-24 Canon Declaration of Seiichi Hamada 11/7/2019", 3 pgs	
	"39 Canon Redacted Opposed Motion to Transfer Venue to Edny", 21 pgs	
	"Application Serial No. 11/825,521, Non Final Office Action mailed 08-15-08", 13 pgs	
	"Application Serial No. 11/825,521, Notice of Allowance mailed 07-23-19", 22 pgs	
	"Application Serial No. 11/825,521, Response filed 04-27-09 to Restriction Requirement mailed 04-02-09", 3 pgs	
	"Application Serial No. 11/825,521, Response filed 12-12-08 to Non Final Office Action mailed 08-15-08", 10 pgs	
	"Application Serial No. 11/825,521, Restriction Requirement mailed 04-02-09", 6 pgs	
	"Application Serial No. 12/586,221, Non Final Office Action mailed 05-24-12", 18 pgs	
	"Application Serial No. 12/586,221, Notice of Allowance mailed 09-06-12", 10 pgs	
	"Application Serial No. 12/586,221, PTO Response to Rule 312 Communication mailed 04-25-13", 2 pgs	
	"Application Serial No. 12/586,221, Response filed 03-02-12 to Restriction Requirement mailed 12-29-11", 11 pgs	
	"Application Serial No. 12/586,221, Response filed 08-23-12 to Non Final Office Action mailed 05-24-12", 19 pgs	
	"Application Serial No. 12/586,221, Restriction Requirement mailed 12-29-11", 5 pgs	
	"Canon GL2 Instruction Manual", 163 pgs	
	"Canon Inc's Invalidity Contentions and Disclosures under P.R. 3-3 and 3-4", 2:19-cv-00246-JRG, 32 pgs	
	"Canon XL 1s A NTSC Instruction Manual", 124 pgs	
	"Canon XL1 A NTSC Instruction Manual", 88 pgs	
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	"Canon ZR10 NTSC Instruction Manual", 113 pgs	
	"Canon ZR100 Instruction Manual", 103 pgs	
	"Canon ZR20 NTSC Instruction Manual", 114 pgs	
	"Canon ZR25 MC NTSC Instruction Manual", 146 pgs	
	"Canon ZR300200 Instruction Manual", 152 pgs	

EXAMINER **DATE CONSIDERED**

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	Application Number	13/691,805
	Filing Date	December 2, 2012
	First Named Inventor	Neal Solomon
	Group Art Unit	2699
	Examiner Name	Marly Camargo
Sheet 3 of 4	Attorney Docket No: 5311.001US3	

OTHER DOCUMENTS – NON PATENT LITERATURE DOCUMENTS

Examiner Initial *	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T 1
	"Canon ZR5045 Instruction Manual", 164 pgs	
	"Canon ZR706560 Instruction Manual", 158 pgs	
	"Canon ZR90IM Instruction Manual", 153 pgs	
	"Coolpix 7900 Canon0063894", 165 pgs	
	"DxO Optics Pro Canon0063666", 153 pgs	
	"EF Lenswork III: The Eyes of EOS", 4 the ED, Canon Inc. Lens Product Group, (2009), 10 pgs	
	"JP H11-313250 11/9/1999 Canon0062291", 5 pgs	
	"JP H11-313250 English Translation 11/9/1999 Canon0065023", 6 pgs	
	"JP2000-184247 6/30/2000 Canon0062296", 12 pgs	
	"JP2000-184247 English Translation 6/30/2000 Canon0065045", 13 pgs	
	"JP2002-190979 7/5/2002 Canon0062325", 11 pgs	
	"JP2002-190979 English Translation 7/5/2002 Canon0065058", 12 pgs	
	"JP2002-199410 7/12/2002 Canon0062336", 17 pgs	
	"JP2002-199410 English Translation 7/12/2002 Canon0065070", 18 pgs	
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	"JP2004-343358 English Translation 12/2/2004 Canon0065109", 31 pgs	
	"JP2006-072660 3/16/2006 Canon0062397", 13 pgs	
	"JP2006-072660 English Translation 3/16/2006 Canon0065140", 14 pgs	
	"Kodak EasyShare V570 Canon0063819", 75 pgs	
	"Lumix DMC-FZ30 Canon 0064649", 148 pgs	
	"Olympus E-1 Canon0064059", 182 pgs	
	"Olympus E-300 Canon0064241", 212 pgs	
	"Olympus E-330 Canon0064453", 196 pgs	
	"Photoshop CS2 Canon0062668", Part 1 of 5, 163 pgs	
	"Photoshop CS2 Canon0062668", Part 2 of 5, 163 pgs	
	"Photoshop CS2 Canon0062668", Part 3 of 5, 163 pgs	
	"Photoshop CS2 Canon0062668", Part 4 of 5, 163 pgs	
	"Photoshop CS2 Canon0062668", Part 5 of 5, 163 pgs	
	"SD200-300 Digital ELPH Canon0063487", 179 pgs	
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	"US 7,738,015 6/15/2010 Canon0064866", 23 pgs	
	"US 7,936,392 5/3/2011 Canon0062617", 51 pgs	
	"US2001/0008418A1 7/19/2001 Canon0062410", 45 pgs	
	"US2003/0095197A1 5/22/2003 Canon0064797", 32 pgs	

EXAMINER **DATE CONSIDERED**

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	Application Number	13/691,805
	Filing Date	December 2, 2012
	First Named Inventor	Neal Solomon
	Group Art Unit	2699
	Examiner Name	Marly Camargo
Sheet 4 of 4	Attorney Docket No: 5311.001US3	

OTHER DOCUMENTS – NON PATENT LITERATURE DOCUMENTS		
Examiner Initial *	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T 1
	"US2004/0150732A1 8/5/2004 Canon0062455", 31 pgs	
	"US2004/0207733A1 10/21/2004 Canon0062486", 60 pgs	
	"WO2005/093653A1 6/10/2005 Canon0064889", 128 pgs	
	"Zuiko Digital 14-45mm f.3.5 Canon0065019", 2 pgs	
	"Zuiko Digital ED50mm f2.0 Macro CANON0065017", 2 pgs	

EXAMINER DATE CONSIDERED

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s):	Neal Solomon	Examiner:	Marly Camargo
Serial No.:	13/691,805	Group Art Unit:	2699
Filed:	December 2, 2012	Docket:	5311.001US3
Customer No.:	21186	Confirmation No.:	6244

Title: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT

MS Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

In compliance with the duty imposed by 37 C.F.R. § 1.56, and in accordance with 37 C.F.R. §§ 1.97 *et. seq.*, the enclosed materials are brought to the attention of the Examiner for consideration in connection with the above-identified patent application. Applicant respectfully requests that this Information Disclosure Statement be entered and the documents listed on the attached PTO 1449 Form be considered by the Examiner and made of record. Pursuant to the provisions of MPEP 609, Applicant requests that a copy of the PTO 1449 Form, initialed as being considered by the Examiner, be returned to the Applicant with the next official communication.

Pursuant to 37 C.F.R. § 1.97(c)(2), Applicant hereby authorizes the Commissioner to charge the fee of $120.00 as set forth in 37 C.F.R. § 1.17(p), to Deposit Account No. 19-0743. Please charge any additional fees or deficiencies, or credit any overpayment to Deposit Account No. 19-0743.

Pursuant to 37 C.F.R. § 1.98(a)(2), copies of cited U.S. Patents and Published Applications, and Non-Published Applications identifiable by USPTO Serial Number, are no longer required to be provided to the Office. Applicant acknowledges the requirement to submit copies of foreign patent documents and non-patent literature in accordance with 37 C.F.R § 1.98(a)(2).

The Examiner is invited to contact the undersigned at the telephone number indicated if there are any questions regarding this communication.

Respectfully submitted,

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. Box 2938
Minneapolis, MN 55402
(612) 373-6912

Date 1/16/2020 By /Timothy E. Bianchi/
Timothy E. Bianchi
TEB:caf Reg. No. 39,610

United States Patent and Trademark Office

Office of the Chief Financial Officer

Document Code:WFEE

User :70580

Sale Accounting Date:01/17/2020

Sale Item Reference Number	Effective Date
13691805	01/16/2020

Document Number	Fee Code	Fee Code Description	Amount Paid	Payment Method
I20201GI47133468	2253	EXTENSION FOR RESPONSE WITHIN 3RD MONTH	$700.00	Deposit Account

Application Number	Application/Control No.	Applicant(s)/Patent under Reexamination	
* 13/691,805 *	13/691,805	Solomon, Neal	
	Examiner	Art Unit	
	CAMARGO, MARLY S.B.	2699	

Document Code - DISQ	Internal Document - DO NOT MAIL

TERMINAL DISCLAIMER	☐ APPROVED	☑ DISAPPROVED
Date Filed: **15 January 2020**	**This patent is subject to a Terminal Disclaimer**	

Approved/Disapproved by:

/PAMELA A YOUNG/

Technology Center: PLRC

Telephone:

See Continuation Sheet

Continuation of Approved/Disapproved Comments: • The terminal disclaimer identifies a party who is not the applicant (only for applications filed on or after September 16, 2012; See FP 14.26.10):

For cases filed on/after 9/16/12, 37 CFR 1.321 specifies that only the applicant can disclaim, and the terminal disclaimer must specify the extent of the applicant's ownership.

Below is what needs to be done to correct the defects:

• A request under 37 CFR 1.46(c) to change the applicant needs to be filed, which is (1) a request, signed by a 1.33(b) party, (2) a corrected ADS (37 CFR 1.76(c)) that identifies the "new" applicant in the applicant information, and is underlined since it is new, and (3) a 3.73(c) statement showing chain of title to the new applicant. Along with the § 1.46(c) request we need a POA that gives power to the attorney who is signing the TD, along with another copy of the TD, unless they file a TD that is signed by the applicant.
Resubmit TD , no fee is required

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	Group Art Unit	2699
	Examiner Name	Marly Camargo
Sheet 1 of 4	Attorney Docket No: 5311.001US3	

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	US-6,850,272	2/1/2005	Terashita, Takaaki
	US-7,245,319	7/17/2007	Enomoto, Jun
	US-7,321,685	1/22/2008	Okada, Miyuki, et al.
	US-7,406,182	7/29/2008	Ono, Shuji
	US-7,551,205	6/23/2009	Kubo, Masahiro, et al.
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	US-20050219391A1	10/6/2005	Sun, Jian, et al.
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	US-20070080280A1	4/12/2007	Havens, William H
	US-20070236574A1	10/11/2007	Alon, Alex, et al.
	US-20070247672A1	10/25/2007	Nguyen, Hugh P
	US-20080151069A1	6/26/2008	Koizumi, Takahiko, et al.
	US-20080174678A1	7/24/2008	Solomon, Neal
	US-20100033604A1	2/11/2010	Solomon, Neal
	US-20100073508A1	3/25/2010	Okamoto, Satoshi
	US-20110096176A1	4/28/2011	Nakami, Yoshihiro, et al.

FOREIGN PATENT DOCUMENTS

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	JP-2004343358A	12/2/2004	Kishida, Hironori	

EXAMINER /MARLY S CAMARGO/ DATE CONSIDERED 01/17/2020

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ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.S.C/

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Sheet 2 of 4	Attorney Docket No: 5311.001US3	

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	"36-22 Canon Declaration of Ana C. Tavares 11/7/2019", 6 pgs	
	"36-23 Canon Declaration of Hironori Aokage 11/7/2019", 3 pgs	
	"36-24 Canon Declaration of Seiichi Hamada 11/7/2019", 3 pgs	
	"39 Canon Redacted Opposed Motion to Transfer Venue to Edny", 21 pgs	
	"Application Serial No. 11/825,521, Non Final Office Action mailed 08-15-08", 13 pgs	
	"Application Serial No. 11/825,521, Notice of Allowance mailed 07-23-19", 22 pgs	
	"Application Serial No. 11/825,521, Response filed 04-27-09 to Restriction Requirement mailed 04-02-09", 3 pgs	
	"Application Serial No. 11/825,521, Response filed 12-12-08 to Non Final Office Action mailed 08-15-08", 10 pgs	
	"Application Serial No. 11/825,521, Restriction Requirement mailed 04-02-09", 6 pgs	
	"Application Serial No. 12/586,221, Non Final Office Action mailed 05-24-12", 18 pgs	
	"Application Serial No. 12/586,221, Notice of Allowance mailed 09-06-12", 10 pgs	
	"Application Serial No. 12/586,221, PTO Response to Rule 312 Communication mailed 04-25-13", 2 pgs	
	"Application Serial No. 12/586,221, Response filed 03-02-12 to Restriction Requirement mailed 12-29-11", 11 pgs	
	"Application Serial No. 12/586,221, Response filed 08-23-12 to Non Final Office Action mailed 05-24-12", 19 pgs	
	"Application Serial No. 12/586,221, Restriction Requirement mailed 12-29-11", 5 pgs	
	"Canon GL2 Instruction Manual", 163 pgs	
	"Canon Inc's Invalidity Contentions and Disclosures under P.R. 3-3 and 3-4", 2:19-cv-00246-JRG, 32 pgs	
	"Canon XL 1s A NTSC Instruction Manual", 124 pgs	
	"Canon XL1 A NTSC Instruction Manual", 88 pgs	
	"Canon XL2 Instruction Manual", 126 pgs	
	"Canon ZR10 NTSC Instruction Manual", 113 pgs	
	"Canon ZR100 Instruction Manual", 103 pgs	
	"Canon ZR20 NTSC Instruction Manual", 114 pgs	
	"Canon ZR25 MC NTSC Instruction Manual", 146 pgs	
/M.S.C/	"Canon ZR300200 Instruction Manual", 152 pgs	

EXAMINER /MARLY S CAMARGO/ DATE CONSIDERED 01/17/2020

* EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant is to place a check mark here if English language Translation is attached

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.S.C/

Modified form PTO/SB/08A(04-07) OMB 651-0031
US Patent & Trademark Office: U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Substitute for form 1449A/PTO **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** (Use as many sheets as necessary)	*Complete if Known*	
	Application Number	13/691,805
	Filing Date	December 2, 2012
	First Named Inventor	Neal Solomon
	Group Art Unit	2699
	Examiner Name	Marly Camargo
Sheet 3 of 4	Attorney Docket No: 5311.001US3	

OTHER DOCUMENTS – NON PATENT LITERATURE DOCUMENTS

Examiner Initial *	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T1
/M.S.C/	"Canon ZR5045 Instruction Manual", 164 pgs	
	"Canon ZR706560 Instruction Manual", 158 pgs	
	"Canon ZR90IM Instruction Manual", 153 pgs	
	"Coolpix 7900 Canon0063894", 165 pgs	
	"DxO Optics Pro Canon0063666", 153 pgs	
	"EF Lenswork III: The Eyes of EOS", 4 the ED, Canon Inc. Lens Product Group, (2009), 10 pgs	
	"JP H11-313250 11/9/1999 Canon0062291", 5 pgs	
	"JP H11-313250 English Translation 11/9/1999 Canon0065023", 6 pgs	
	"JP2000-184247 6/30/2000 Canon0062296", 12 pgs	
	"JP2000-184247 English Translation 6/30/2000 Canon0065045", 13 pgs	
	"JP2002-190979 7/5/2002 Canon0062325", 11 pgs	
	"JP2002-190979 English Translation 7/5/2002 Canon0065058", 12 pgs	
	"JP2002-199410 7/12/2002 Canon0062336", 17 pgs	
	"JP2002-199410 English Translation 7/12/2002 Canon0065070", 18 pgs	
	"JP2004-328506 English Translation 11/18/2004 Canon0065088", 21 pgs	
	"JP2004-328506 11/18/2004 Canon0062353", 17 pgs	
	"JP2004-343358 English Translation 12/2/2004 Canon0065109", 31 pgs	
	"JP2006-072660 3/16/2006 Canon0062397", 13 pgs	
	"JP2006-072660 English Translation 3/16/2006 Canon0065140", 14 pgs	
	"Kodak EasyShare V570 Canon0063819", 75 pgs	
	"Lumix DMC-FZ30 Canon 0064649", 148 pgs	
	"Olympus E-1 Canon0064059", 182 pgs	
	"Olympus E-300 Canon0064241", 212 pgs	
	"Olympus E-330 Canon0064453", 196 pgs	
	"Photoshop CS2 Canon0062668", Part 1 of 5, 163 pgs	
	"Photoshop CS2 Canon0062668", Part 2 of 5, 163 pgs	
	"Photoshop CS2 Canon0062668", Part 3 of 5, 163 pgs	
	"Photoshop CS2 Canon0062668", Part 4 of 5, 163 pgs	
	"Photoshop CS2 Canon0062668", Part 5 of 5, 163 pgs	
	"SD200-300 Digital ELPH Canon0063487", 179 pgs	
	"US 5,905,530 5/18/1999 Canon 0062546", 71 pgs	
	"US 7,590,305 9/15/2009 Canon0064843", 23 pgs	
	"US 7,738,015 6/15/2010 Canon0064866", 23 pgs	
	"US 7,936,392 5/3/2011 Canon0062617", 51 pgs	
	"US2001/0008418A1 7/19/2001 Canon0062410", 45 pgs	
/M.S.C/	"US2003/0095197A1 5/22/2003 Canon0064797", 32 pgs	

EXAMINER /MARLY S CAMARGO/ DATE CONSIDERED 01/17/2020

* EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant is to place a check mark here if English language Translation is attached

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.S.C/

Modified form PTO/SB/08A(04-07) OMB 651-0031
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Substitute for form 1449A/PTO **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** (Use as many sheets as necessary)	*Complete if Known*	
	Application Number	13/691,805
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	Group Art Unit	2699
	Examiner Name	Marly Camargo
Sheet 4 of 4	Attorney Docket No: 5311.001US3	

OTHER DOCUMENTS – NON PATENT LITERATURE DOCUMENTS

Examiner Initial *	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T1
/M.S.C/	"US2004/0150732A1 8/5/2004 Canon0062455", 31 pgs	
/M.S.C/	"US2004/0207733A1 10/21/2004 Canon0062486", 60 pgs	
/M.S.C/	"WO2005/093653A1 6/10/2005 Canon0064889", 128 pgs	
/M.S.C/	"Zuiko Digital 14-45mm f.3.5 Canon0065019", 2 pgs	
/M.S.C/	"Zuiko Digital ED50mm f2.0 Macro CANON0065017", 2 pgs	

EXAMINER /MARLY S CAMARGO/ DATE CONSIDERED 01/17/2020

* EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant is to place a check mark here if English language Translation is attached

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.S.C/

Notice of References Cited	Application/Control No. 13/691,805	Applicant(s)/Patent Under Reexamination Solomon, Neal	
	Examiner MARLY S CAMARGO	Art Unit 2699	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-2005/0261849-A1	11-2005	Kochi; N.	G06K9/36	382/254
*	B	US-2010/0106841-A1	05-2012	Tzur; Y.	G06K9/40	382/167
*	C	US2008/0291447-A1	11-2008	Vakrat; D.	H04N5/225	348/241
*	D	US-2007/0103744-A1	05-2007	Chibal; T.	H04N9/646	348/252
*	E	US-8,194,136-B1	01-2012	Askey; P.	H04N5/2351	348/187
	F					
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FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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NOTICE OF ALLOWANCE AND FEE(S) DUE

21186 7590 01/29/2020
SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402

EXAMINER	
CAMARGO, MARLY S.B.	
ART UNIT	PAPER NUMBER
2699	

DATE MAILED: 01/29/2020

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/691,805	12/02/2012	Neal Solomon	5311.001US3	6244

TITLE OF INVENTION: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$500	$0.00	$0.00	$500	04/29/2020

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Maintenance fees are due in utility patents issuing on applications filed on or after Dec. 12, 1980. It is patentee's responsibility to ensure timely payment of maintenance fees when due. More information is available at www.uspto.gov/PatentMaintenanceFees.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

21186 7590 01/29/2020
SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

(Typed or printed name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/691,805	12/02/2012	Neal Solomon	5311.001US3	6244

TITLE OF INVENTION: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$500	$0.00	$0.00	$500	04/29/2020

EXAMINER	ART UNIT	CLASS-SUBCLASS
CAMARGO, MARLY S.B.	2699	348-241000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. Fees submitted: ❑ Issue Fee ❑ Publication Fee (if required) ❑ Advance Order - # of Copies _____

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

❑ Electronic Payment via EFS-Web ❑ Enclosed check ❑ Non-electronic payment by credit card (Attach form PTO-2038)

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. _____

5. **Change in Entity Status** (from status indicated above)

❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/691,805	12/02/2012	Neal Solomon	5311.001US3	6244

21186 7590 01/29/2020

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402

EXAMINER	
CAMARGO, MARLY S.B.	
ART UNIT	**PAPER NUMBER**
2699	

DATE MAILED: 01/29/2020

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 13/691,805	Applicant(s) Solomon, Neal	
	Examiner MARLY S CAMARGO	Art Unit 2699	AIA (FITF) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to 11/15/2019 and 1/15/2020.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☑ The allowed claim(s) is/are 1-30 . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☑ Notice of References Cited (PTO-892)
2. ☑ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☑ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☐ Examiner's Amendment/Comment
6. ☑ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/MARLY S CAMARGO/
Examiner, Art Unit 2699

Notice of Pre-AIA or AIA Status

The present application is being examined under the pre-AIA first to invent provisions.

Change in Art Unit Designation for Your Application

1. The Art Unit designation of your application in the USPTO has changed from 2664 to 2699. The examiner assigned to this application remains the same. To aid in correlating any papers for this application, all further correspondence regarding this application should be directed to Art Unit 2699.

Detailed Action

Response to Amendment

2. In response Applicant amendment filed on January 15, 2020, the Examiner acknowledges the following:

- Note: Applicant had filed a previous version of amendment to claims on November 15, 2019, wherein claim 24 was missing and after the Examiner called the Applicant representative, this last version of claims was filed as to address that problem.
- Claims 1 – 11, 14 – 16, 18 and 19 were amended.
- Previous claims included two versions of claim 18 ant the second version is now correct as to be claim #19, which was also amended. The previous claim objection in reference to the two versions of claim 18 is withdrawn by the Examiner.

- Claims 12 and 17 remain unchanged.
- New claims 20 – 30 were filed.
- A terminal disclaimer was filed by Applicant on 11/15/2019; however, at the same time claims were amended to overcome the previous Double Patent rejection; therefore, the Terminal Disclaimer was not needed. In response, the Examiner withdraws the previous rejection.
- Currently claims 1 – 30 are pending and they are being examined on the merits.

Information Disclosure Statement

3. The information disclosure statement (IDS) submitted on 01/16/2020 has been considered by the Examiner.

Allowable Subject Matter

4. Claims 1 – 30 are allowed.

5. The following is an examiner's statement of reasons for allowance. The closest art of record teaches: 1) a camera with objective optics and a digital filter used to determine aberration due to the objective optics and wherein the image signal outputted by the image sensor is filtered (Alon – US 2007/0236574 A1); 2) a method for correcting lateral chromatic aberration using an in-camera auto-calibration procedure (Vakrat – US 2008/0291447 A1); 3) a digital filter to be used by a digital image processor in a camera device (Robinson – US 2007/0002158 A1); however, each of them either alone or in

combination fails to provide the combination limitations as in the amended independent claims 1, 6 and 14, as it follows below.

Regarding Claim 1:

The prior art of record fails to explicitly disclose a digital video camera comprising an optical lens mechanism, a digital sensor, an integrated circuit, a digital signal processor, in-camera system software, *a database management system and a memory storage sub-system; wherein the optical lens mechanism is a zoom lens or a fixed focal length lens; wherein integrated circuit uses in-camera software to identify at least one optical aberration and to correct the at least one optical image aberration in at least one frame of the digital video using at least one of a plurality of optical image aberration corrections in the database; wherein the video is captured by at least one digital sensor and forwarded to the digital signal processor; wherein the image file with the at least one optical image aberration is corrected by applying digital filtration by using the digital signal processor; and wherein the corrected video consisting of the digital data optimized from the at least one optical image aberration that are corrected from the original video image is stored in the memory storage sub-system.*

Therefore, as discussed above, claim 1 is allowable over the prior art of record.

Regarding Claims 2 – 5 and 20 – 30:

Claims 2 – 5 and 20 – 30 are allowable because they depend directly to claim 1 which is allowable over the prior art of record. Therefore, claims 2 – 5 and 20 – 30 are allowable for the same reasons as claim 1.

Regarding Claim 6:

The prior art of record fails to explicitly disclose a digital video camera comprising an optical lens mechanism, a digital sensor for capturing digital video, an integrated circuit, *a digital signal processor to access a database management system including a plurality of optical image aberration corrections, in-camera system software, and a memory storage sub-system; wherein the optical lens mechanism is a zoom lens or a fixed focal length lens; wherein the video is forwarded to storage in memory; wherein at least one optical aberration in at least two frames of the digital video are identified using the in-camera software and the identified circuit; wherein the at least one optical aberration from the optical lens mechanism of the at least two frames of the digital video are corrected by using the digital signal processor to apply at least one digital filtration algorithm; and wherein the corrected digital video file is stored in memory.*

Therefore, as discussed above, claim 6 is allowable over the prior art of record.

Regarding Claims 7 – 13:

Claims 7 – 13 are allowable because they depend directly to claim 6 which is allowable over the prior art of record.

Regarding Claim 14:

The prior art of record fails to explicitly disclose a digital video camera comprising an optical lens mechanism, a digital sensor for capturing digital video, an integrated circuit, *a digital signal processor to access a database management system including a*

plurality of optical image aberration corrections, in-camera system software, and a memory storage sub-system; wherein the optical lens mechanism is a zoom lens; wherein the zoom lens changes focal length positions; wherein when the digital video is forwarded to the digital signal processor and to memory; wherein the integral circuit uses system software to access the database to identify at least one optical aberration in at least one frame of the video at any focal length of a zoom lens configuration; wherein the integrated circuit access the database to obtain at least one filtration correction algorithm to the optical image aberration of at least one frame in the video file and forwards the at least one filtration algorithms to the digital processor; wherein the digital video is forwarded to the digital signal processor which applies at least one filtration algorithm to optimize the digital video and corrects the at least one optical image aberration in at least one video frame for the at least one focal length in the zoom lens configuration; and wherein the corrected digital video is stored in memory.

Therefore, as discussed above, claim 14 is allowable over the prior art of record.

Regarding Claims 15 – 19:

Claims 15 – 19 are allowable because they depend directly to claim 14 which is allowable over the prior art of record.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled “Comments on Statement of Reasons for Allowance.”

Conclusion

6. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

1. N. Kochi et al., US 2005/0261849 A1 – it teaches an image calibration method, comprising the steps of: receiving, at an image calibration processing device, a calibration request from a user terminal; receiving, at the image calibration processing device, a calibration object image photographed in accordance with an instruction for calibration photographing; performing a calibration process using the received calibration object image; and transmitting results of the calibration process from the image calibration processing device, wherein the user terminal performs a calibration on a subject image photographed by a camera used to photograph the calibration object image, using the results of the calibration process transmitted from the image calibration processing device, to form a corrected subject image. As for the method, aberrations are corrected as well.

2. Y. Tzur et al., US 2012/0106841 A1 – it teaches a system, method, and computer program product for automatically detecting and correcting the "purple fringing" effect, typically due to axial chromatic aberration in imaging devices. A chromaticity score is computed, denoting the amount of false color related to a purple fringing artifact.

3. D. Vakrat et al., US 2008/0291447 A1 – it teaches a device and its method of operation for the correction of lateral chromatic aberration within a digital camera or other imaging device, using calibration approaches that do not require previously acquired lens data to effect the correction. An in-camera auto-calibration procedure is performed on the

attached lens, such as when a lens is exchanged, and extracts parameters required for chromatic aberration correction, respecting zoom and focus, from one or more captured images. Based on image data extracted as a plurality of channels of a chromatic decomposition of the image, the chromatic aberration information for the lens is extracted. From the chromatic aberration information, the correction factors for the lens are determined.

4. P. Askey et al., US 8,194,136 B1 – it teaches methods and systems which are provided for measuring, analyzing, and/or providing analysis results of optical characteristics of optical articles, such as camera lenses. For example, certain embodiments measure, analyze, and/or provide analysis results of some or all of the following characteristics: sharpness, chromatic aberration, distortion, vignetting, and other characteristics.

5. T. Chibal, US 2007/0103744 A1 – it teaches an information processing apparatus for correcting chromatic aberration of video data, comprising: white saturation pixel detecting means for detecting a white saturation pixel having white saturation using a G signal of the video data composed of an RGB signal; spatial signal processing means for performing a spatial signal process on the RGB signal across a plurality of lines; color signal generating means for generating a color signal from the RGB signal processed by the spatial signal processing means; white saturation distribution information generating means for generating white saturation distribution information representing a distribution of the white saturation pixels detected by the white saturation pixel detecting means; and chromatic aberration correcting means for correcting a chromatic aberration of the color signal generated by the color signal generating means, using the white saturation

distribution information generated by the white saturation distribution information generating means.

Contact

7. Any inquiry concerning this communication or earlier communications from the examiner should be directed to MARLY CAMARGO whose telephone number is (571)270-3729. The examiner can normally be reached on 6:00AM - 10PM, M-F, EST.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Lin Ye can be reached on (571)272-7372. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/MARLY S CAMARGO/
Examiner, Art Unit 2699

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	64	(US-20030210343-$ | US-20050219391-$ | US-20080174678-$ | US-20110096176-$ | US-0062546-$ | US-0064649-$ | US-6023977-$ | US-6055330-$ | US-6508764-$ | US-6850272-$ | US-7245319-$ | US-7321685-$ | US-7406182-$ | US-7551205-$ | US-7612805-$ | US-7619663-$ | US-7636111-$ | US-7701484-$ | US-7764874-$ | US-8106976-$ | US-8451339-$ | US-5905530-$ | US-7590305-$ | US-7738015-$ | US-7936392-$ | US-20020163586-$ | US-20050099507-$ | US-20060285761-$ | US-20070002158-$ | US-20070236574-$ | US-20080151069-$ | US-20100073508-$ | US-20040150732-$).DID.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1 09:58
L2	4	(11/825521 | 12/586221 | 13/691805).APP.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1 09:58
L3	4	(TO-030212-$ | TO-042709-$ | TO-082312-$ | TO-121208-$ | AI-20060285761-$ | HI-1313250-$ | HI-1313250119-$ | JP-2004343358-$ | JP-20001842476-$ | JP-20021909797-$ | JP-20021994107-$ | JP-2004328506-$ | JP-20060726803-$ | ZR-706560-$).DID.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1 09:59
L4	2	1 and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1 10:48
L5	3	2 and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1 10:48
L6	0	3 and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1 10:49
S1	0	13/691805	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1 12:06
S2	2	12/586221	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1 12:06
S3	4	11/825521	US-PGPUB; USPAT; USOCR; FPRS;	OR	ON	2019/05/1 12:08

			EPO; JPO; DERWENT; IBM_TDB			
S4	139	(neal with solomon).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(12:09
S5	17	(neal with solomon).in. and (correct$4 with aberration$1)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(12:10
S6	11	(neal with solomon).as.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(12:11
S7	6	("20070080280" | "20070236574").PN. OR ("8451339").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:19
S8	0	(11/278268).APP.	USPAT; USOCR	OR	ON	2019/05/1(12:25
S9	1	(11/546531).APP.	USPAT; USOCR	OR	ON	2019/05/1(12:26
S10	116	("1269422" | "20030098952" | "20040008853" | "20040218283" | "20040227063" | "20040228003" | "20050002113" | "20050014306" | "20050100270" | "20050212952" | "20050218231" | "20060072915" | "20060076540" | "20060086596" | "20070063048" | "20070080280" | "20070116858" | "20080144185" | "20080144186" | "20080245872" | "20090072037" | "2062468" | "2300251" | "3161718" | "3305294" | "3583790" | "3761157" | "3778170" | "4134393" | "4191594" | "4210121" | "4249516" | "4261655" | "4286839" | "4289379" | "4312709" | "4407567" | "4487659" | "4514048" | "4783153" | "4783155" | "4784479" | "4802746" | "5091801" | "5150234" | "5305356" | "5389222" | "5396144" | "5684637" | "5892625" | "5917657" | "5973852" | "6081388" | "6109852" | "6188526" | "6212015" | "6368954" | "6369954" | "6376971" | "6399954" | "6437925" | "6449081" | "6475639" | "6529620" | "6538823" | "6542309" | "6545815" | "6545816" | "6586859" | "6628040" | "6702483" | "6715876" | "6734903" | "6747806" | "6762210" | "6806621" | "6806988" | "6809462" | "6812624" | "6882086" | "6891317" | "6934090" | "6936809" | "7169822" | "7224106" | "7301708" | "7416125" | "RE39874").PN. OR ("8027095").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:27
S11	28	("20020176148" | "20040228003" | "5071229" | "5150234").PN. OR ("6934090").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:32
S12	480	(marly with camargo).xa,xp.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(12:36
S13	18	(marly with camargo).xa,xp. and (correct$4 with aberration$1)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(12:36
S14	5	("20060228097" | "8395677" | "9077842" | "9392176" | "9998652").PN. OR ("10237485").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:38
S15	9	("20080309771" | "20090256952" | "20100013947" | "20100194966" | "20120274837" | "20140036134" | "20140340567" | "6363220").PN. OR ("9998652").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:39
S16	12	(aberration$1 with digital with database)	US-PGPUB;	OR	ON	2019/05/1(

			USPAT; USOCR			12:42
S17	10	(aberration$1 with digital with database) and vignet$5	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:43
S18	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:44
S19	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:46
S20	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:46
S21	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1)))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:49
S22	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1))) and (algorithm or procedure)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(12:49
S23	33470	348/241,231.99,222.1,335,240.99,240.1,240.3,333.08,340,342,208.11,345,346-350,355,349.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(17:32
S24	15928	382/254,255,264,263,266,275.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(17:32
S25	5250	359/16,637,666,665,207.2,354,676.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(17:33
S26	119424	(H04N5/357 | H04N5/217 | H04N5/2253 | H04N5/2254 | H04N5/228 | H04N5/238 | H04N5/76 | H04N5/225 | H04N5/374 | G06K9/36 | G06K9/40 | G01J1/20).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(18:20
S27	17	(aberration$1 with digital with database)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(18:21
S28	9	S23 and S27	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(18:21
S29	0	S24 and S27	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(18:21

S30	0	S25 and S27	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(18:21
S31	5	S26 and S27	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(18:22
S32	0	canon.as. and (aberration$1 with digital with database)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/1(18:22
S34	0	canon.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:23
S35	0	fuji.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:23
S36	0	microsoft.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:23
S37	0	panasoninc.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:24
S38	0	nikon.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:24
S39	0	omnivision.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:26
S40	0	olympus.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:29
S41	0	olympus.as. and ((aberration$1 with digital with database) and vignet$5)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:29
S42	0	pelican.as. and ((aberration$1 with digital with database) and vignet$5)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:29
S43	0	fotonation.as. and ((aberration$1 with digital with database) and vignet$5)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:30
S44	0	(carl with zeiss).as. and ((aberration$1 with digital with database) and vignet$5)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/1(18:30
S45	139	(neal with solomon).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1(09:56
S46	11	(neal with solomon).as.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1(09:57
S47	104	((("SOLOMON") near3 ("Neal"))).INV.	US-PGPUB; USPAT; USOCR;	OR	ON	2020/01/1(09:59

			EPO; JPO; DERWENT			
S48	17	(neal with solomon).in. and (correct$4 with aberration$1)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:01
S49	522	(marly with camargo).xa,xp.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:03
S50	18	(marly with camargo).xa,xp. and (correct$4 with aberration$1)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:03
S51	7	("20070080280" | "20070236574").PN. OR ("8451339").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2020/01/13 10:06
S52	12	(aberration$1 with digital with database)	US-PGPUB; USPAT; USOCR	OR	ON	2020/01/13 10:26
S53	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:31
S54	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:31
S55	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:32
S56	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1))) and (algorithm or procedure)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:33
S57	0	canon.as. and (aberration$1 with digital with database)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:34
S58	0	canon.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:34
S59	0	fuji.as. and ((aberration$1 with digital with database) and vignet$5 and	US-PGPUB;	OR	ON	2020/01/13

		(integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			10:34
S60	0	sony.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1 10:34
S61	0	microsoft.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1 10:35
S62	0	apple.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1 10:35
S63	0	aptina.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1 10:35
S64	0	oplympus.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1 10:36
S65	0	panasonic.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1 10:36
S66	0	omnivision.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1 10:36
S67	0	fotonation.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1 10:37
S68	0	pelican.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/1 10:37
S69	0	nikon.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS;	OR	ON	2020/01/1 10:38

			EPO; JPO; DERWENT; IBM_TDB			
S70	0	(eastman with kodak).as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:39
S71	0	(blur with technologies).as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:45
S72	0	(d$blur with technologies).as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:46
S73	0	casio.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:48
S74	8	(digital with camera$1 or video$1) and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (fixed focus lens) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:55
S75	8	("20050261849" | "20070030357" | "20070236574" | "20080174678").PN. OR ("8384785").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2020/01/13 11:03
S76	6	("20070236574" | "20080174678").PN. OR ("8395668").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2020/01/13 11:09
S77	21	(dudi with vakrat).in.	US-PGPUB; USPAT; USOCR	OR	ON	2020/01/13 11:13
S78	7	(dudi with vakrat).in. and aberration$1	US-PGPUB; USPAT; USOCR	OR	ON	2020/01/13 11:13
S79	19	("20030038957" | "20040150732" | "20040227978" | "20050162532" | "20060061664" | "20060062562" | "20060232681" | "20070103744" | "4466018" | "5713053" | "6788822" | "6807299" | "6822762" | "6862373" | "7088388" | "7158686" | "7973850" | "8089555" | "8194136").PN. OR ("8654240").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2020/01/13 11:20
S80	48	(katsuhiko with nagata).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:33
S81	9	(katsuhiko with nagata).in. and aberration$1	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:34
S82	1	(12/717769).APP.	USPAT; USOCR	OR	ON	2020/01/13 11:37

S83	174	(jeffrey with stafford).in.	USPAT; USOCR	OR	ON	2020/01/13 11:39
S84	1109	(jeffrey with stafford).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:39
S85	212	(jeffrey with roger with stafford).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:39
S86	8	(jeffrey with roger with stafford).in. and aberration$1	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:39
S87	34600	348/241,231.99,222.1,335,240.99,240.1,240.3,333.08,340,342,208.11,345,346-350,355,349.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:41
S88	23944	382/167,254,255,264,263,266,275.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:41
S89	5422	359/16,637,666,665,207.2,354,676.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:41
S90	132232	(H04N5/357 | H04N5/217 | H04N5/2253 | H04N5/2254 | H04N5/228 | H04N5/238 | H04N5/76 | H04N5/225 | H04N5/374 | G06K9/36 | G06K9/40 | G01J1/20).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:41
S91	7	S87 and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:42
S92	0	S88 and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:43
S93	0	S89 and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:43
S94	5	S90 and ((aberration$1 with digital with database) and vignet$5 and	US-PGPUB;	OR	ON	2020/01/13

		(integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			11:43
S95	6	S87 and ((digital with camera$1 or video$1) and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (fixed focus lens) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3))))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:44
S96	0	S88 and ((digital with camera$1 or video$1) and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (fixed focus lens) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3))))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:45
S97	0	S89 and ((digital with camera$1 or video$1) and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (fixed focus lens) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3))))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:45
S98	4	S90 and ((digital with camera$1 or video$1) and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (fixed focus lens) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3))))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:45
S99	10	((aberration$1 with digital with database)).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:49
S100	0	((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1)))).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:50
S101	0	(camera and (aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1))) and (algorithm or procedure)).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:51
S102	1	((digital with camera$1 or video$1) and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (fixed focus lens) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3)))).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:52
S103	0	((digital with camera$1 or video$1) and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (chang$3 with focus with position$1) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3)))).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:54

EAST Search History (Interference)

Ref	Hits	Search Query	DBs	Default	Plurals	Time

#				Operator		Stamp
S104	96	(neal with solomon).in.	US-PGPUB; USPAT	OR	ON	2020/01/13 11:47
S105	3	(neal with solomon).as.	US-PGPUB; USPAT	OR	ON	2020/01/13 11:47
S106	21404	348/241,231.99,222.1,335,240.99,240.1,240.3,333.08,340,342,208.11,345,346-350,355,349.ccls.	US-PGPUB; USPAT	OR	ON	2020/01/13 11:47
S107	15418	382/167,254,255,264,263,266,275.ccls.	US-PGPUB; USPAT	OR	ON	2020/01/13 11:47
S108	3017	359/16,637,666,665,207.2,354,676.ccls.	US-PGPUB; USPAT	OR	ON	2020/01/13 11:48
S109	42109	(H04N5/357 | H04N5/217 | H04N5/2253 | H04N5/2254 | H04N5/228 | H04N5/238 | H04N5/76 | H04N5/225 | H04N5/374 | G06K9/36 | G06K9/40 | G01J1/20).CPC.	US-PGPUB; USPAT	OR	ON	2020/01/13 11:48
S110	10	((aberration$1 with digital with database)).clm.	US-PGPUB; USPAT	OR	ON	2020/01/13 11:49
S111	0	((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1)))).clm.	US-PGPUB; USPAT	OR	ON	2020/01/13 11:50
S112	0	(camera and (aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1))) and (algorithm or procedure)).clm.	US-PGPUB; USPAT	OR	ON	2020/01/13 11:51
S113	1	((digital with camera$1 or video$1) and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (fixed focus lens) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3)))).clm.	US-PGPUB; USPAT	OR	ON	2020/01/13 11:52
S114	0	((digital with camera$1 or video$1) and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (chang$3 with focus with position$1) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3)))).clm.	US-PGPUB; USPAT	OR	ON	2020/01/13 11:54

1/17/2020 11:25:51 AM
C:\Users\mcamargo\Documents\EAST\Workspaces\13691805.wsp

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13/691,805	Solomon, Neal
	Examiner	**Art Unit**
	MARLY S CAMARGO	2699

CPC						
Symbol					**Type**	**Version**
H04N	/	5	/	217	F	2013-01-01
H04N	/	5	/	238	I	2013-01-01
H04N	/	5	/	2253	I	2013-01-01
H04N	/	5	/	2254	I	2013-01-01

CPC Combination Sets							
Symbol					**Type**	**Set**	**Ranking**	**Version**
	/		/					

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	30	
/MARLY S CAMARGO/ Examiner, Art Unit 2699	18 January 2020	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office — Part of Paper No.: 20200118

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13/691,805	Solomon, Neal
	Examiner	**Art Unit**
	MARLY S CAMARGO	2699

INTERNATIONAL CLASSIFICATION					
CLAIMED					
H04N	/	5	/	225	
H04N	/	5	/	217	
H04N	/	5	/	238	
H04N	/	5	/	228	
H04N	/	5	/	357	
H04N	/	5	/	374	

NON-CLAIMED				
	/		/	

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**

CROSS REFERENCES(S)						
CLASS	**SUBCLASS (ONE SUBCLASS PER BLOCK)**					
348	241	335	222.1	207.99	340	345
382	275	252	321	167	253	264
359	16	637	666	665	676	

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 30	
/MARLY S CAMARGO/ Examiner, Art Unit 2699 (Primary Examiner)	18 January 2020 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

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Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13/691,805	Solomon, Neal
	Examiner	**Art Unit**
	MARLY S CAMARGO	2699

☑ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
	1		10		19		28								
	2		11		20		29								
	3		12		21		30								
	4		13		22										
	5		14		23										
	6		15		24										
	7		16		25										
	8		17		26										
	9		18		27										

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	30	
/MARLY S CAMARGO/ Examiner, Art Unit 2699	18 January 2020	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

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Part of Paper No.: 20200118

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BIB DATA SHEET

CONFIRMATION NO. 6244

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
13/691,805	12/02/2012 RULE	348	2699	5311.001US3

APPLICANTS

INVENTORS

Neal Solomon, Oakland, CA;

**** CONTINUING DATA ***************************

**** FOREIGN APPLICATIONS ***************************

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED **** ** SMALL ENTITY **
12/27/2012

Foreign Priority claimed ❑ Yes ☑ No 35 USC 119(a-d) conditions met ❑ Yes ☑ No Verified and Acknowledged /MARLY S.B. CAMARGO/ Examiner's Signature	❑ Met after Allowance Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		CA	19	18	3

ADDRESS

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
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MINNEAPOLIS, MN 55402
UNITED STATES

TITLE

Digital imaging system for correcting video image aberrations

FILING FEE RECEIVED		
1365	FEES: Authority has been given in Paper No._____ to charge/credit DEPOSIT ACCOUNT No._____ for following:	❑ All Fees ❑ 1.16 Fees (Filing) ❑ 1.17 Fees (Processing Ext. of time) ❑ 1.18 Fees (Issue) ❑ Other _____ ❑ Credit

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13/691,805	Solomon, Neal
	Examiner	Art Unit
	MARLY S CAMARGO	2699

CPC - Searched*		
Symbol	**Date**	**Examiner**
(H04N5/357 | H04N5/217 | H04N5/2253 | H04N5/2254 | H04N5/228 | H04N5/238 | H04N5/76 | H04N5/225 | H04N5/374 | G06K9/36 | G06K9/40 | G01J1/20).CPC.	05/10/2019	M. Camargo
(H04N5/357 | H04N5/217 | H04N5/2253 | H04N5/2254 | H04N5/228 | H04N5/238 | H04N5/76 | H04N5/225 | H04N5/374 | G06K9/36 | G06K9/40 | G01J1/20).CPC.	01/13/2020	M. Camargo

CPC Combination Sets - Searched*		
Symbol	**Date**	**Examiner**

US Classification - Searched*			
Class	**Subclass**	**Date**	**Examiner**
348	241,231.99,222.1,335,240.99,240.1,240.3,333.08,340,342,208.11,345,346-350,355,349	05/10/2019	M. Camargo
382	254,255,264,263,266,275	05/10/2019	M. Camargo
359	16,637,666,665,207.2,354,676	05/10/2019	M. Camargo
348	241,231.99,222.1,335,240.99,240.1,240.3,333.08,340,342,208.11,345,346-350,355,349	01/13/2020	M. Camargo
382	167,254,255,264,263,266,275	01/13/2020	M. Camargo
359	16,637,666,665,207.2,354,676	01/13/2020	M. Camargo

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

/MARLY S CAMARGO/ Examiner, Art Unit 2699	

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	13/691,805	Solomon, Neal
	Examiner	Art Unit
	MARLY S CAMARGO	2699

Search Notes		
Search Notes	**Date**	**Examiner**
(H04N5/357 | H04N5/217 | H04N5/2253 | H04N5/2254 | H04N5/228 | H04N5/238 | H04N5/76 | H04N5/225 | H04N5/374 | G06K9/36 | G06K9/40 | G01J1/20).CPC. and the results teaxt limited - see attached search history printout.	05/10/2019	M. Camargo
EAST as BRS	05/10/2019	M. Camargo
inventor	05/10/2019	M. Camargo
assignee	05/10/2019	M. Camargo
Google and Google Patents	05/01-10/2019	M. Camargo
(H04N5/357 | H04N5/217 | H04N5/2253 | H04N5/2254 | H04N5/228 | H04N5/238 | H04N5/76 | H04N5/225 | H04N5/374 | G06K9/36 | G06K9/40 | G01J1/20).CPC. and the results text limited - see attached search history printout.	01/13/2020	M. Camargo
EAST - updated	01/13,17/2020	M. Camargo
inventor - updated	01/13/2020	M. Camargo
assignee - updated	01/13/2020	M. Camargo
Google & Google Patents	01/10/2020- 01/17/ 2020	M. Camargo

Interference Search			
US Class/CPC Symbol	**US Subclass/CPC Group**	**Date**	**Examiner**
EAST		01/13/2020	M. Camargo
inventor		01/13/2020	M. Camargo
assignee		01/13/2020	M. Camargo
348	241,231.99,222.1,335,240.99,240.1,240.3,333.08,340,342,208.11,345,346-350,355,349	01/13/2020	M. Camargo
382	167,254,255,264,263,266,275	01/13/2020	M. Camargo
359	16,637,666,665,207.2,354,676	01/13/2020	M. Camargo

/MARLY S CAMARGO/ Examiner, Art Unit 2699	

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13/691,805	Solomon, Neal
	Examiner	Art Unit
	MARLY S CAMARGO	2699

CPC	(H04N5/357 | H04N5/217 | H04N5/2253 | H04N5/2254 | H04N5/228 | H04N5/238 | H04N5/76 | H04N5/225 | H04N5/374 | G06K9/36 | G06K9/40 | G01J1/20).CPC.	01/13/2020	M. Camargo
claim (US PAT/ US PG Pub)	((aberration$1 with digital with database)).clm.	01/13/2020	M. Camargo
claim	((aberration$1 with digital with database) and vignet $5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1)))). clm.	01/13/2020	M. Camargo
claim	(camera and (aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag $3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1))) and (algorithm or procedure)).clm.	01/13/2020	M. Camargo
claim	((digital with camera$1 or video$1) and ((aberration $1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (fixed focus lens) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3)))).clm.	01/13/2020	M. Camargo
claim	((digital with camera$1 or video$1) and ((aberration $1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (chang$3 with focus with position$1) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3)))).clm.	01/13/2020	M. Camargo

/MARLY S CAMARGO/ Examiner, Art Unit 2699	

Examiner-Initiated Interview Summary	**Application No.** 13/691,805	**Applicant(s)** Solomon, Neal	
	Examiner MARLY S CAMARGO	**Art Unit** 2699	**AIA (FITF) Status** No

All participants (applicant, applicant's representative, PTO personnel):

(1) MARLY S.B.. CAMARGO. (3) _____.

(2) Mr. Timothy Bianchi (RG# 39,610). (4) _____.

Date of Interview: 16 January 2020.

Type: ☑ Telephonic ☐ Video Conference
☐ Personal [copy given to: ☐ applicant ☐ applicant's representative]

Exhibit shown or demonstration conducted: ☐ Yes ☑ No.
If Yes, brief description: _____.

Issues Discussed ☐ 101 ☐ 112 ☐ 102 ☐ 103 ☑ Others
(For each of the checked box(es) above, please describe below the issue and detailed description of the discussion)

Claim(s) discussed: 24.

Identification of prior art discussed: n/a.

Substance of Interview
(For each issue discussed, provide a detailed description and indicate if agreement was reached. Some topics may include: identification or clarification of a reference or a portion thereof, claim interpretation, proposed amendments, arguments of any applied references etc...)

See Continuation Sheet.

Applicant recordation instructions: It is not necessary for applicant to provide a separate record of the substance of interview.

Examiner recordation instructions: Examiners must summarize the substance of any interview of record. A complete and proper recordation of the substance of an interview should include the items listed in MPEP 713.04 for complete and proper recordation including the identification of the general thrust of each argument or issue discussed, a general indication of any other pertinent matters discussed regarding patentability and the general results or outcome of the interview, to include an indication as to whether or not agreement was reached on the issues raised.

☐ Attachment

/MARLY S CAMARGO/ Examiner, Art Unit 2699	

Continuation of Substance of Interview including description of the general nature of what was agreed to if an agreement was reached, or any other comments: The Examiner had called Mr. Bianchi previously and left a message about a TD which was disapprove and a missing claim 24 on the amendment filed on 11/15/2019 and left a message about the problems. Since Mr. Bianchi did not call back, the Examiner called him to inform him that since he amended the claims, which overcame the previous Double Patent rejection, the TD was not needed. It was discussed about the missing claim 24 and about the amendment he filed on 01/15/2020. Mr. Bianchi informed the Examiner that they were filing a new IDS later on 01/16/2020 and that they wanted it to be searched and it to be part of the file documentation. The Examiner did that search and the case is allowable over the art cited in the ids.



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Office of the Chief Financial Officer

Document Code:WFEE

User :72230

Sale Accounting Date:01/30/2020

Sale Item Reference Number	Effective Date
13691805	01/15/2020

Document Number	Fee Code	Fee Code Description	Amount Paid	Payment Method
I20201TD16379316	1814	STATUTORY OR TERMINAL DISCLAIMER	$160.00	Deposit Account

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/691,805	12/02/2012	2699	1365	5311.001US3	18	3

CONFIRMATION NO. 6244

CORRECTED FILING RECEIPT

21186
SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402

OC000000115087528

Date Mailed: 03/02/2020

Receipt is acknowledged of this non-provisional utility patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF FIRST INVENTOR, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection.

Please verify the accuracy of the data presented on this receipt. If an error is noted on this Filing Receipt, please submit a written request for a corrected Filing Receipt, including a properly marked-up ADS showing the changes with strike-through for deletions and underlining for additions. If you received a "Notice to File Missing Parts" or other Notice requiring a response for this application, please submit any request for correction to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections provided that the request is grantable.

Inventor(s)

Neal Solomon, Oakland, CA;

Applicant(s)

Neal Solomon, Oakland, CA;

Power of Attorney: The patent practitioners associated with Customer Number 21186

Domestic Priority data as claimed by applicant

This application is a CON of 12/586,221 09/18/2009 PAT 8451339
which is a CON of 11/825,521 07/06/2007 PAT 7612805
which claims benefit of 60/807,065 07/11/2006

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: No

Permission to Access Search Results: No

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 12/27/2012

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/691,805**

Projected Publication Date: Request for Non-Publication Acknowledged

Non-Publication Request: Yes

Early Publication Request: No
**** SMALL ENTITY ****
Title

DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

Preliminary Class

348

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

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Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

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OFFICE OF PETITIONS

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402

Inventor: Neal Solomon
Application No. 13/691,805
Filing Date: December 2, 2012
Attorney Docket No. 5311.001US3

Decision on Petition under
37 C.F.R. §§ 1.78(c) and 1.78(e)

This is a decision on the renewed petition under 37 C.F.R. §§ 1.78(c) and 1.78(e) filed October 17, 2019, to accept unintentionally delayed claims under 35 U.S.C. §§ 119(e) and 120.

The petition is **granted**.

A petition under 37 C.F.R. §§ 1.78(c) and 1.78(e) was filed on August 20, 2019.

The Office issued a decision dismissing the petition on October 15, 2019.

The renewed petition was filed on October 17, 2019. The renewed petition corrects the deficiency identified in the prior decision.

The requirements set forth in 37 C.F.R. §§ 1.78(c) and (e) have been satisfied, and the late claims for priority under 35 U.S.C. §§ 119(e) and 120 are accepted as being unintentionally delayed.

This decision grants the petition to accept the unintentionally delayed domestic benefit claim to the prior-filed applications because the petition requirements of 37 C.F.R. §§ 1.78(c) and 1.78(e) and the formal requirements for claiming domestic benefit (*See* MPEP §§ 211.01 et. seq.) have been met. This acceptance should not be construed as meaning that this application is entitled to the benefit of the prior-filed applications. Whether a claimed invention in a nonprovisional application is entitled to the benefit of the filing date of a prior-filed application on the basis of the disclosure thereof is determined during examination if it becomes necessary to do so (e.g., intervening reference and interference proceeding). *See* MPEP § 211.05.

A corrected Filing Receipt including the unintentionally delayed benefit claims accompanies this decision on petition.

Any questions concerning this matter may be directed to Attorney Advisor Steven Brantley at (571) 272-3203.

Charles Steven Brantley
Attorney Advisor
Office of Petitions
Attachment: Corrected Filing Receipt

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/691,805	12/02/2012	2699	1365	5311.001US3	18	3

CONFIRMATION NO. 6244

CORRECTED FILING RECEIPT

21186
SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402



Date Mailed: 03/02/2020

Receipt is acknowledged of this non-provisional utility patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF FIRST INVENTOR, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection.

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Applicant(s)

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Permission to Access Application via Priority Document Exchange: No

Permission to Access Search Results: No

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Projected Publication Date: Request for Non-Publication Acknowledged

Non-Publication Request: Yes

Early Publication Request: No
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/691,805	12/02/2012	Neal Solomon	5311.001US3	6244

7590 03/11/2020

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402

EXAMINER	
CAMARGO, MARLY S.B.	
ART UNIT	PAPER NUMBER
2699	
NOTIFICATION DATE	DELIVERY MODE
03/11/2020	ELECTRONIC

NOTICE REQUIRING INVENTOR'S OATH OR DECLARATION

☐ An inventor's oath or declaration in compliance with 37 CFR 1.63 or substitute statement in compliance with 37 CFR 1.64 executed by or with respect to each inventor has not yet been submitted.

The inventor's oath or declaration or substitute statement dated 11/28/19 is defective. The inventor's oath or declaration does not comply with 37 CFR 1.63 or the substitute statement does not comply with 37 CFR 1.64 because it:

☐ does not include a statement that the person executing the oath or declaration or substitute statement believes the named inventor or joint inventor to be the original inventor or an original joint inventor of a claimed invention in the application for which the oath or declaration is being submitted.

☐ does not state that the application was made or was authorized to be made by the person executing the oath or declaration or substitute statement.

☐ does not acknowledge that any willful false statement made in such oath or declaration or substitute statement is punishable under section 1001 of title 18 by fine or imprisonment of not more than 5 years, or both.

☐ does not identify the person executing the oath or declaration or substitute statement by his or her legal name.

☐ does not identify the application to which the oath or declaration or substitute statement is directed.

☑ Other: Oath 11/28/19 does not provide residence information. Oath should include inventor residence or be submitted with ADS per 37 CFR 1.76

The substitute statement dated _____ does not comply with 37 CFR 1.64 because it:

☐ does not identify the inventor with respect to whom the statement applies.

☐ does not identify the relationship to the non-signing inventor.

☐ does not identify the circumstances permitting execution of the statement.

☐ was signed by someone other than the applicant.

☑ Other: Please note: ADS 10/17/19 provided only for Continuity data.

An oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each inventor MUST be filed **no later than the date on which the issue fee is paid.** See 35 U.S.C. 115(f). Failure to timely comply will result in ABANDONMENT of this application. This period for reply is not extendable under 37 CFR 1.136(a).

Questions relating to this Notice should be directed to the Application Assistance Unit at 571-272-4200.

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21186 7590 03/18/2020

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EXAMINER
CAMARGO, MARLY S.B.

ART UNIT	PAPER NUMBER
2699	

NOTIFICATION DATE	DELIVERY MODE
03/18/2020	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

SLW@blackhillsip.com
uspto@slwip.com

Corrected ***Notice of Allowability***	**Application No.** 13/691,805	**Applicant(s)** Solomon, Neal	
	Examiner MARLY S CAMARGO	**Art Unit** 2699	**AIA (FITF) Status** No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to X-RUSH of 3/9/2020 and petition filed by Applicant of 3/3/2020.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☑ The allowed claim(s) is/are 1-30 . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☐ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/MARLY S CAMARGO/
Examiner, Art Unit 2699

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

BIB DATA SHEET

CONFIRMATION NO. 6244

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
13/691,805	12/02/2012 **RULE**	348	2699	5311.001US3

APPLICANTS

INVENTORS
Neal Solomon, Oakland, CA;

** **CONTINUING DATA** *************************
This application is a CON of 12/586,221 09/18/2009 PAT 8451339
which is a CON of 11/825,521 07/06/2007 PAT 7612805
which claims benefit of 60/807,065 07/11/2006

** **FOREIGN APPLICATIONS** *************************

** **IF REQUIRED, FOREIGN FILING LICENSE GRANTED** ** ** SMALL ENTITY **
12/27/2012

Foreign Priority claimed / 35 USC 119(a-d) conditions met / Verified and Acknowledged	Met after Allowance	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
Foreign Priority claimed ☐ Yes ☑ No 35 USC 119(a-d) conditions met ☐ Yes ☑ No Verified and Acknowledged /MARLY S.B. CAMARGO/ Examiner's Signature	☐ Met after Allowance Initials	CA	19	18	3

ADDRESS

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402
UNITED STATES

TITLE

DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

FILING FEE RECEIVED		
1365	FEES: Authority has been given in Paper No.____________ to charge/credit DEPOSIT ACCOUNT No.____________ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other ________________ ☐ Credit

BIB (Rev. 05/07).

Electronic Patent Application Fee Transmittal

Application Number:	13691805
Filing Date:	02-Dec-2012
Title of Invention:	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS
First Named Inventor/Applicant Name:	Neal Solomon
Filer:	Garrett M. Hall/Clayton Finn
Attorney Docket Number:	5311.001US3

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
SUBMISSION- INFORMATION DISCLOSURE STMT	2806	1	120	120
		Total in USD ($)		**120**

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	13691805
Filing Date	2012-12-02
First Named Inventor	Neal Solomon
Art Unit	2699
Examiner Name	Marly Camargo
Attorney Docket Number	5311.001US3

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	10210602		2019-02-19	Campbell, Richard John	
	2	7327390		2008-02-05	Gallagher, Andrew C	
	3	9077842		2015-07-07	Natsume, Satoshi	

If you wish to add additional U.S. Patent citation information please click the Add button. Add

U.S.PATENT APPLICATION PUBLICATIONS Remove

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20020012054	A1	2002-01-31	Osamoto, Akira	
	2	20020041383	A1	2002-04-11	Lewis, Clarence A, et al.	
	3	20030039402	A1	2003-02-27	Robins, David R, et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13691805
	Filing Date	2012-12-02
	First Named Inventor	Neal Solomon
	Art Unit	2699
	Examiner Name	Marly Camargo
	Attorney Docket Number	5311.001US3

	4	20040150726	A1	2004-08-05	Gallagher, Andrew C	
	5	20050030394	A1	2005-02-10	Mendis, Sunetra K, et al.	
	6	20060120599	A1	2006-06-08	Steinberg, Eran, et al.	
	7	20070252074	A1	2007-11-01	Ng, Yi-ren, et al.	
	8	20080175514	A1	2008-07-24	Nose, Atsushi, et al.	
	9	20120229654	A1	2012-09-13	Solomon, Neal	

If you wish to add additional U.S. Published Application citation information please click the Add button. Add

FOREIGN PATENT DOCUMENTS Remove

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1							

If you wish to add additional Foreign Patent Document citation information please click the Add button Add

NON-PATENT LITERATURE DOCUMENTS Remove

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13691805
	Filing Date	2012-12-02
	First Named Inventor	Neal Solomon
	Art Unit	2699
	Examiner Name	Marly Camargo
	Attorney Docket Number	5311.001US3

	1	"Application Serial No. 16 692,972, Notice of Allowance mailed 01-24-20", 17 pages.	
	2	"Application Serial No. 16 692,939, Non Final Office Action mailed 02-04-20", 22 pages.	
	3	"Application Serial No. 16 694,838, Non Final Office Action mailed 02-13-20", 21 pages.	
	4	"Application Serial No. 16 694,850, Non Final Office Action mailed 03-04-20", 25 pages.	

If you wish to add additional non-patent literature document citation information please click the Add button Add

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13691805
	Filing Date	2012-12-02
	First Named Inventor	Neal Solomon
	Art Unit	2699
	Examiner Name	Marly Camargo
	Attorney Docket Number	5311.001US3

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

☒ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Timothy E. Bianchi/	Date (YYYY-MM-DD)	2020-04-21
Name/Print	Timothy E. Bianchi	Registration Number	39,610

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Acknowledgement Receipt	
EFS ID:	39222807
Application Number:	13691805
International Application Number:	
Confirmation Number:	6244
Title of Invention:	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS
First Named Inventor/Applicant Name:	Neal Solomon
Customer Number:	21186
Filer:	Garrett M. Hall/Clayton Finn
Filer Authorized By:	Garrett M. Hall
Attorney Docket Number:	5311.001US3
Receipt Date:	21-APR-2020
Filing Date:	02-DEC-2012
Time Stamp:	17:03:42
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$120
RAM confirmation Number	E20204KH03595867
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	13691805_Transmittal_4-21-2020.pdf	1108448 3f4abd6cd1d2491bad087b2b93e48cebbd6b4a90	no	2
Warnings:					
Information:					
2	Information Disclosure Statement (IDS) Form (SB08)	13691805_IDS_4-21-2020.pdf	645706 0936aa17b91d292303ed71feba030bf342a7cd09	no	5
Warnings:					
Information:					
3	Non Patent Literature	0001_2_npl_5311001us4_oarnpe_2420_f.pdf	1035771 9111af30e53381ae68ad512288de7eba43dd814f	no	22
Warnings:					
Information:					
4	Non Patent Literature	0002_2_npl_5311001us5_noar_12420_f.pdf	1000472 a601751d2f8f21b1022947d3362bf31a51e68857	no	17
Warnings:					
Information:					
5	Non Patent Literature	0003_2_npl_5311001us6_oarnpe_21320_f.pdf	1168774 96e4d6b50770a931da18afe3873fc00c1266ecd6	no	21
Warnings:					
Information:					
6	Non Patent Literature	0004_2_npl_5311001us7_oarnpe_3420_f.pdf	1307110 c616a31655f3b922415ce5ef977333bdbb673ee9	no	25
Warnings:					
Information:					

7	Fee Worksheet (SB06)	fee-info.pdf	30074 0882d18a002f20fb994cca8233a9c5e7510598e7	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	6296355	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s):	Neal Solomon	Examiner:	Marly Camargo
Serial No.:	13/691,805	Group Art Unit:	2699
Filed:	December 2, 2012	Docket:	5311.001US3
Customer No.:	21186	Confirmation No.:	6244
Title:	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS		

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT

MS Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

In compliance with the duty imposed by 37 C.F.R. § 1.56, and in accordance with 37 C.F.R. §§ 1.97 *et. seq.*, the enclosed materials are brought to the attention of the Examiner for consideration in connection with the above-identified patent application. Applicant respectfully requests that this Information Disclosure Statement be entered and the documents listed on the attached PTO 1449 Form be considered by the Examiner and made of record. Pursuant to the provisions of MPEP 609, Applicant requests that a copy of the PTO 1449 Form, initialed as being considered by the Examiner, be returned to the Applicant with the next official communication.

Pursuant to 37 C.F.R. § 1.97(c)(2), Applicant hereby authorizes the Commissioner to charge the fee of $120.00 as set forth in 37 C.F.R. § 1.17(p), to Deposit Account No. 19-0743. Please charge any additional fees or deficiencies, or credit any overpayment to Deposit Account No. 19-0743.

Pursuant to 37 C.F.R. § 1.98(a)(2), copies of cited U.S. Patents and Published Applications, and Non-Published Applications identifiable by USPTO Serial Number, are no longer required to be provided to the Office. Applicant acknowledges the requirement to submit copies of foreign patent documents and non-patent literature in accordance with 37 C.F.R § 1.98(a)(2).

The Examiner is invited to contact the undersigned at the telephone number indicated if there are any questions regarding this communication.

Respectfully submitted,

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. Box 2938
Minneapolis, MN 55402
(612) 373-6912

Date 4/21/2020 By /Timothy E. Bianchi/
Timothy E. Bianchi
TEB:caf Reg. No. 39,610

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s):	Neal Solomon	Examiner: Marly Camargo	
Serial No.:	13/691,805	Group Art Unit: 2699	
Filed:	December 2, 2012	Docket No.: 5311.001US3	
Customer No.:	21186	Confirmation No.: 6244	
Title:	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS		

COMMUNICATION RE: FEE ADDRESS

Mail Stop Issue Fee
Commissioner for Patents
P.O.Box 1450
Alexandria, VA 22313-1450

In response to the Notice of Allowance and Issue Fee Due, please record the Fee Address under the provisions of 37 CFR 1.363 as the following:

Customer Number 21186

Please direct any inquiries to the undersigned attorney at (612) 373-6912.

Respectfully submitted,

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. Box 2938
Minneapolis, MN 55402
(612) 373-6912

Date 4/24/2020 By /Timothy E. Bianchi/
Timothy E. Bianchi
Reg. No. 39,610

TEB:CMG:kap

Electronic Acknowledgement Receipt	
EFS ID:	39262432
Application Number:	13691805
International Application Number:	
Confirmation Number:	6244
Title of Invention:	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS
First Named Inventor/Applicant Name:	Neal Solomon
Customer Number:	21186
Filer:	James D. Hallenbeck/Kimberlie Pates
Filer Authorized By:	James D. Hallenbeck
Attorney Docket Number:	5311.001US3
Receipt Date:	24-APR-2020
Filing Date:	02-DEC-2012
Time Stamp:	17:13:11
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$500
RAM confirmation Number	E20204NH13478766
Deposit Account	190743
Authorized User	Kimberlie Pates
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

37 CFR 1.19 (Document supply fees)

37 CFR 1.20 (Post Issuance fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		5311001US3_IFEE.pdf	288317 4d42134dc77cd007d9d5dcc55fbc6cbe1ce63c77	yes	3

Multipart Description/PDF files in .zip description

Document Description	Start	End
Transmittal Letter	1	1
Issue Fee Payment (PTO-85B)	2	2
Miscellaneous Incoming Letter	3	3

Warnings:

Information:

2	Fee Worksheet (SB06)	fee-info.pdf	30352 4fd34ee8e1258f3f9be6e80d95b3d88c773f4e33	no	2

Warnings:

Information:

Total Files Size (in bytes):	318669

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

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National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

21186 7590 01/29/2020
SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

Kimberlie Pates	(Typed or printed name)
/Kimberlie Pates/	(Signature)
April 24, 2020	(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/691,805	12/02/2012	Neal Solomon	5311.001US3	6244

TITLE OF INVENTION: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$500	$0.00	$0.00	$500	04/29/2020

EXAMINER	ART UNIT	CLASS-SUBCLASS
CAMARGO, MARLY S.B.	2699	348-241000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☒ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Schwegman Lundberg
2 & Woessner, P.A.
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: Optimum Imaging Technologies LLC

(B) RESIDENCE: (CITY and STATE OR COUNTRY): Austin, Texas

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. Fees submitted: ☒ Issue Fee ☐ Publication Fee (if required) ☐ Advance Order - # of Copies _____

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

☒ Electronic Payment via EFS-Web ☐ Enclosed check ☐ Non-electronic payment by credit card (Attach form PTO-2038)

☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. 190743

5. **Change in Entity Status** (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /Timothy E. Bianchi/ Date 4/24/2020

Typed or printed name Timothy E. Bianchi Registration No. 39,610

Electronic Patent Application Fee Transmittal

Application Number:	13691805
Filing Date:	02-Dec-2012
Title of Invention:	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS
First Named Inventor/Applicant Name:	Neal Solomon
Filer:	James D. Hallenbeck/Kimberlie Pates
Attorney Docket Number:	5311.001US3

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
UTILITY APPL ISSUE FEE	2501	1	500	500

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**500**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s): Neal Solomon
Title: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

Docket No.:	5311.001US3	Serial No.:	13/691,805
Filed:	December 2, 2012	Due Date:	April 29, 2020
Examiner:	Marly Camargo	Group Art Unit:	2699
Customer No.:	21186	Confirmation No.:	6244

Notice of Allowance Date: January 29, 2020

Mail Stop Issue Fee
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

We are transmitting herewith the following:

X Issue Fee Transmittal (Form PTOL-85).
X Communication Re: Fee Address (1 page).
X Authorization to charge Deposit 19-0743 in the amount of $500.00 to cover the Small Entity Issue Fee Payment.

Please charge any additional required fees or credit overpayment to Deposit Account No. 19-0743.

SCHWEGMAN LUNDBERG & WOESSNER, P.A. By /Timothy E. Bianchi/
Customer No.: 21186 Timothy E. Bianchi
TEB:CMG:kap Reg. No. 39,610

CERTIFICATE UNDER 37 CFR 1.8: The undersigned hereby certifies that this correspondence is being filed using the USPTO's electronic filing system EFS-Web, and is addressed to: Mail Stop Issue Fee, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on this 24th day of April, 2020.

Kimberlie Pates /Kimberlie Pates/
Name Signature

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s):	Neal Solomon	Examiner: Marly Camargo
Serial No.:	13/691,805	Group Art Unit: 2699
Filed:	December 2, 2012	Docket: 5311.001US3
Customer No.:	21186	Confirmation No.: 6244
Title:	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS	

COMMUNICATION RE: LATE SUBMISSION OF DECLARATION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

In compliance with 37 CFR 1.63, we submit the Signed Declaration. Corresponding fees with regard to the late submission were paid with the filing of the application on December 2, 2012 therefore applicants believe no additional fees are due at this time.

Applicants assume the application is now in proper order and in condition for allowance. Please direct any inquiries to the undersigned at (612) 373-6912. If necessary, please charge any additional fees or credit overpayment to Deposit Account 19-0743.

Respectfully submitted,

Schwegman Lundberg & Woessner, P.A.
P.O. Box 2938
Minneapolis, MN 55402
(612) 373-6912

Date 4/24/2020

By /Timothy E. Bianchi/
Timothy E. Bianchi
Reg. No. 39,610

TEB:CMG:kap

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s): Neal Solomon
Title: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

Docket No.:	5311.001US3	Serial No.:	13/691,805
Filed:	December 2, 2012	Due Date:	
Examiner:	Marly Camargo	Group Art Unit:	2699
Customer No.:	21186	Confirmation No.:	6244

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

We are transmitting herewith the attached:

X Communication Re: Update to Application Data Sheet (1 Pg.).
X Marked Up Application Data Sheet (6 Pgs.).
X Communication Re: Late Submission of Declaration (1 pg.).
X Signed Declaration (1 pg.).

It is believed that no additional fee is required. However, if necessary, please charge any additional required fees or credit overpayment to Deposit Account No. 19-0743.

Schwegman Lundberg & Woessner, P.A.
Customer No.: 21186

By /Timothy E. Bianchi/
Timothy E. Bianchi
Reg. No. 39,610

CERTIFICATE UNDER 37 CFR 1.8: The undersigned hereby certifies that this correspondence is being filed using the USPTO's electronic filing system EFS-Web, and is addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on this 24th day of April, 2020.

Kimberlie Pates
Name

/Kimberlie Pates/
Signature

Electronic Acknowledgement Receipt

EFS ID:	39262148
Application Number:	13691805
International Application Number:	
Confirmation Number:	6244
Title of Invention:	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS
First Named Inventor/Applicant Name:	Neal Solomon
Customer Number:	21186
Filer:	James D. Hallenbeck/Kimberlie Pates
Filer Authorized By:	James D. Hallenbeck
Attorney Docket Number:	5311.001US3
Receipt Date:	24-APR-2020
Filing Date:	02-DEC-2012
Time Stamp:	16:59:19
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		5311001US3_UADS.pdf	331380 48f372d3d0c022e19a1ad678a4c1d88aefb8403a	yes	10

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Transmittal Letter	1	1
	Miscellaneous Incoming Letter	2	2
	Application Data Sheet	3	8
	Miscellaneous Incoming Letter	9	9
	Oath or Declaration filed	10	10
Warnings:			
Information:			
	Total Files Size (in bytes):	331380	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s):	Neal Solomon	Examiner:	Marly Camargo
Serial No.:	13/691,805	Group Art Unit:	2699
Filed:	December 2, 2012	Docket:	5311.001US3
Customer No.:	21186	Confirmation No.:	6244
Title:	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS		

COMMUNICATION RE: UPDATE TO APPLICATION DATA SHEET

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Applicants hereby request that the information provided on the Application Data Sheet filed in the above-referenced application on December 2, 2012, be updated with the information as provided on the enclosed marked up Application Data Sheet.

We therefore submit a marked up copy of the Application Data Sheet which shows the Inventor's address/residence.

Once this request is entered, it is respectfully requested that the USPTO update their records and provide confirmation of the above request by way of an Updated Filing Receipt.

It is believed that no fee is required to fulfill this request, however, if necessary, please charge any additional required fees or credit overpayment to Deposit Account No. 19-0743.

Respectfully submitted,

Schwegman Lundberg & Woessner, P.A.
P.O. Box 2938
Minneapolis, MN 55402
(612) 373-6912

Date 4/24/2020 By /Timothy E. Bianchi/
Timothy E. Bianchi
Reg. No. 39,610

Amended PTO/AIA/01 (06-12)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number 13/691,805, filed on December 2, 2012 .

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Neal Solomon Date (Optional) : _____

Signature: /Neal I. Solomon/

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

5311.001US3

Modified PTO/AIA/14 (12-13)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor: Neal Solomon

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Neal		Solomon	

Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service

City	Oakland	State/Province	California	Country of Residence	United States of America

Mailing Address of Inventor:

Address 1	PO Box 21297		
Address 2			
City	Oakland	State/Province	California
Postal Code	94620	Country	United States of America

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ An Address is being provided for the correspondence Information of this application.

Customer Number	
Email Address	

Application Information:

Title of the Invention			
Attorney Docket Number		Small Entity Status Claimed ☐	
Application Type			
Subject Matter			
Suggested Class (if any)		Sub Class (if any)	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)		Suggested Figure for Publication (if any)	

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country Publication

Publication Information:

☐ **Request Early Publication (Fee required at time of Request 37 CFR 1.219)**

☐ **Request Not to Publish. I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application has not and will not be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.**

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Enter either Customer Number or complete the Representative Name section below. If both sections are completed the Customer Number will be used for the Representative Information during processing.

Please Select One:	☐ Customer	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)
Customer Number			

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78(a)(2) or CFR 1.78(a)(4), and need not otherwise be made part of the specification.

Prior Application Status	Patented		
Application Number	**Continuity Type**	**Prior Application Number**	**Filing or 371(c) Date (YYYY-MM-DD)**
This application	is a continuation of	12/586,221	2009-09-18
Prior Application Status	Patented		
Application Number	**Continuity Type**	**Prior Application Number**	**Filing or 371(c) Date (YYYY-MM-DD)**
12/586,221	is a continuation of	11/825,521	2007-07-06
Prior Application Status	Expired		
Application Number	**Continuity Type**	**Prior Application Number**	**Filing or 371(c) Date (YYYY-MM-DD)**
11/825,521	Claims benefit of provisional	60/807,065	2006-07-11

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(d). When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)i the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(h)(1) and (2). Under the POX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Application Number	Country	Parent Filing Date (YYYY-MM-DD)	Access Code (if applicable)

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant must opt-out of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is ONLY reviewed and processed with the INITIAL filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby grants the USPTO authority to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ **A. Applicant DOES NOT authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.**

☐ **B. Applicant DOES NOT authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.**

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

☐ Assignee	☐ Legal Representative under 35 U.S.C. 117	☐ Joint Inventor
☐ Person to whom the inventor is obligated to assign	☐ Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

☐ Deceased	☐ Legally incapacitated

Name of the Deceased or Legally Incapacitated Inventor :

If the Applicant is an Organization check here: ☐

Organization Name:

Prefix	Given Name	Middle Name	Family Name	Suffix

Mailing Address Information:

Address 1			
Address 2			
City		State/Province	
Country		Postal Code	
Phone Number			
Email Address			

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	5311.001US3
	Application Number	13/691,805
Title of Invention	DIGITAL IMAGING SYSTEM FOR CORRECTING IMAGE ABERRATIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	Given Name	Middle Name	Family Name	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		State/Province	
Country		Postal Code	
Phone Number		Fax Number	
Email Address			

Signature:

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is **a juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, all joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of all joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Timothy E. Bianchi/			Date (YYYY-MM-DD)	2020-04-24
First Name	Timothy	Last Name	Bianchi	Registration Number	39,610

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-14**

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/691,805	12/02/2012	Neal Solomon	5311.001US3	6244

7590 04/28/2020

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402

EXAMINER	
CAMARGO, MARLY S.B.	
ART UNIT	**PAPER NUMBER**
2697	
NOTIFICATION DATE	**DELIVERY MODE**
04/28/2020	ELECTRONIC

NOTICE OF NON-COMPLIANT INFORMATION DISCLOSURE STATEMENT

An Information Disclosure Statement (IDS) filed 04/21/2020 in the above-identified application fails to meet the requirements of 37 CFR 1.97(d) for the reason(s) specified below. Accordingly, the IDS will be placed in the file, but the information referred to therein has not been considered.

The IDS is not compliant with 37 CFR 1.97(d) because:

☒ The IDS lacks a statement as specified in 37 CFR 1.97(e).

☐ The IDS lacks the fee set forth in 37 CFR 1.17(p).

☐ The IDS was filed after the issue fee was paid. Applicant may wish to consider filing a petition to withdraw the application from issue under 37 CFR 1.313(c) to have the IDS considered. See MPEP 1308.

/BC/

571-272-4200 or 1-888-786-0101
Application Assistance Unit
Office of Data Management

Notice of References Cited	Application/Control No. 13/691,805	Applicant(s)/Patent Under Reexamination Solomon, Neal	
	Examiner MARLY S CAMARGO	Art Unit 2699	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-2005/0261849-A1	11-2005	Kochi; N.	G06K9/36	382/254
*	B	US-2010/0106841-A1	~~05-2012~~ 01/2010	~~Tzur; Y.~~ Barnert	G06K9/40	382/167
*	C	US2008/0291447-A1	11-2008	Vakrat; D.	H04N5/225	348/241
*	D	US-2007/0103744-A1	05-2007	Chibal; T.	H04N9/646	348/252
*	E	US-8,194,136-B1	01-2012	Askey; P.	H04N5/2351	348/187
	F					
	G					
	H					
	I					
	J					
	K					
	L					
	M					

Change(s) applied to document. /S.B./ 4/6/2020

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Electronic Acknowledgement Receipt

EFS ID:	39416746
Application Number:	13691805
International Application Number:	
Confirmation Number:	6244
Title of Invention:	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS
First Named Inventor/Applicant Name:	Neal Solomon
Customer Number:	21186
Filer:	Nathan D. Ellefson/Robyn Miller
Filer Authorized By:	Nathan D. Ellefson
Attorney Docket Number:	5311.001US3
Receipt Date:	12-MAY-2020
Filing Date:	02-DEC-2012
Time Stamp:	13:41:40
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		5311001US3_RESCISSIONFORFILING.pdf	1017924 03c1c360edd373e0cbf02d4b14ff3dac6d56288d	yes	3

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Transmittal Letter	1	1
	Rescind Nonpublication Request for Pre Grant Pub	2	2
	Miscellaneous Incoming Letter	3	3
Warnings:			
Information:			
	Total Files Size (in bytes):	1017924	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s): Neal Solomon
Title: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

Docket No.:	5311.001US3	Serial No.:	13/691,805
Filed:	December 2, 2012	Due Date:	N/A
Examiner:	Marly Camargo	Group Art Unit:	2699
Customer No.:	21186	Confirmation No.:	6244

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

We are transmitting herewith the following attached items (as indicated with an "X"):

X Rescission of Previous NonPublication Request (35 U.S.C. 122(b)(2)(B)(ii)) (1 pg.)
X Communication Re: NonPublication Rescission (1 pg)

If not provided for in a separate paper filed herewith, please consider this a PETITION FOR EXTENSION OF TIME for sufficient number of months to enter these papers and please charge any additional fees or credit overpayment to Deposit Account No. 19-0743. If applicable, any papers or fees supplied herewith are considered to be timely filed pursuant to 37 C.F.R. § 1.7(a), the response period falling on a Federal Holiday, Saturday or Sunday being extended to the next succeeding business day.

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
Customer No.: 21186

By: /Timothy E. Bianchi/
Timothy E. Bianchi
Reg. No. 39,610

A/N 16/692,939 **PATENT**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s): Neal Solomon Examiner: MARLY S.B. CAMARGO

Application No.: 13/691,805 Group Art Unit: 2699

Filed: December 12, 2012 Docket No.: 5311.001US3

Confirmation No.: 6244

Title: DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

COMMUNICATION RE: NONPUBLICATION RESCISSION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Applicant and inventor Neal Solomon hereby rescinds the *pro-se* nonpublication request filed with the above-identified U.S. application on December 12, 2012. Applicant notes that the certification for the nonpublication request was improper based on a prior-filed, lapsed PCT application (PCT/US07/15544 filed on July 7, 2007), which was filed before the December 12, 2012 filing date of the above-identified U.S. application. Pursuant to M.P.E.P. § 1122(III), "…the Office will not consider the U.S. application as abandoned for having made the nonpublication request." M.P.E.P. § 1122(III).

If the Office requires any more information for processing this rescission, Applicant will provide such information upon request.

Respectfully submitted,

Date 5/12/20

By Neal Solomon

Neal Solomon
Inventor, Optimum Imaging Technologies LLC

Modified PTO/SB/36 (07-09)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

RESCISSION OF PREVIOUS NONPUBLICATION REQUEST
(35 U.S.C. 122(b)(2)(B)(ii))
AND, IF APPLICABLE NOTICE OF FOREIGN FILING
(35 U.S.C. 122(b)(2)(B)(iii))

Send completed form to:
Mail Stop PG Pub
Commissioner for Patents
P.O. Box 1450 Alexandria, VA 22313-1450 FAX: (571) 273-8300

Application Number	13/691,805
Filing Date	December 2, 2012
First Named Inventor	Neal Solomon
Title	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS
Atty Docket Number	5311.001US3
Art Unit	2699
Examiner	Marly Camargo

A request that the above-identified application not be published under 35 U.S.C. 122(b) (nonpublication request) was included with the above-identified application on filing pursuant to 35 U.S.C. 122(b)(2)(B)(i).
I hereby rescind the previous nonpublication request.

If a notice of foreign or international filing is or will be required by 35 U.S.C. 122(b)(2)(B)(iii) and 37 CFR 1.213(c), I hereby provide such notice. This notice is being provided no later than forty-five (45) days after the date of such foreign or international filing.

If a notice of subsequent foreign or international filing required by 35 U.S.C. 122(b)(2)(B)(iii) and 37 CFR 1.213(c) was not filed within forty-five (45) days after the date of filing of the foreign or international application, the application is ABANDONED, and a petition to revive under 37 CFR 1.137(b) is required. See 37 CFR 1.137(f).

/Timothy E. Bianchi/ — Signature
05/12/2020 — Date
Timothy E. Bianchi — Typed or printed name
39,610 — Registration Number
(612) 373-6912 — Telephone Number

This request must be signed in compliance with 37 CFR 1.33(b).

If information or assistance is needed in completing this form, please contact the Pre-Grant Publication Division at (703)605-4283 or by e-mail at PGPub@USPTO.gov.

CERTIFICATE OF MAILING OR TRANSMISSION

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Mail Stop PG Pub, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, or facsimile transmitted to the U.S. Patent and Trademark Office on the date shown below.

Signature: / ROBYN MILLER/	
Name (Print/Type): Robyn Miller	Date: 05/12/2020

SEND TO: Mail Stop PG Pub, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/691,805	06/02/2020	10674046	5311.001US3	6244

21186 7590 05/13/2020

SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Neal Solomon, Oakland, CA;

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage and facilitate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.

IR103 (Rev. 10/09)

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/691,805	12/02/2012	Neal Solomon	5311.001US3

CONFIRMATION NO. 6244

21186
SCHWEGMAN LUNDBERG & WOESSNER, P.A.
P.O. BOX 2938
MINNEAPOLIS, MN 55402

NONPUBLICATION RESCISSION LETTER

OC000000116968914

Date Mailed: 05/14/2020

Communication Regarding Rescission Of Nonpublication Request and/or Notice of Foreign Filing

Applicant's rescission of the previously-filed nonpublication request and/or notice of foreign filing is acknowledged. The paper has been reflected in the Patent and Trademark Office's (USPTO's) computer records so that the earliest possible projected publication date can be assigned.

The projected publication date is 08/20/2020.

If applicant rescinded the nonpublication request before or on the date of "foreign filing,"[1] then no notice of foreign filing is required.

If applicant foreign filed the application after filing the above application and before filing the rescission, and the rescission did not also include a notice of foreign filing, then a notice of foreign filing (not merely a rescission) is required to be filed within 45 days of the date of foreign filing. See 35 U.S.C. § 122(b)(2)(B)(iii), and Clarification of the United States Patent and Trademark Office's Interpretation of the Provisions of 35 U.S.C. § 122(b)(2)(B)(ii)-(iv), 1272 Off. Gaz. Pat. Office 22 (July 1, 2003).

If a notice of foreign filing is required and is not filed within 45 days of the date of foreign filing, then the application becomes abandoned pursuant to 35 U.S.C. § 122(b)(2)(B)(iii). In this situation, applicant should either file a petition to revive or notify the Office that the application is abandoned. See 37 CFR 1.137(f). Any such petition to revive will be forwarded to the Office of Petitions for a decision. Note that the filing of the petition will not operate to stay any period of reply that may be running against the application.

Questions regarding petitions to revive should be directed to the Office of Petitions at (571) 272-3282.

[1] Note, for purpose of this notice, that "foreign filing" means "filing an application directed to the same invention in another country, or under a multilateral international agreement, that requires publication of applications 18 months after filing".

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/ggasgedom/

Electronic Patent Application Fee Transmittal

Application Number:	13691805
Filing Date:	02-Dec-2012
Title of Invention:	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS
First Named Inventor/Applicant Name:	Neal Solomon
Filer:	Joseph P. Mehrle/Amanda Brace
Attorney Docket Number:	5311.001US3

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
PETITION FEE-37CFR 1.17(H) (GROUP II)	2464	1	70	70
RCE- 1ST REQUEST	2801	1	650	650
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**720**

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
NEAL SOLOMON
P.O. BOX 21297
OAK LAND, CA 94620

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Applicant's or agent's file reference	Date of mailing (*day/month/year*) 26 AUG 2008 **FOR FURTHER ACTION** See paragraph 2 below

International application No.	International filing date (*day/month/year*)	Priority date (*day/month/year*)
PCT/US07/15544	07 July 2007 (07.07.2007)	06 July 2007 (06.07.2007)

International Patent Classification (IPC) or both national classification and IPC

IPC: **H04N 5/76**(2006.01) H04N 5/225(2006.01)
USPC: 348/231.99,340

Applicant

SOLOMON, NEAL

1. This opinion contains indications relating to the following items:

- ☒ Box No. I — Basis of the opinion
- ☐ Box No. II — Priority
- ☐ Box No. III — Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV — Lack of unity of invention
- ☒ Box No. V — Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI — Certain documents cited
- ☐ Box No. VII — Certain defects in the international application
- ☐ Box No. VIII — Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(*b*) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA/ US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450	04 August 2008 (04.08.2008)	David Ometz
Facsimile No. (571) 273-3201		Telephone No. (571) 270-1131

Form PCT/ISA/237 (cover sheet) (April 2007)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US07/15544

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:

☒ the international application in the language in which it was filed

☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a))

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of:

a. type of material

☐ a sequence listing

☐ table(s) related to the sequence listing

b. format of material

☐ on paper

☐ in electronic form

c. time of filing/furnishing

☐ contained in the international application as filed.

☐ filed together with the international application in electronic form.

☐ furnished subsequently to this Authority for the purposes of search.

4. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table(s) relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US07/15544

Box No. V Reasoned statement under Rule 43 *bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims 1-4,6-10	YES
	Claims 5	NO
Inventive step (IS)	Claims 3,4,6-10	YES
	Claims 1,2,5	NO
Industrial applicability (IA)	Claims 1-10	YES
	Claims NONE	NO

2. Citations and explanations:

Please See Continuation Sheet

Form PCT/ISA/237 (Box No. V) (April 2007)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US07/15544

Supplemental Box
In case the space in any of the preceding boxes is not sufficient.

V. 2. Citations and Explanations:
Claim 5 lack novelty under PCT Article 33(2) as being unpatentable over USPN Alon et al. (US PgPub 2007/0236574).

Regarding **claim 5,** Alon et al. teaches a digital imaging system (paragraph 0007 and 0025 *et seq.*) comprising: a digital camera mechanism (paragraph 0007 *et seq.* and 0025 *et seq.*), an optical lens mechanism (paragraphs 0008, 0039, and 0051 *et seq.*), a digital sensor (paragraphs 0011 and 0020 *et seq.*), a microprocessor (paragraph 0047), a nano-grid mechanism (paragraphs 0008 *et seq.* filter), a digital signal processor (paragraphs 0048 and 0092), system software (paragraphs 0020 and 0054) and a memory storage sub-system (paragraphs 0089, 0092, and 0095 - 0096); wherein the nano-grid mechanism is between the optical lens mechanism and the digital sensor (paragraphs 0008 *et seq.* filter); wherein the nano-grid mechanism is comprised of an array of nano-filaments (paragraphs 0008 *et seq.* filter); wherein the nano-grid mechanism receives an electrical signal from the microprocessor and modifies its filament structure by modulating the filaments (paragraphs 0008 *et seq.* filter); wherein the nano-grid mechanism performs a function to provide filtration to the image before the digital sensor captures the image (paragraphs 0008 *et seq.* filter); wherein the image is captured by the digital sensor (paragraphs 0011 and 0020 *et seq.*) and the digital image file forwarded to the digital signal processor (paragraphs 0048 and 0092)and; wherein the digital file is stored in memory (paragraphs 0089, 0092, and 0095 - 0096).

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US07/15544

Supplemental Box
In case the space in any of the preceding boxes is not sufficient.

Claims 1 - 2 lack novelty under PCT Article 33(2) as being unpatentable over Alon et al. (US PgPub 007/0236574) in view of over Havens (US PgPub 2007/0080280).

Regarding **claim 1,** Alon et al. teaches a digital imaging system (paragraph 0007 and 0025 *et seq.*) comprising: A digital camera mechanism (paragraph 0007 *et seq.* and 0025 *et seq.*), an optical lens mechanism (paragraphs 0008, 0039, and 0051 *et seq.*), a digital sensor (paragraphs 0011 and 0020 *et seq.*), a microprocessor (paragraph 0047), a digital signal processor (paragraphs 0048 and 0092), system software (paragraphs 0020 and 0054), a database management system (paragraphs 0089, 0092, and 0095 - 0096) and a memory storage sub-system (paragraphs 0089, 0092, and 0095 - 0096); wherein the optical lens mechanism is a fixed focal length (paragraphs 0008, 0039, and 0051 *et seq.*); wherein the aberrations from the optical lens mechanism are corrected by applying digital filtration by using the digital signal processor (paragraphs 0007 0011 – 00209, 0047 and 0097); wherein a microprocessor is used to provide digital and optical data to the digital signal processor (paragraph 0047); wherein the system software is organized to identify specific optical aberrations and to access the database to identify specific corrections to the aberrations (paragraphs 0020 and 0054); wherein the system software forwards the data file from the digital sensor to the digital signal processor (paragraphs 0020 and 0054); wherein the digital signal processor selects a specific procedure to optimize the image and corrects the aberrations (paragraphs 0048 and 0092; Also, paragraphs 0007 0011 – 0020, 0047 and 0097) and; wherein the modified digital file consisting of the digital data optimized from the aberrations that are corrected from the original optical image is stored in memory (paragraphs 0089, 0092, and 0095 - 0096).

However, Alon et al. fails to teach an application specific integrated circuit used for correcting aberrations. Havens, on the other hand teaches an application specific integrated circuit along with a microprocessor can be used for processing data.

More specifically, Havens teaches an application specific integrated circuit along with a microprocessor can be used for processing data (paragraphs 0045 – 0046, 0063).

Therefore, one of ordinary skill in the art at the time the invention was made would have been motivated to incorporate the teachings of Havens with the teachings of Alon et al. since the use of both an ASIC and a microprocessor in a system will increase the system speed.

Regarding **claim 2,** Alon et al. teaches a digital imaging system (paragraph 0007 and 0025 *et seq.*) comprising: A digital camera mechanism (paragraph 0007 *et seq.* and 0025 *et seq.*), an optical lens mechanism (paragraphs 0008, 0039, and 0051 *et seq.*), a digital sensor (paragraphs 0011 and 0020 *et seq.*), a microprocessor (paragraph 0047), a digital signal processor (paragraphs 0048 and 0092), system software (paragraphs 0020 and 0054), a database management system (paragraphs 0089, 0092, and 0095 - 0096) and a memory storage sub-system (paragraphs 0089, 0092, and 0095 - 0096); wherein the optical lens mechanism is a fixed focal length (paragraphs 0008, 0039, and 0051 *et seq.*); wherein image depth-

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No. PCT/US07/15544

Supplemental Box
In case the space in any of the preceding boxes is not sufficient.

of-field is optimized by forwarding the digital file from the digital sensor to the microprocessor (paragraphs 0047, 0049, 0056 - 0057, and 0071); wherein system software accesses a database to determine the optimal aperture by comparing the distance data to similar images in the database (paragraphs 0020 and 0054; also, 0089, 0092, and 0095 - 0096); wherein a microprocessor is used to provide digital image data to the digital signal processor (paragraph 0047); wherein the digital signal processor optimizes the digital file aperture setting by comparing it to the database data (paragraphs 0089, 0092, and 0095 - 0096); wherein the microprocessor adjusts the camera's aperture setting (paragraphs 0047, 0049, 0056 - 0057, and 0071); wherein the digital sensor captures the image and forwards the image data file to the digital signal processor to make modifications to the digital file (paragraphs 0048 and 0092; Also, paragraphs 0007 0011 – 0020, 0047 and 0097) and; wherein the digital file is stored in memory (paragraphs 0089, 0092, and 0095 - 0096).

However, Alon et al. fails to teach an application specific integrated circuit used for correcting aberrations. Havens, on the other hand teaches an application specific integrated circuit along with a microprocessor can be used for processing data.

More specifically, Havens teaches an application specific integrated circuit along with a microprocessor can be used for processing data (paragraphs 0045 – 0046, 0063).

Therefore, one of ordinary skill in the art at the time the invention was made would have been motivated to incorporate the teachings of Havens with the teachings of Alon et al. since the use of both an ASIC and a microprocessor in a system will increase the system speed.

Claims 3 - 4 and 6 - 10 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest the.

In claim 3: A system as claimed in claim 1 in which the type of filtration applied by the digital signal processor are special effects; wherein the digital signal processor applies a fast Fourier transform to the digital file in order to satisfy a user specified special effects function.

In claim 4: A system as claimed in claim 1 in which the type of filtration applied by the digital signal processor are applied only to specific objects; wherein the digital file is analyzed by the microprocessor to separate specific objects in the image using the differentiation of the depth-of-field; wherein the digital signal processor applies filtration only to specific objects in the image and.

In claim 6: The system of claim 1; wherein the digital sensor contains a tri-pixel configuration; wherein three differentiated sub-pixels in each pixel in which one of the sub-pixels is in the center of the pixel and is the largest and deepest of the sub-pixels; wherein the other two sub-pixels are smaller than the center sub-pixel and are on the sides of the center sub-pixel; wherein the sub-pixels forward image data to the filament on each row and; wherein each row forwards the

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US07/15544

Supplemental Box
In case the space in any of the preceding boxes is not sufficient.

image data to the digital signal processor.

In claim 7: The system of claim 1 comprising: wherein the lens focal length alternates from specific fixed focal length lens settings in a succession of steps and; wherein optical aberrations are corrected with digital filtration to modify multiple images from different focal lengths in a succession of data files.

In claim 8: The system of claim 1: wherein the imaging system is integrated into a video camera.

In claim 9: The system of claim 1; wherein the type of filtration applied by the digital signal processor is applied to specific moving objects; wherein the digital image that is captured is forwarded from the digital sensor to the microprocessor and to the digital signal processor; wherein the digital file is analyzed by the microprocessor to separate specific objects in the image using the temporal differentiation of caching in which successive images share geometric elements; wherein the digital signal processor applies filtration only to a specific continuous object that is isolated and is in motion and; wherein the digital signal processor forwards the modified digital file to be stored in memory.

In claim 10: The system of claim 1; wherein a network of digital imaging sensors is linked together in a fixed structure; wherein the network is coordinated to track specific objects that are within its collective field of vision; wherein the network captures images of objects using the digital imaging sensors; wherein the individual digital imaging sensors forward the imaging data to a central digital signal processor.

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13691805
	Filing Date	2012-12-02
	First Named Inventor	Neal Solomon
	Art Unit	2699
	Examiner Name	Marly Camargo
	Attorney Docket Number	5311.001US3

U.S.PATENTS						
Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	10210602		2019-02-19	Campbell, Richard John	
	2	10674047		2020-06-02	Solomon, Neal	
	3	7327390		2008-02-05	Gallagher, Andrew C	
	4	9077842		2015-07-07	Natsume, Satoshi	

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS						
Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20020012054	A1	2002-01-31	Osamoto, Akira	
	2	20020041383	A1	2002-04-11	Lewis, Clarence A, et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13691805
	Filing Date	2012-12-02
	First Named Inventor	Neal Solomon
	Art Unit	2699
	Examiner Name	Marly Camargo
	Attorney Docket Number	5311.001US3

	3	20030039402	A1	2003-02-27	Robins, David R, et al.	
	4	20040150726	A1	2004-08-05	Gallagher, Andrew C	
	5	20050030394	A1	2005-02-10	Mendis, Sunetra K, et al.	
	6	20060120599	A1	2006-06-08	Steinberg, Eran, et al.	
	7	20070252074	A1	2007-11-01	Ng, Yi-ren, et al.	
	8	20080175514	A1	2008-07-24	Nose, Atsushi, et al.	
	9	20120229654	A1	2012-09-13	Solomon, Neal	

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1							☐

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NON-PATENT LITERATURE DOCUMENTS

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13691805
	Filing Date	2012-12-02
	First Named Inventor	Neal Solomon
	Art Unit	2699
	Examiner Name	Marly Camargo
	Attorney Docket Number	5311.001US3

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1	"Application Serial No. 16 692,972, Notice of Allowance mailed 01-24-20", 17 pages.	☐
	2	"Application Serial No. 16 692,939, Non Final Office Action mailed 02-04-20", 22 pages.	☐
	3	"Application Serial No. 16 694,838, Non Final Office Action mailed 02-13-20", 21 pages.	☐
	4	"Application Serial No. 16 694,850, Non Final Office Action mailed 03-04-20", 25 pages.	☐
	5	"Application Serial No. 16 692,939, Examiner Interview Summary mailed 05-06-20", 4 pg	☐
	6	"Application Serial No. 16 692,939, Response to Non Final Office Action mailed 02-04-20 filed 05-04-20", 12 pages.	☐
	7	"PCTUS2007015544 Published International Application 10-23-2008", (10 23 2008), 3 pages.	☐
	8	"PCTUS2007015544 Notification Recording Change 11-21-2008", (11 21 2008), 1 page.	☐
	9	"PCTUS2007015544 Written Opinion ISA 01-11-2009", (1 11 2009), 7 pages.	☐
	10	"PCTUS2007015544 IPRP 01-13-2009", (1 13 2009), 8 pages.	☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13691805
	Filing Date	2012-12-02
	First Named Inventor	Neal Solomon
	Art Unit	2699
	Examiner Name	Marly Camargo
	Attorney Docket Number	5311.001US3

	11	"Application Serial No. 16 694,838, Examiner Interview Summary mailed 05-13-20", 4 pages.	☐
	12	"Application Serial No. 16 694,850, Examiner Interview Summary mailed 05-13-20", 4 pages.	☐
	13	"PCTUS2007015544 Documents 1-17-2008", (1 17 2008), 147 pages.	☐

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13691805
	Filing Date	2012-12-02
	First Named Inventor	Neal Solomon
	Art Unit	2699
	Examiner Name	Marly Camargo
	Attorney Docket Number	5311.001US3

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Timothy E. Bianchi/	Date (YYYY-MM-DD)	2020-05-15
Name/Print	Timothy E. Bianchi	Registration Number	39,610

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Acknowledgement Receipt	
EFS ID:	39454535
Application Number:	13691805
International Application Number:	
Confirmation Number:	6244
Title of Invention:	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS
First Named Inventor/Applicant Name:	Neal Solomon
Customer Number:	21186
Filer:	Joseph P. Mehrle/Amanda Brace
Filer Authorized By:	Joseph P. Mehrle
Attorney Docket Number:	5311.001US3
Receipt Date:	15-MAY-2020
Filing Date:	02-DEC-2012
Time Stamp:	15:50:59
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$720
RAM confirmation Number	E20205EF50540866
Deposit Account	190743
Authorized User	Amanda Brace
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

37 CFR 1.19 (Document supply fees)

37 CFR 1.20 (Post Issuance fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Petition automatically granted by EFS	petition-request.pdf	31525 2e532351a2cc870895b509b9cdf9a01049dfd314	no	2
Warnings:					
Information:					
2		5311001US3_SIDSforFiling.pdf	196452 76b01e4ea5e16f47d467d08bb4d21b4a9f4ddca7	yes	7
	Multipart Description/PDF files in .zip description				
	Document Description		**Start**	**End**	
	Request for Continued Examination (RCE)		1	1	
	Information Disclosure Statement (IDS) Form (SB08)		2	7	
Warnings:					
Information:					
3	Other Reference-Patent/App/Search documents	0001_2_npl_16692939exirexaminer_interview_summary20200506_f.pdf	229722 00471011fc1aeef3c5033d7a04f116ca35154891	no	4
Warnings:					
Information:					
4	Other Reference-Patent/App/Search documents	0002_2_npl_16694838exirexaminer_interview_summary20200513_f.pdf	250336 e19523106f1f77384c926bc0e548ede4e9bd1e18	no	4
Warnings:					
Information:					
5	Other Reference-Patent/App/Search documents	0003_2_npl_16694850exirexaminer_interview_summary20200513_f.pdf	234709 1cf1e04af9195cd0206a5f9447be89abd49cc992	no	4
Warnings:					
Information:					

6	Other Reference-Patent/App/Search documents	0004_2_npl_5311001us4_aarn_050420_f.pdf	86528 8f184cb287e07076a80e8a9377d2d331e6404c7f	no	12
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7	Other Reference-Patent/App/Search documents	0005_2_npl_5311001us4_oarnpe_2420_f.pdf	1035771 4538cb0c41771408a7de077789fb065aa50710ac	no	22
Warnings:					
Information:					
8	Other Reference-Patent/App/Search documents	0006_2_npl_5311001us5_noar_12420_f.pdf	1000472 749af474fe275854ba393d9dc12a52f1ff917262	no	17
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Information:					
9	Other Reference-Patent/App/Search documents	0007_2_npl_5311001us6_oarnpe_21320_f.pdf	1168774 189efe6ee15fce1f685e731fe9adfb0ca2aec8f6	no	21
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Information:					
10	Other Reference-Patent/App/Search documents	0008_2_npl_5311001us7_oarnpe_3420_f.pdf	1307110 4f672bf0118b45b533868f4578f701dd5e29beae	no	25
Warnings:					
Information:					
11	Other Reference-Patent/App/Search documents	0009_2_npl_pctus2007015544_documents_17012008_f.pdf	6824352 355c8d99e66de7c18f08cecfdebaa3dbc930125f	no	147
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Information:					
12	Other Reference-Patent/App/Search documents	0010_2_npl_pctus2007015544_iprp_13012009_f.pdf	326102 c539113aa445b0adacfbedc494606d877b54ad38	no	8
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Information:					

13	Other Reference-Patent/App/Search documents	0011_2_npl_pctus2007015544_notification_recording_change_211_f.pdf	42477 f33a6f01c63f486b1db4d99321aa0a0d3df554db	no	1
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Information:					
14	Other Reference-Patent/App/Search documents	0012_2_npl_pctus2007015544_published_international_application_f.pdf	110824 8b82f826dda3c845c66cb18718f4ada089052390	no	3
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Information:					
15	Other Reference-Patent/App/Search documents	0013_2_npl_pctus2007015544_written_opinion_isa_11012009_f.pdf	286030 298299a089555edacac4830eef2907fdd94dca5c	no	7
Warnings:					
Information:					
16	Fee Worksheet (SB06)	fee-info.pdf	32180 2d837ef8f652ed1ab44ac8b8366ad89ae92869e6	no	2
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		Total Files Size (in bytes):	13163364		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>New Applications Under 35 U.S.C. 111</u>
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
<u>National Stage of an International Application under 35 U.S.C. 371</u>
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450
www.uspto.gov

Decision Date : May 15, 2020

In re Application of :

Neal Solomon

DECISION ON PETITION
UNDER CFR 1.313(c)(2)

Application No : 13691805
Filed : 02-Dec-2012
Attorney Docket No : 5311.001US3

This is an electronic decision on the petition under 37 CFR 1.313(c)(2), filed May 15, 2020 , to withdraw the above-identified application from issue after payment of the issue fee.

The petition is **GRANTED.**

The above-identified application is withdrawn from issue for consideration of a submission under 37 CFR 1.114 (request for continued examination). See 37 CFR 1.313(c)(2).

Petitioner is advised that the issue fee paid in this application cannot be refunded. If, however, this application is again allowed, petitioner may request that it be applied towards the issue fee required by the new Notice of Allowance.

Telephone inquiries concerning this decision should be directed to the Patent Electronic Business Center (EBC) at 866-217-9197.

This application file is being referred to Technology Center AU 2697 for processing of the request for continuing examination under 37 CFR 1.114 .

Office of Petitions

Doc Code: PET.AUTO Document Description: Petition automatically granted by EFS-Web	PTO/SB/140 U.S. Patent and Trademark Office Department of Commerce

Electronic Petition Request	**PETITION TO WITHDRAW AN APPLICATION FROM ISSUE AFTER PAYMENT OF THE ISSUE FEE UNDER 37 CFR 1.313(c)**
Application Number	13691805
Filing Date	02-Dec-2012
First Named Inventor	Neal Solomon
Art Unit	2697
Examiner Name	MARLY CAMARGO
Attorney Docket Number	5311.001US3
Title	DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

An application may be withdrawn from issue for further action upon petition by the applicant. To request that the Office withdraw an application from issue, applicant must file a petition under this section including the fee set forth in § 1.17(h) and a showing of good and sufficient reasons why withdrawal of the application from issue is necessary.

APPLICANT HEREBY PETITIONS TO WITHDRAW THIS APPLICATION FROM ISSUE UNDER 37 CFR 1.313(c).

A grantable petition requires the following items:
(1) Petition fee; and
(2) One of the following reasons:
(a) Unpatentability of one or more claims, which must be accompanied by an unequivocal statement that one or more claims are unpatentable, an amendment to such claim or claims, and an explanation as to how the amendment causes such claim or claims to be patentable;
(b) Consideration of a request for continued examination in compliance with § 1.114 (for a utility or plant application only); or
(c) Express abandonment of the application. Such express abandonment may be in favor of a continuing application, but not a CPA under 37 CFR 1.53(d).

Petition Fee

- (●) Small Entity
- ( ) Micro Entity
- ( ) Regular Undiscounted

Reason for withdrawal from issue

◯ One or more claims are unpatentable ◉ Consideration of a request for continued examination (RCE) (List of Required Documents and Fees) ◯ Applicant hereby expressly abandons the instant application (any attorney/agent signing for this reason must have power of attorney pursuant to 37 CFR 1.32(b)).
RCE request,submission, and fee. ☐ I certify, in accordance with 37 CFR 1.4(d)(4) that : The RCE request ,submission, and fee have already been filed in the above-identified application on ☒ Are attached.
THIS PORTION MUST BE COMPLETED BY THE SIGNATORY OR SIGNATORIES I certify, in accordance with 37 CFR 1.4(d)(4) that I am: ◉ An attorney or agent registered to practice before the Patent and Trademark Office who has been given power of attorney in this application. ◯ An attorney or agent registered to practice before the Patent and Trademark Office, acting in a representative capacity. ◯ A sole inventor ◯ A joint inventor; I certify that I am authorized to sign this submission on behalf of all of the inventors as evidenced by the power of attorney in the application ◯ A joint inventor; all of whom are signing this e-petition

Signature	/Timothy E. Bianchi/
Name	Timothy E. Bianchi
Registration Number	39610

Box No. VIII (ii) DECLARATION: ENTITLEMENT TO APPLY FOR AND BE GRANTED A PATENT

The declaration must conform to the standardized wording provided for in Section 212; see Notes to Boxes Nos. VIII, VIII (i) to (v) (in general) and the specific Notes to Box No. VIII (ii). If this Box is not used, this sheet should not be included in the request.

Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent (Rules 4.17(ii) and 51*bis*.1(a)(ii)), in a case where the declaration under Rule 4.17(iv) is not appropriate:

Neal Solomon is entitled to apply for and be granted a patent by virtue of the following:

Neal Solomon of P.O. Box 21297, Oakland, CA, 94620, USA, is the inventor of the subject matter for which protection is sought by way of this international application.

☐ This declaration is continued on the following sheet, "Continuation of Box No. VIII (ii)".

RECORD COPY

PCT/US2007/015544

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No. PCT/US 07/15544

International Filing Date: 07 JULY 2007 (07.07.07)

Name of receiving Office and "PCT International Application": PCT INTERNATIONAL APPLICATION RO/US

Applicant's or agent's file reference *(if desired) (12 characters maximum)*:

Box No. I TITLE OF INVENTION

Digital Imaging System

Box No. II APPLICANT ☑ This person is also inventor

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

Solomon, Neal
P.O. Box 21297
Oakland, CA 94620
USA

Telephone No.: 415 433 5400

Facsimile No.: 415 433 4033

Applicant's registration No. with the Office:

State *(that is, country)* of nationality: USA

State *(that is, country)* of residence: USA

This person is applicant for the purposes of: ☑ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

☐ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☐ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

Telephone No.:

Facsimile No.:

Agent's registration No. with the Office:

☑ Address for correspondence: Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Form PCT/RO/101 (first sheet) (April 2007) *See Notes to the request form*

Sheet No. 2

Box No. V DESIGNATIONS

The filing of this request constitutes under Rule 4.9(a), the designation of all Contracting States bound by the PCT on the international filing date, for the grant of every kind of protection available and, where applicable, for the grant of both regional and national patents.
However,

- ☐ DE Germany is **not designated** for any kind of national protection
- ☐ JP Japan is **not designated** for any kind of national protection
- ☐ KR Republic of Korea is **not designated** for any kind of national protection
- ☐ RU Russian Federation is **not designated** for any kind of national protection

(The check-boxes above may only be used to exclude (irrevocably) the designations concerned if, at the time of filing or subsequently under Rule 26bis.1, the international application contains in Box No. VI a priority claim to an earlier national application filed in the particular State concerned, in order to avoid the ceasing of the effect, under the national law, of this earlier national application.)

Box No. VI PRIORITY CLAIM

The priority of the following earlier application(s) is hereby claimed:

Filing date of earlier application *(day/month/year)*	Number of earlier application	Where earlier application is:		
		national application: country or Member of WTO	regional application: regional Office	international application: receiving Office
item (1) 11/07/06	US 60/807,065	US		
item (2) 06/07/07	Neal Solomon – Digital Imaging System	US		
item (3)				

☐ Further priority claims are indicated in the Supplemental Box.

Transmit certified copy: the receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of this international application is the receiving Office)* identified above as:

☑ all items ☐ item (1) ☐ item (2) ☐ item (3) ☐ other, see Supplemental Box

Restore the right of priority: the receiving Office is requested to restore the right of priority for the earlier application(s) identified above or in the Supplemental Box as item(s) (_____). *(See also the Notes to Box No. VI: further information must be provided to support a request to restore the right of priority.)*

Incorporation by reference: where an element of the international application referred to in Article 11(1)(iii)(d) or (e) or a part of the description, claims or drawings referred to in Rule 20.5(a) is not otherwise contained in this international application but is completely contained in an earlier application whose priority is claimed on the date on which one or more elements referred to in Article 11(1)(iii) were first received by the receiving Office, that element or part is, subject to confirmation under Rule 20.6, incorporated by reference in this international application for the purposes of Rule 20.6.

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):*

ISA / .....

Request to use results of earlier search; reference to that search *(if an earlier search has been carried out by or requested from the International Searching Authority):*

Date *(day/month/year)* Number Country *(or regional Office)*

Box No. VIII DECLARATIONS

The following declarations are contained in Boxes Nos. VIII (i) to (v) *(mark the applicable check-boxes below and indicate in the right column the number of each type of declaration)*:		Number of declarations
☐ Box No. VIII (i)	Declaration as to the identity of the inventor :	
☑ Box No. VIII (ii)	Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent :	
☑ Box No. VIII (iii)	Declaration as to the applicant's entitlement, as at the international filing date, to claim the priority of the earlier application :	
☑ Box No. VIII (iv)	Declaration of inventorship (only for the purposes of the designation of the United States of America) :	1
☐ Box No. VIII (v)	Declaration as to non-prejudicial disclosures or exceptions to lack of novelty :	

Sheet No. 6

Box No. IX CHECK LIST; LANGUAGE OF FILING

This international application contains:

(a) on paper, the following number of sheets:

request (including declaration and supplemental sheets)	:	6
description (excluding sequence listing and/or tables related thereto)	:	54
claims	:	4
abstract	:	1
drawings	:	19
Sub-total number of sheets	:	~~86~~ 84
sequence listing	:	
tables related thereto	:	
(for both, actual number of sheets if filed on paper, whether or not also filed in electronic form; see (c) below)		
Total number of sheets	:	~~86~~ 84

(b) ☐ **only in electronic form** (Section 801(a)(i))
- (i) ☐ sequence listing
- (ii) ☐ tables related thereto

(c) ☐ **also in electronic form** (Section 801(a)(ii))
- (i) ☐ sequence listing
- (ii) ☐ tables related thereto

Type and number of carriers (diskette, CD-ROM, CD-R or other) on which are contained the
- ☐ sequence listing: .....
- ☐ tables related thereto: .....

(additional copies to be indicated under items 9(ii) and/or 10(ii), in right column)

This international application is accompanied by the following item(s) *(mark the applicable check-boxes below and indicate in right column the number of each item)*: — Number of items

1. ☑ fee calculation sheet :
2. ☐ original separate power of attorney :
3. ☐ original general power of attorney :
4. ☐ copy of general power of attorney; reference number, if any: ..... :
5. ☐ statement explaining lack of signature :
6. ☐ priority document(s) identified in Box No. VI as item(s): ..... :
7. ☐ translation of international application into *(language)*: ..... :
8. ☐ separate indications concerning deposited microorganism or other biological material :
9. ☐ sequence listing in electronic form *(indicate type and number of carriers)*
   - (i) ☐ copy submitted for the purposes of international search under Rule 13*ter* only (and not as part of the international application) :
   - (ii) ☐ *(only where check-box (b)(i) or (c)(i) is marked in left column)* additional copies including, where applicable, the copy for the purposes of international search under Rule 13*ter* :
   - (iii) ☐ together with relevant statement as to the identity of the copy or copies with the sequence listing mentioned in left column :
10. ☐ tables in electronic form related to sequence listing *(indicate type and number of carriers)*
    - (i) ☐ copy submitted for the purposes of international search under Section 802(b-*quater*) only (and not as part of the international application) :
    - (ii) ☐ *(only where check-box (b)(ii) or (c)(ii) is marked in left column)* additional copies including, where applicable, the copy for the purposes of international search under Section 802(b-*quater*) :
    - (iii) ☐ together with relevant statement as to the identity of the copy or copies with the tables mentioned in left column :
11. ☐ other *(specify)*: ..... :

Figure of the drawings which should accompany the abstract: English

Language of filing of the international application: English

Box No. X SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

Neal Solomon (inventor)

(07.07.07)

For receiving Office use only

1. Date of actual receipt of the purported international application: IAP6 Rec'd PCT/PTO 07 JUL 2007
2. Drawings: ☐ received: ☐ not received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:
4. Date of timely receipt of the required corrections under PCT Article 11(2):
5. International Searching Authority (if two or more are competent): ISA / US
6. ☐ Transmittal of search copy delayed until search fee is paid

For International Bureau use only

Date of receipt of the record copy by the International Bureau:

Form PCT/RO/101 (last sheet) (April 2007) *See Notes to the request form*

Box No. VIII (iv) DECLARATION: INVENTORSHIP (only for the purposes of the designation of the United States of America)
The declaration must conform to the following standardized wording provided for in Section 214; see Notes to Boxes Nos. VIII, VIII (i) to (v) (in general) and the specific Notes to Box No. VIII (iv). If this Box is not used, this sheet should not be included in the request.

Declaration of inventorship (Rules 4.17(iv) and 51*bis*.1(a)(iv))
for the purposes of the designation of the United States of America:

I hereby declare that I believe I am the original, first and sole (if only one inventor is listed below) or joint (if more than one inventor is listed below) inventor of the subject matter which is claimed and for which a patent is sought.

This declaration is directed to the international application of which it forms a part (if filing declaration with application).

This declaration is directed to international application No. PCT/..... (if furnishing declaration pursuant to Rule 26*ter*).

I hereby declare that my residence, mailing address, and citizenship are as stated next to my name.

I hereby state that I have reviewed and understand the contents of the above-identified international application, including the claims of said application. I have identified in the request of said application, in compliance with PCT Rule 4.10, any claim to foreign priority, and I have identified below, under the heading "Prior Applications," by application number, country or Member of the World Trade Organization, day, month and year of filing, any application for a patent or inventor's certificate filed in a country other than the United States of America, including any PCT international application designating at least one country other than the United States of America, having a filing date before that of the application on which foreign priority is claimed.

Prior Applications: .....

.....

I hereby acknowledge the duty to disclose information that is known by me to be material to patentability as defined by 37 C.F.R. § 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the PCT international filing date of the continuation-in-part application.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name: Neal Solomon

Residence: Oakland, California
(city and either US state, if applicable, or country)

Mailing Address: P.O. Box 21297
Oakland, CA 94620

Citizenship: US

Inventor's Signature: Neal Solomon Date: 7/7/07
(The signature must be that of the inventor, not that of the agent)

Name: .....

Residence: .....
(city and either US state, if applicable, or country)

Mailing Address: .....

.....

Citizenship: .....

Inventor's Signature: ..... Date: .....
(The signature must be that of the inventor, not that of the agent)

☐ This declaration is continued on the following sheet, "Continuation of Box No. VIII (iv)".

Box No. VIII (iii) DECLARATION: ENTITLEMENT TO CLAIM PRIORITY

The declaration must conform to the standardized wording provided for in Section 213; see Notes to Boxes Nos. VIII, VIII (i) to (v) (in general) and the specific Notes to Box No. VIII (iii). If this Box is not used, this sheet should not be included in the request.

Declaration as to the applicant's entitlement, as at the international filing date, to claim the priority of the earlier application specified below, where the applicant is not the applicant who filed the earlier application or where the applicant's name has changed since the filing of the earlier application (Rules 4.17(iii) and 51*bis*.1(a)(iii)):

in relation to this international application, Neal Solomon is entitled to claim priority of earlier application number US/60/807,065 by virtue of the following:

the applicant is the inventor of the subject matter for which protection was sought by way of the earlier application.

☐ This declaration is continued on the following sheet, "Continuation of Box No. VIII (iii)".

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

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PCT

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(30) Priority Data:

60/807,065	11 July 2006 (11.07.2006)	US
Not furnished	6 July 2007 (06.07.2007)	US

(71) Applicant and
(72) Inventor: **SOLOMON, Neal** [US/US]; P.O. Box 21297, Oakland, CA 94620 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*
— *of inventorship (Rule 4.17(iv))*

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) **Title:** DIGITAL IMAGING SYSTEM

(57) **Abstract:** A system is disclosed for the automated correction of optical and digital aberrations in a digital imaging system. The system includes several main parts, including (a) digital filters, (b) hardware modifications, (c) digital system corrections, (d) digital system dynamics and (e) network aspects. The system solves numerous problems in still and video photography that are presented in the digital imaging environment.

WO 2008/008280 A2

DIGITAL IMAGING SYSTEM

CROSS-REFERENCES TO RELATED APPLICATIONS

The present application claims the benefit of priority under 35 U.S.C. section 119 from U.S. Provisional Patent Application Serial No. US60/807,065, filed on July 11, 2006, the disclosures of which are hereby incorporated by reference in their entirety for all purposes.

FIELD OF THE INVENTION

The present invention pertains to imaging systems. The invention presents electronic methods to optimize optical processing, the digital capture of light and post-capture image organization of digital data sets. The system may be used in any device that captures, records, replicates, scans, reproduces, accesses, organizes, modifies, edits or stores images digitally. The invention applies to any imaging system that includes interaction between optics, digital image sensors, post-capture integrated circuits and digital storage components. The system includes self-organizing apparatus for optical image collection, electronic organization and optimization of digital data using integrated circuits and software applications. The system applies to consumer and professional still and video photography, including cinematography, to the processing of images with digital sensors, and to copying and scanning technologies. The system also applies to complex grids of multiple video cameras and satellites for surveillance and reconnaissance.

BACKGROUND OF THE INVENTION

The history of photography in the twentieth century is a story of finding solutions for optimizing optical problems. The main challenges have involved improving lens configurations to optimize image quality for film capture. As an example of this, lens aberrations have been reliably corrected by creating aspherical lens elements in wide-angle lenses and by creating apochromatic lens elements in telephoto lenses. The use of lens element coatings has also improved optical quality. Similarly, the evolution of zoom lenses has included improvement in optical quality via the combining of complex optical element configurations; as the optical quality of zoom lenses improved dramatically, their simplicity and utility led them to dominate

lens sales. Complex computer-aided design (CAD) software has been used to test a broad range of possible lens configurations so as to optimize the optical performance in terms of clarity and contrast of each lens type, as much as optically possible within economic constraints.

In the last twenty-five years, an additional revolution has occurred with the advent of auto-focus (AF) technology in still photographic and video cameras. Invented by Minolta in the early 1980s, AF technology was a photographic application of technology developed for the U.S. military. The AF system used an infrared light sensor to reflect light onto an object that allowed a camera's lens to focus on the object by employing a motor in the camera. Canon eventually developed improved methods of auto focus by using electronic means (viz., micro ultrasonic motors) to increase speed and accuracy. This AF technology was integrated with automatic exposure (AE) technology which developed complex algorithms in a "program" mode to combine shutter and aperture data to match each lens with particular subject matter, as well as an aperture-priority exposure mode and a shutter-priority exposure mode. Of course, the photographer could use manual focus and manual exposure at any time, but these improvements increased the creative process and the competitive advantages of camera makers and photographers that employed them. Ultimately, the combination of these developments allowed ordinary photographers to achieve high quality standards.

AE was improved by Nikon, particularly with the use of a "3D color matrix" system, which included a library of pre-programmed image types. The combination of the improved AF and AE subsystems allowed a dramatic simplification of photographic imaging because the photographer no longer labored over the time-consuming focus and the exposure variables. Automated film advance, in the form of built in motor drives, increased the working speeds of camera operation as well. Nearly all consumer and professional cameras became automated to some degree by the mid-1990s, including formats beyond the 35mm film standard.

In the last decade, a new technology of image stabilization (IS) has emerged to help correct the problem of vibrations caused camera shake that lead to image blur. This technology is implemented in lenses by the use of gyros to reorient the light plane to compensate for camera shake; when combined with the earlier automated camera technologies such as AF and AE, IS further improves the photographic experience, particularly for larger lenses.

In addition to these advances in camera automation, technologies improved in the category of artificial flash as well. With microprocessors and sensors employed to measure

minute variances, the development of photographic flash systems allowed the photographer to control the lighting in an environment to some degree. Nikon's use of distance information in its flash system advanced the state of the art in flash photography. The combination of AF and AE with automated flash mechanisms provided increased efficiency and simplicity in image capture processes.

The last several years have witnessed a revolution in digital photography. Because of its simplicity, potential quality improvement, immediate feedback and cost savings, digital photography has captured an increasing market share relative to film-based cameras. Kodak holds a number of patents involving the charge coupled device (CCD) for converting and recording light into electronic format. A competing technology for digital capture is complementary metal-oxide semiconductor (CMOS) which, though developed by Fairchild Semiconductor over forty years ago, is predominantly used in photographic cameras by Canon. Although there are trade-offs in the application of CCD and CMOS digital sensors for image capture, they both find wide acceptance in the market.

In order to correct for digital artifacts in image capture mechanisms, anti-aliasing filters are placed in front of digital sensors. Despite this improvement, digital imaging still has some challenges to overcome in competing with the image quality of film.

At the present time, the most recent advances in digital imaging for professional still photography have come from Hasselblad, which offers a Phase One camera back with a 39 MP digital sensor from Kodak. This system uses software that automatically corrects for digital capture limitations to produce a quality image. Their "digital APO correction" (DAC) technology performs an analysis of meta-data to color-correct the digital capture resulting in moiré-free images.

At the limits of current technology, a Canadian company, Dalsa, has produced a 111MP (10,560 by 10,560 pixels) CCD digital sensor that measures four inches square. This technology must be mated with large format-type lenses with large image area, and may be used for satellite surveillance applications and for other astronomical applications.

With both the larger sensor surface area of a medium format camera system and the high-quality fixed focal-length lenses of Zeiss, Schneider and Rodenstock, the quality of even the top optics will be a limiting barrier to advanced digital sensors' ability to perceive maximum

resolution. Without new improvements in optical and digital technologies, further progression of photographic camera systems will be limited.

Photographic Problems

Though every major advance in photography has solved an important problem, there are still remaining photographic problems to be solved in order to meet the goals of optimizing optical imaging quality while increasing simplicity and efficiency and lowering cost. Despite the advent and evolution of digital imaging, a number of problems have emerged in the digital realm in addition to earlier problems involving optics. Nevertheless, an opportunity exists to solve some of these problems via digital approaches. These problems are generally categorized as optical or digital.

Optical Problems

In the case of optics, lens aberrations are characterized according to lens type, with wide-angle lens problems differentiated from telephoto lens problems. Some of the problems affecting wide-angle lenses arose from the creation of the single lens reflex (SLR) camera. Before the SLR, the rear element of a lens could be placed in a rangefinder to protrude to a point immediately in front of the film plane in order to correct for aberrations. While the advantages of the mirror mechanism include ability to see exactly what one is photographing, because the mirror of the SLR flips up during exposure, the rear element of the lens must be placed in front of the mirror's plane of movement. This mechanical fact limits lens designs in most 35mm and medium-format camera systems and particularly affects wide-angle lens configurations.

It is very difficult to control the five aberrations of Seidel – spherical aberration, distortion (barrel distortion and pin cushion distortion), comatic aberration, astigmatism and curvature of field. In wide-angle SLR lenses as they are currently designed, these aberrations are particularly prominent.

For wide-angle lenses, optical vignetting affects peripheral illumination. Though optical vignetting will affect even retrofocus wide-angle lenses in rangefinders, it is particularly prominent in SLR cameras. According to the Cosine law, light fall-off in peripheral areas of an image increases as the angle-of-view increases. While optical vignetting can be reduced by

stopping down the lens, the aberrations in rectilinear wide-angle lenses generally exhibit more distortion the wider the lens.

In the case of wide-angle lenses, the depth of field range is much broader, with close focusing causing aberrations without stopping down the aperture. To solve this problem, close-distance focusing is improved by the creation of floating groups of lens elements. The rear lens group elements float to correct close-distance aberrations. With wide-angle lenses that have wide apertures, floating lens elements improve lens aberrations in focusing on distance points also.

Modulation transfer function (MTF) curves represent a quantitative methodology used to assess the resolution and contrast of lens performance at specific apertures. Each lens type has a specific lens element composition, formula and behavior as measured by MTF. In general, MTF measures lens sharpness to 30 lines/mm and contrast to 10 lines/mm.

Because different colors of the visible light spectrum behave uniquely, the goal of lens design is to have all colors accurately hit a film plane or digital sensor plane. The particular challenge for telephoto lenses is that the red and green light colors strike the film plane at different times than blue light colors; thus a compensation must be made in the lens configuration to adjust for chromatic aberrations. Camera lens manufacturers have used extra low dispersion glass and fluorite glass elements in telephoto lenses primarily to adjust the red color light spectra to the film plane. In addition, telephoto lenses use carefully designed lens coatings to limit light diffraction-based aberrations.

Due to their construction, super-telephoto lenses are very large and heavy. While modifying the materials used in the lens barrels could reduce size and weight problems, a technological improvement in telephoto lens design was developed by Canon with the addition of diffractive optical (DO) elements, which behave as a sort of highly-refined fresnel lens magnifier. Though the MTF analyses of wide-angle lenses show dramatic latitude in performance of even high quality SLR lenses, with particular loss in resolution and contrast toward the edges of the image, high quality telephoto lenses show control of aberrations. However, the price of these lenses is prohibitively high.

In the case of zoom lenses, as many as four distinct groups of lens elements correct various optical aberrations. These lens element groups include (a) a focusing group, (b) a magnification variation group, (c) a correction group and (d) an image formation group.

Modulating the focal length range of a zoom lens enables the lens to perform within the scope of operation, yet the zoom lens architecture has limits. In particular, the zoom lens configuration sacrifices resolution and wide potential aperture. Generally, the degree of resolution and contrast at the smaller angle of view is traded away in favor of competence at a wider angle of view, or vice-versa. This explains why MTF analyses of zoom lenses generally show a dramatic lowering in resolution and contrast relative to excellent fixed focal length lenses.

Digital Problems

Digital photography has built on the edifice of *film* camera systems. For instance, the size of the sensor is generally limited to the size of the optical circumference of a lens system. In the case of 35mm lenses that are designed for a specific angle of view, the largest that a digital sensor in a 35mm lens system could be, is 24mm by 36mm, with a corresponding maximum image circle of 43mm. In the case of medium format lenses, the largest digital sensors would duplicate the corresponding film plane size, whether 6x4.5 cm, 6x6 cm, 6x7 cm, 6x8 cm, 6x9 cm, 6x12 cm or 6x17 cm (which results in an effective image circle as large as 7 inches).

Digital sensors that are smaller than the limits of a corresponding lens system have been introduced. For example, Nikon digital sensors are smaller than 24mm x 36mm, or advanced photo system (APS) size. Efficient stacking of pixels allows a smaller sensor to eventually match the performance of a corresponding film system, while using the smaller circumference of the same lenses. Since the outside edges of the lens typically degrade resolution and contrast, this model using the smaller digital sensor can have an advantage of using primarily the centralized "sweet spot" of the image area. However, this smaller sensor size sacrifices the peripheral effects of a wide-angle lens, so a 14mm becomes a 21mm in a 1.5x conversion-sized sensor in a 35mm lens system. On the other hand, with telephoto lenses, the angle of view is limited to the center 65% of the image. This gives the appearance of upconverting a telephoto lens by 1.5x and thus provides an impression of increased magnification; a 400mm f/2.8 lens appears as a 600mm f/2.8 lens on a camera with a cropped digital sensor. Ultra-wide-angle lenses have been introduced with smaller image areas than 35mm to compensate for smaller sensor size.

Though invented over thirty years ago by Dr. Bayer, the charge coupled device (CCD) that is used in many digital cameras generally emulates the behavior of film. Specifically, since

most photographic film has three layers of green, red and blue, with green representing fifty percent of the emulsion and red and blue twenty-five percent each, the CCD architecture also configured pixels to capture fifty percent of the green photonic visible light spectrum and twenty-five percent each for pixels recording red and blue light. Human eyes see more green than red and blue, so both film and digital sensors seek to emulate the way that we see. Each light color is captured by a different pixel in the CCD, just as there are three emulsion layers of film. In recent years, Foveon has developed a digital sensor for image capture that further seeks to emulate film by structuring the pixels into three *layers*, again with fifty percent capturing green light and twenty-five percent each capturing red and blue light.

Unfortunately, unwanted artifacts are also captured by the digital image capture process. These include banding and moiré effects that present false patterns and colors. Moiré patterns are created because the dot pattern of a sensor will intermittently overlap with the pattern of a subject to create a third pattern; these effects are optically-generated digital distortions that represent the effect of light hitting a pixel without correction. In order to compensate for these effects, digital sensors have employed low pass filters consisting of liquid crystal structures; however, these filters tend to have the effect of softening image resolution. Additionally, RGB or CMYG color filters are placed in front of digital sensors to ensure the accurate capture of colors.

CMOS digital sensors present an alternative to CCDs. By employing alternating positive and negative transistor networks, the CMOS sensors use less power. While they do not have the low noise ratio of the CCD, they do have greater light exposure latitude, in both range of ISO and dynamic range of detail in highlight and shadow. More importantly, CMOS sensors contain the circuitry, including analog to digital converter (ADC) and digital to analog converter (DAC), for post-processing digital images on the chip itself and enabling increased micro-miniaturization of the digital imaging process. An increase in the bit rate of the CMOS chip up to 32-bit makes possible a much richer color palate and level of detail than with earlier generation CCDs.

CMOS sensors can be full-frame, matching the lens specifications for the camera systems for which they are designed. A relatively bigger sensor has a wider depth of field capability, so the background can appear as a blur to set apart the main subject. Given these capabilities, one problem that emerges is that a digital sensor's enhanced capabilities to capture details may exceed the maximum optical resolution capabilities of many lenses. Nevertheless, CMOS

sensors still require an anti-aliasing filter to be used in front of the sensor, which marginally degrades resolution.

Over the years, cameras have gotten smaller. While in the 19th century cameras were 11x14 or 8x10, literally capturing images on large emulsion plates, cameras of today are smaller and more automated. Yet the larger the film size, the bigger the enlargement potential and the increase in relative detail in the overall image. Similarly in digital photography, the larger the sensor, the more detail available and the bigger the output print can be enlarged. Because of this correspondence of digital sensor to film, the evolution of digital photography has been restricted to respective film camera systems, with 35mm and medium format systems dominating the field because well-developed lens systems have already been organized for these camera formats. The potential exists, however, to develop 35mm camera system digital sensors that rival film-based medium format or large format camera system quality or to surpass the limits of 35mm camera systems with medium format camera system digital sensors. The relative size, cost and automation advantages of 35mm camera systems generally show that these systems not only are competitive, but that these markets are increasingly accelerated relative to larger format systems. For example, the development of large aperture lenses, super-telephotos, rapid auto-focus, refined automated exposure and image stabilization systems in 35mm systems has solved various problems that have emerged in the last century and has improved image quality and camera system efficiency.

However, in the digital imaging realm additional problems have emerged, including the need to improve color (hue and saturation) quality, exposure highlight range, contrast range and other tonal adjustments. In addition, digital image capture brings its own set of aberrations, including moiré and banding effects and noise and ISO range limits. Additional aberrations are linked to the unique design of each type of digital sensor, with trade-offs presented between types of CCDs or CMOS chips. Moreover, there are still optical problems in the digital realm, namely, a range of optical aberrations created particularly by wide-angle and zoom lenses as well as the limits of very large, costly and heavy super-telephoto lenses.

In order to transcend the optical and digital limits of present camera systems, software systems have been developed that deal with the problems in post-production. While the most notable of these post-production digital editing software programs is Adobe Photoshop, each camera manufacturer has its own proprietary program. In the main, these post-production

software programs are limited to color correction and sharpening/softening of images. Additionally, some of these software programs are able to emulate specific artificial filter techniques to produce creative modifications of an original image. Nevertheless, manipulating unfiltered RAW image files in post-production processes is time-consuming and expensive and requires considerable skill.

One unintended effect of using digital sensors to capture images in digital photography is that dust accumulates on the sensor surface and thereby obstructs a clear optical image. The vacuum behavior of increasingly ubiquitous zoom lenses moves dust in lenses that are not internally sealed and the existence of dust is a prevalent feature of digital photography. Dust on the sensor is a non-trivial problem that requires tedious post-production correction for each image. The existence of dust on a digital sensor is an inconvenient impediment to achievement of optical imaging quality.

What is needed to correct these various optical and digital aberrations and unfiltered image files is in-camera modification capability for each specific image problem. The present invention describes a digital imaging system to optimize optical results.

Applications of the Present Invention

The present invention has several practical applications. The digital imaging system applies to consumer and professional still and video camera technologies, to cellular telephones and to personal digital assistants (PDAs). Since video technologies are evolving into digital formats, including HDTV and its successors, the present invention would be applicable to these technologies. The present invention also applies to networks of remote camera sensors for surveillance. The system also applies to native digital cinematography and telecine conversion from analogue to digital media. The system may be applied to image scanning and image copying technologies. Finally, the present system may be applied to any optical digital capture, processing and storage sub-system technologies, including groups of sensors or satellites.

Advantages of the Present Invention

There are several important advantages of the present invention. The present system dramatically improves image quality. This digital imaging system eliminates, or minimizes, post-production processes. In addition, the system presents substantial cost savings as well as

time savings relative to existing digital imaging systems because of the automation of integrated in-camera optical and digital corrections of aberrations.

With the present system, in-camera digital filters will largely replace optical filters. With less distortion, cost and weight/size than current optical filters and with far more control and quality results, the present system demonstrates that in-camera digital filtration out-performs better than external filters. The in-camera filter system is also an improvement over post-production digital filter systems which require substantial time, cost and skill to implement.

By using the present invention, users will be able to use lens apertures that are wider open, because lens aberrations will be corrected. In turn, this increased latitude will allow more efficient (2+ stops) use of available light and will allow slower lenses to achieve quality images that have traditionally been in the domain of expensive fast lenses. The process of photography will be made generally more efficient.

The present system allows camera manufacturers to design different, predominantly smaller, lenses. Moreover, with providing a system for digital corrections, camera lenses may use less expensive optics and still obtain good results. This process will, in turn, accelerate the adoption of low-cost digital photographic systems and, in the aggregate, increase the overall size of the digital photographic market. Similarly, there will be an increase in the effectiveness of zoom lenses, which are already becoming popular. With the present system, 35mm optics may obtain the quality typically recognized by 4x5 film camera systems. The present system will thus facilitate photographic digital imaging to supplant the film era.

Its application to digital scanning and copying will allow the present system to become ubiquitous as a system to improve imaging.

Because the system presents an integration of several critical subsystems that are centered on digital imaging processes, the system has applications to video photography, satellite systems and surveillance systems. The dynamics of the operation of the subsystems of the present digital imaging system reveal the refinement, efficiency and optimization of the digital photographic paradigm.

Importantly, since the present system uses apparatus and methods that are implemented with software processes, in-camera software can be constantly upgraded and remotely downloaded, while image files can be automatically uploaded, organized and published.

If the goal of the evolution of photographic technology is to increase the number and quality of excellent images, the present system will revolutionize photography.

Solutions to Digital Imaging Problems that the Present System Presents

The present system provides in-camera digital corrections to both optical and digital aberrations. In the case of optical aberrations, distinct lens-specific imperfections are caused by wide-angle, telephoto and zoom lens types. In the case of digital aberrations, specific digital artifacts, such as aliasing and dust, must be corrected.

The present invention also designs specific improvements to digital sensor design. These hardware architecture modifications allow digital imaging to maximize both optical resolution and image exposure range.

Post-capture in-camera filtration is only part of the solution. There is also a need to modify the digital sensor, whether CCD or CMOS, with specific filtration in some cases, including a low pass anti-aliasing filter and a polarizing filter. This post-optic pre-sensor filtration works with post-sensor in-camera filtration processes.

In the context of specific complex processes, such as in zoom lens modifications of focal length and in full-motion video processing, additional corrections are performed using the digital imaging system which continuously optimizes performance.

Finally, the present system reveals approaches to improve network coordination and wireless external storage and publication capabilities for digital imaging systems.

BRIEF SUMMARY OF THE INVENTION

The present invention is divided into several main sub-systems: (1) digital filters to correct optical and digital aberrations; (2) digital sensor improvements and nano-grids; (3) digital system improvements that link multiple digital corrections; (4) dynamic digital imaging system improvements that apply to zoom lenses and video imaging; and (5) digital image network improvements. There are several distinct improvements for each category of sub-system listed.

DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic drawing of a digital imaging system.

Fig. 2 is a flow chart of an analog to digital signal process.

Fig. 3 is an image of the vignetting corrective filter in an optical lens.

Fig. 4 is a list of wide angle 35mm lens types.

Fig. 5 is a flow chart of the digital corrective process.

Fig. 6 is a schematic diagram of different types of optical aberrations in different configurations of the same lens.

Fig. 7 is a flow chart of the process of digital image capture, processing and storage.

Fig. 8 is a flow chart illustrating the process of selecting filtration settings.

Fig. 9 is a pair of diagrams showing the varied depth of field optimization at different apertures.

Fig. 10 is a flow chart showing exposure optimization using digital correction in camera.

Fig. 11 is a flow chart illustrating the use of in-camera special effects filtration.

Fig. 12 is a flow chart showing the selective in-camera filtration of specific objects.

Fig. 13 is a flow chart describing the exposure adjustment of an image using in-camera filtration.

Fig. 14 is a flow chart showing the process of in-camera special effects filtration.

Fig. 15 is a flow chart showing the process of in-camera digital correction for sensor dust.

Fig. 16 is a diagram showing a digital camera with an ASIC array.

Fig. 17 is a diagram illustrating a digital camera with interchangeable CCD and CMOS sensors.

Fig. 18 is a diagram of a digital camera with a nano-grid before the sensor.

Fig. 19 is a diagram of a nano-grid.

Fig. 20 is a diagram showing the feedback loop connecting the processor and the nano-grid.

Fig. 21 is a diagram illustrating the tri-pixel architecture in a digital sensor.

Fig. 22 is a flow chart showing the pre-programmed modules for in-camera functionality.

Fig. 23 is a diagram showing the pre-sensor modification process in a digital camera.

Fig. 24 is a flow chart showing the integration of optical and digital corrections with feedback.

Fig. 25 is a flow chart showing the interactive feedback mechanism of integrated corrections.

Fig. 26 is a flow chart describing the adaptive user pattern learning process to process images.

Fig. 27 is a flow chart describing the feedback process in filtering images.

Fig. 28 is a flow chart showing software privacy function in a digital imaging system.

Fig. 29 is a flow chart showing the dynamics of zoom lens corrections in digital imaging.

Fig. 30 is a diagram illustrating object tracking in dynamic changes in video corrections.

Fig. 31 is a flow chart showing object tracking of a digital imaging system.

Fig. 32 is a flow chart showing the caching process of an object in motion in a stationary scene.

Fig. 33 is a diagram showing network coordination of fixed sensor grid tracking multiple objects.

Fig. 34 is a diagram showing the wireless communication features of the digital imaging system.

Fig. 35 is a flow chart showing an image organization system.

DETAILED DESCRIPTION OF THE INVENTION

(I) Digital Filters to Correct Optical and Digital Aberrations

(1) Lens-specific digital correction of fixed focal-length lens for specific optical aberrations in camera.

Each lens has some sort of aberrations because of the trade-offs involved in producing lenses of usable size and practical commercial cost. The challenge of building lenses for SLR camera systems lies in accounting for particular restrictions and compromises, particularly for wide-angle and zoom lenses. In the case of wide-angle fixed focal length lenses, several main kinds of aberrations occur, including spherical aberration, distortion (pin cushion distortion and barrel distortion), astigmatism, curvature of field (manifesting as the reduced corner exposure of vignetting) and comatic aberration (a distortion evident with long exposures). The extremes of each of these aberrations have to be corrected in post-production.

In the case of vignetting, a type of aberration in which the corners of an image are exposed a stop less than the image's center area, software can digitally emulate a center-neutral density filter to compensate for the light fall-off on the edges. This operation identifies the

degree of light fall-off for each specific lens and adjusts the brighter areas in the center of the lens by appropriate exposure compensation. A consequence of this digital equivalent of the traditional optical solution to vignetting is that the image will require exposure metering of the subject at a level consistent with the outside edges of the image rather than the typical inner section. In the present system, the camera will use pre-set calculations compensating (generally one stop) for the specific gradations of the curvature of the field for each lens, with an increasing compensation correlated to an increased angle of view. Similarly, barrel distortion and pin-cushion distortion, which also manifest in image corners, are corrected using processes of employing pre-set calculations, to compensate for optical distortion, particularly in wide-angle and zoom lenses.

In addition to integrating into the camera the traditional process of image correction for exposure gradations of vignetting, the present invention offers two further embodiments. First, instead of darkening the center to match the darker corners, the in-camera digital compensation system will lighten the corners to match the exposure of the center of the image. In the second embodiment, the in-camera digital compensation system will both lighten the corners somewhat and darken the center of the image somewhat, to produce a more pleasing and realistic effect. The in-camera digital corrections of the vignetting problem dramatically improve the traditional optical solution of a center-weighted neutral density filter, which typically degrades image quality as it evenly illuminates the full image.

Since each lens has specific aberrations, depending on manufacturer and even differences in the specimens themselves, the camera software system will have preprogrammed general corrections for each specific lens type. For instance, while a 20mm f2.8 lens varies among manufacturers, the general optical aberrations will be similar. An effective software solution is one which brings the optical image quality to a level consistent with a benchmark as measured by low MTF curves for each lens in its class in terms of both resolution and contrast throughout the image. To exemplify this benchmark, retrofocus rangefinder lens performance results of wide-angle lenses, which lack a shutter mechanism to design around, can be used for comparison. To accommodate the mirror in the SLR design type, the rear nodal point in SLR lenses are shifted forward, creating distortion. In contrast, the present system suggests applying a digital solution to compensate for this problem.

In a general sense, this process of correction is similar to correcting an ocular astigmatism with reading glasses. However, rather than using an optical solution to an ocular problem, the present system reveals a digital solution to an optical problem.

In the process, the camera identifies a specific lens and refers to a database that matches the lens type with the specific aberrations. The aberrations are consistent throughout all images for each formula of a specific prime lens type and are thus corrected by adjusting for each specific aberration category. Generally, the larger the angle of view of a lens, the greater the distortion and the greater the need for in-camera digital corrections.

In addition to the kinds of distortions created in wide-angle lenses, other types of distortion occur primarily in large aperture telephoto lenses, most notably chromatic aberrations that require apochromatic corrections. Rather than employing large, heavy and expensive extra dispersion glass, such as fluorite elements, the present system allows each lens type to be digitally corrected for these types of aberrations. The in-camera digital process works by identifying a specific lens and comparing the lens pattern to an internal database. Mathematical calculations compensate for the shift in red and green light that apochromatic corrections require for very low MTF curves registering high standards of resolution and contrast by emulating the optical benefits of extra low dispersion glass elements.

Since lenses of the same focal length but with different maximum apertures represent completely different lens designs, modifications of their aberrations will vary relative to each specific lens type. For example, a 24mm f/2.8 lens will have a different optical formula than a 24mm f1.4 lens in a 35mm camera system. Similarly, a 28mm f/2.8 will differ from both a 28mm f/2 lens and a 28mm f1.4 lens and will thus each require different adjustments for vignetting, spherical aberration, pin cushion distortion, barrel distortion and coma. In other words, each lens with a unique optical formula will have specific aberrations, the corrections for which will be accessible in a database.

Another type of optical aberration that affects lenses involves flare, which is a sort of specific reflection of light sources. While improvements in lens coatings have been used to correct for flare, high refractive glass also eliminates flare. The present system uses digital processes to emulate these flare reduction functions on lenses even at maximum apertures.

In addition to the lens-specific types of corrections that are supplied by in-camera software, a function that optimizes contrast provided by limited reflected light is required. In

general, lens hoods reduce reflected light. However, in the absence of a lens hood, scattered light will adversely affect contrast in all lenses. Thus, a general digital solution will optimize contrast from reflected light by emulating the effects of a lens hood.

Because the pixels on a digital sensor behave as neutral intermediaries to record light, the aberrations on specific fixed focal length lenses will be prominent. It is therefore necessary to filter out various optical impurities. In all cases, the digital in-camera software program emulates specific filters to effectively correct specific optical aberrations.

By digitally adjusting for optical distortions, the present system advances the state of the art for fixed focal length lens optics, beyond any opportunities available in film cameras. The following chart illustrates a list of optical distortions that are corrected by in-camera digital solutions.

	Fixed Focal Length Lens Type		Zoom Lens Type		
Specific Aberrations	**Wide-angle**	**Telephoto**	**Wide-angle**	**Wide-to-Tele**	**Telephoto**
Spherical	X		X	X	
Comatic	X	X	X	X	X
Astigmatism	X		X		
Distortion (Pin Cushion and Barrel Distortion	X		X		
Curvature of Field	X		X		
Chromatic		X		X	X
Flare	X	X	X	X	X
Scattered light (Unpolarized)	X	X	X	X	X
Color Accuracy	X	X	X	X	X
No Lens Coatings	X	X	X	X	X

(2) Multivariate digital correction using matrix filter system in camera

Since typically several distinct aberrations exist in a lens, it is necessary to correct each of the aberrations. For this multi-dimensional problem there is a multivariate digital in-camera software correction solution. The problem of correcting multiple aberrations presents the additional challenge of requiring acceleration to complete multiple tasks rapidly. In most cases, the hardware employed in a camera's chip set will include an application specific integrated circuit (ASIC) which processes a particular program rapidly. It is appropriate to facilitate the combination of corrections to multiple simultaneous aberrations with an ASIC or multiple ASICs.

There is a need to optimize both resolution and contrast across the image area for accurate light reproduction. One way to do this is to stop down the lens to an optimum aperture of about f/8. However, this solution sacrifices the advantages of a fast lens design and capability, namely, limited depth of field and bokeh (smooth out-of-focus area). Though

resolution is typically improved by stopping down a lens, digital sensors are generally still restricted in their latitude of contrast. Therefore, regarding both resolution and contrast, it is necessary to provide multiple adjustments of the native image with in-camera digital corrections.

While it is possible to produce mathematical algorithms for automatic correction of optical aberrations, it is also useful to have manually adjustable variables. Therefore, the present system includes a function whereby one may omit a specific correction in an image by using a lens with multiple aberrations in order to induce a particular creative effect. This factor may involve a lack of exposure compensation, a lack of correction for spherical aberration or an improperly or partially corrected apochromatic modification.

In one example of the use of multiple corrections, simultaneous application of multiple digital filters concurrently corrects multiple aberrations. In effect, this is like adding layers of different eye glasses to repair multiple types of astigmatisms for each specific ocular condition. The dynamics of correcting multiple simultaneous aberrations may be complex, but since the number and type of aberrations are constrained to a specific lens type, a centralized database may be accessed with specific corrections for each respective aberration. For example, lenses with multiple complex aberrations, such as in very wide-angle lenses, will require multiple corrections. These combinations of corrections become complex as focal length modes change in zoom lenses and as aperture changes.

The following is a list of filter types that provide digital methods of correcting image problems or creating specific effects. The list is not intended to be comprehensive or systematic.

Filter Type in Digital App.	**Most Common Uses**	**Other Filter Types**
UV (and Sky)	General Use	Polarizer
Color-enhancing (and warming)	17mm-200mm (in 35mm)	Close-up
Contrast	17mm-200mm (in 35mm)	Special effects filters
Black and White (Red, Orange, Yellow, Green)	17mm-200mm (in 35mm)	
Infrared	17mm-200mm (in 35mm)	
Color Graduated (Neutral Density)	17mm-200mm (in 35mm)	
Diffusion (Soft, mist/fog, star, streak)	24mm-135mm (in 35mm)	
Combinations (Neutral density and enhancing, Polarizer and UV)	17mm-200mm (in 35mm)	

In the past, these optical filtration processes were added after the production process via editing software such as Photoshop. However, in the present system, these combinations of processes are performed in-camera by user-adjusted settings. In the case of artificial color changes to an image, digital processes emulate specific optical filters by adding a specific color or a combination of colors. On the other hand, in the case of diffusion filtration, the in-camera digital process creates an emulation of optical filters. The classic example of this diffusion approach is the soft filter, which is used for portraiture. In this case, various user-adjustable settings in the camera digitally manipulate soft filtration.

(3) Depth-of-field optimization using digital correction in camera

In addition to correcting optically-generated aberrations with in-camera digital processes, the present system allows in-camera depth-of-field (DOF) optimization by affecting the aperture of the lens that is used.

DOF in an image is dependent on the aperture setting in a lens, in which a moderate DOF range – allowing a subject to be isolated in an image – can be manipulated, that is, extended or narrowed, by the camera's digital processing capability. In the film paradigm, one obtains a specific aperture, and thus the corresponding DOF, that is preset by the photographer. However, in the digital paradigm, by contrast, one can *narrow* an image's surplus DOF range in-camera by manipulating the aperture. This process can only be done in the camera, because once the digital file is sent to post-production editing, the aperture and DOF is already set and incapable of being changed. The aperture is narrowed in camera by isolating the subject and shifting the field of view (forward from the rear range of DOF and backward from the front range of the DOF). Distance information is used to recalculate an optimal DOF. In another embodiment, the camera provides feedback from an internal computational analysis that results in a specification of less DOF and takes another image (or images) with a larger aperture to accomplish reduced DOF at a specific focus point.

The camera will effectively identify a type of subject and provide an optimal aperture for this subject. For instance, for a portrait, the camera will select a shallow DOF around the subject. In the case of a distant landscape, the camera will focus on a distance at infinity and provide a nominal aperture to correspond to shutter speed that will fit the available light as matched to a specific lens. A near landscape photographed with a wide-angle lens will, on the other hand, have a near focus and a maximum DOF; specific subjects will be highlighted with

ample DOF. The camera will also have the capability to bracket exposures in several successive images based on DOF variations.

The DOF manipulation thus depends on a combination of data sets including the particular lens used (wide-angle lenses have greater DOF at moderate distances than telephoto lenses), the distance information and the unique combinations of aperture and shutter speed. DOF will narrow with less distance, with use of a telephoto lens and a fast aperture; contrarily, DOF will expand with a further distance, with use of a wide-angle lens and a slower aperture.

In another embodiment of this process, test images are taken and analyzed, then later images taken with new settings optimize DOF for each image type.

(4) Exposure optimization using digital correction in camera

One phenomenon that film currently records better than digital photo technology is exposure latitude. Film is capable of greater exposure latitude than either CCD or CMOS digital sensors, though each digital sensor type has strengths and weaknesses. For the crucial detail recorded in a scene, film provides far more depth of tonal range. Yet some of this problem – caused by the limits of digital sensors themselves and the way that photons are recorded by electrically charged pixels – can be digitally corrected and optimized in-camera.

The problem derives equally from the method of measuring exposure as well as the method of image capture by a digital sensor. In general, since there is less exposure latitude in digital sensors, as compared to film, the maximum scope is two or three stops in the image tonal range. Consequently, the camera must meter the image within constraints of the tonal range of the digital sensor, with the sacrifice of either shadow detail or highlight detail. In an image with broad exposure range, then, the image will generally be either too light or too dark because metering for one area sacrifices the other tonal category.

One way to solve this problem is to manipulate the lens aperture, because increased aperture within an optimal limit generally increases detail. An optimal aperture of f/8 provides more detail and clarity than at f/2 or at f/32. The in-camera processor may thus seek out more detail in the image by manipulating the aperture to the optimal range of f/5.6 to f/11, depending on the type of subject and the availability of light. With more detail in the original image, it is possible to interpolate the digital data in the image file by increasing both shadow and highlight detail and to gain an additional stop or two of tonal range.

In another embodiment, the tonal range of an image data set is enhanced in-camera by using meta-data to sample the range of shadow and highlight detail. The data sets are interpolated to add requested shadow detail and/or highlight detail. Obviously, some subjects require more or less shadow or highlight (or both), which the camera can correspondingly adjust. These tonal range corrections are user-adjustable.

In an additional embodiment of in-camera tonal range corrections, exposure data are bracketed by manipulating the aperture and shutter speed to lower or raise the overall exposure in one-third to one-half stop increments. This bracketing method may be correspondingly limited to a specific image type. For instance, in a portrait, the extraneous background, which ought to be out of focus, is not emphasized in the exposure data, while the main subject is carefully nuanced for balancing an optimum of both highlight and shadow, or for an exclusive emphasis on either highlight or shadow.

The overall problem of limited tonal range in digital photography stems from mismatched exposure-metering mechanisms of digital sensors with substantially restricted tonal range capabilities. One interesting example of this problem occurs in scenes with two or more stops of difference, such as a landscape with sky on top and earth on bottom. A filtration process will operate on the key parts of such an image, as described above regarding the vignetting phenomenon; the overexposed top half of the scene will be gradually underexposed while the lower half of the scene will be gradually overexposed. This scene-specific adjustment of exposure greatly increases the tonal range of digital images and is made possible via analysis of the scene and comparison to a database of typical scenes categorized by the in-camera digital processor which effects correction using the methods described herein. In this example, the corrective process emulates the use of neutral-density optical filters.

(5) Special effects digital filtration of specific objects

Though there are several main categories of special effects optical filters, including color enhancing, infrared and diffusion, the use of diffusion filters appears to elicit the most dramatic effect. Diffusion filters are categorized as soft effect, mist/fog, black mist, gold diffusion, and star and streak, with various degrees of diffusion producing lesser or greater distortions. In effect, rather than removing optically-generated distortions, we are deliberately creating photographically desirable distortions. It is possible to reproduce these special effects by using

the digital post-capture production processes in the camera. In this case, the camera digitally emulates the special effect by applying user-adjustable filter settings.

Portraits have traditionally used some sort of soft effect filtration approach which is producible in the camera using the methods described here. After the image is captured, the camera analyzes the image's meta-data and applies a correction by interpolating the data with specific filter emulation. In the past, specific camera lenses, such as the 135mm soft effects (also called "defocus control") lenses performed this function optically with an included adjustable lens element. This defocus control lens type will focus on the main subject and a lens element setting of the telephoto lens to produce a soft filter effect. In addition, because this lens type uses a nine blade aperture, the background that is out of focus has a pleasing bokeh in which the gradations of tone are evenly smooth. Nevertheless, a sophisticated digital camera is able to produce the same results with more information provided by a normal telephoto lens, using the method of emulating special effects in-camera.

Another novel special effect that is a further embodiment of the system is the ability of the in-camera digital corrective system to use complex data sets contained and analyzed in an image to create a three dimensional (3-D) representation of the image. The camera creates a 3-D image by arranging the DOF in a way that optimizes the aperture by using distance information and autofocus data to isolate a subject. By removing the foreground and background of the image as a center of subject focus, the DOF will emphasize the subject only as 3-D. The key to this effect is the application of specific exposure data as indicated above, because it is in the increased extension of the range of highlight and shadow that the subject in the image will attain a 3-D quality in contrast to its out of focus foreground and background.

An additional embodiment of the present system would extend the still photography in-camera special effects to video with full-motion ranges of filtration actions.

Finally, it is possible to *combine* different user-programmable special effects in-camera by adding the various types of diffusion methods for a specific image.

(6) Selective in-camera filtration of specific objects

The combination of sophisticated auto-focus technologies and in-camera auto-exposure systems provides the opportunity to isolate a subject by focusing on the subject and narrowing the DOF range by manipulating the aperture. In a further extension of the subject-isolating capabilities of these technologies, it is possible to digitally filter out specific objects in a scene

in-camera while focusing on other selected objects that are in a specific range of DOF. In other words, one may apply filtration to correct aspects of a single object or only the background of a scene to the exclusion of an isolated object, rather than correcting a whole scene. Selective filtering of specific objects in an image by in-camera digital processing affords greater creative flexibility.

Because the camera uses distance information to isolate a specific object by focusing on the object within a range of DOF, it is possible to isolate a particular object for the purposes of applying a specific filtration preference, such as manipulating the color, correcting the optical aberration (say, if the object is in a corner of the image of a wide-angle lens), providing a special effect (such as a soft effect only on a specific object rather than the scene as a whole) or using some combination of these corrections. Once the camera isolates the selected object (using auto-focus mechanisms and distance information), the user selects programmable correction features to perform a corrective function only on the specific object (or only on the parts of the scene that are exclusive of the object). In a further embodiment, contrastively, once the object is isolated, only the background may be selectively manipulated with filtration, achieving pleasing effects. This in-camera corrective feature provides a powerful tool to rapidly manipulate an image without using post-production editing software tools.

These object-specific in-camera selective filtration capabilities are particularly dramatic with fast-moving action photography in which split-second timing produces the preferred complex effects. Selectively identifying a particular object for intensive combinations of filtration is a highlight of the present system.

(7) Digital correction in-camera of intermittent aberrations caused by dust on digital sensor

Dust on a digital sensor is a major concern for photographers. The use of zoom lenses compounds this condition, because as the zoom lens changes focal-length positions, air is transmitted, which results in the proliferation and diffusion of sensor dust. Unless photography is isolated to a clean room, the problem of dust on a digital sensor will remain prevalent. The present system provides a method to correct for this phenomenon.

In the case of dust on a sensor, a specific consistent pattern emerges on each image captured by the digital sensor. Consequently, information from various images is analyzed, and the pixels affected by dust are identified. Information from the consistent fixed pixel positions that are affected by the dust are then isolated. The specific positions with the dust are then

analyzed by comparing the immediate areas surrounding the dust that are not affected by it. These unaffected areas are analyzed, and the affected areas are interpolated to provide a continuous tone. In effect, the images identify the locations with dust by using caching technology. The continuity of the location of the dust between multiple images provides information to the in-camera image processor to detect the specific pixel locations. The camera will then apply a corrective process to the isolated dust locations with adjoining exposures by interpolating these distinct locations for each specific image configuration.

In another embodiment of the present system, "hot" (too bright) or "dead" (too dark) pixels are interpolated out of the scene using the method described above. Unlike hot or dead pixels, dust is a similar but temporary version of the same problem of an artifact that requires in-camera modification. In effect, a map is built to discover, isolate and interpolate bad pixels, which are a permanent problem revealing a key limit in digital sensor technology. Separate maps are constructed for permanent pixel dysfunctions and temporary pixel aberrations (viz., dust). In both cases, the camera works from these maps to correct the aberrations on a pixel-level.

In a further embodiment of the present system, Monte Carlo analysis is applied to the problem of identifying the location of dust on specific pixels (or partial pixels) by randomly creating an initial map from information of at least two contaminated images.

In still another embodiment of the present system, the process of modifying pixel aberrations (either permanent or temporary) uses a sequence of operation which begins by correcting the major aberrations first, then repairing the minor aberrations, thereby maximizing efficiency. This is done by starting the corrective process in a specific location of the image and moving to other positions in an efficient pattern.

(8) Sequence of corrections for multiple (optical and digital) types of aberrations in camera

Since it is evident that multiple digital filtration approaches may be used for specific types of problems or aberrations or to achieve specific effects, it is clear that a combination of the techniques may be employed simultaneously on specific images. The present invention allows the various optical and digital corrections to be performed in camera in a sequence of actions. The user selects the various combinations of functions required to be performed, inspects the effects, and chooses the most effective combination of effects. Thus the invention offers a combinatorial optimization of the totality of corrective filtration approaches.

After the images have been taken, it is possible to inspect them in the camera using the camera's image read-out. This makes it possible to create new files, or to adapt a RAW file, in real time, by manipulating the various corrections in sequence. This post-image-capture in-camera editing process allows multiple corrections to be applied to a range of optical and digital aberrations by combining various specific corrective techniques.

In some cases, the user can pre-set specific corrections. For instance, to correct for optical aberrations, a user may leave this function on permanently. In other cases, such as selective filtration of a specific object or optimization for DOF or exposure, there may be discriminating use of specific corrective functions. In the case of selective user choice, it is possible, by using the present invention, to select a priority sequence of corrections in layers. While specific select layers may be permanently activated, for example to automatically adjust specific optical aberrations, additional sets of layers may be manually selected in order to modify the specific aspects of each image, particularly to adjust or correct digital aberrations. This process can be performed with a single microprocessor, multiple microprocessors, multiple ASICs or a combination of microprocessors and ASICs.

An additional embodiment of the system provides multiple combinations of corrections and effects via multiple independent ASICs, which only perform specific functions, working in parallel. The various tasks are divided into specific-function ASICs for rapid processing. The advantage of this approach is accelerated processing speed in performing multiple simultaneous functions.

(II) Digital Sensor Improvement and Nano-grids

(9) Interchangeable digital sensor system using both CCD and CMOS to optimize best results

Because the main digital sensor types of CCD and CMOS, like film types, each have benefits and detriments, it is sometimes advantageous to provide the utility of both sensor types in a camera system. With the exception of a video camera, which employs three CCDs, the use of multiple sensors has not been adopted. Two generations ago, however, the idea of using a twin reflex camera for medium format photography was implemented. In this case, though focus was coupled between the lenses, one lens was used to see the subject, while the other lens took the picture. This method was used to obtain the benefits of a rangefinder camera with a single lens reflex camera.

The use of two types of sensors in a camera is compelling, because the user benefits from the strengths of both. In the present invention, one sensor is selected from among at least two different types of sensors that are rotated to an active position by the user. One advantage of this approach is that if one sensor experiences a problem, there is a reserve sensor available at the push of a button.

This capability usefully exploits the strengths of each particular sensor. For instance, in situations in which high resolution is required, a CCD may be preferable, while in cases in which increased tonal range or low noise is preferable, a CMOS sensor may be preferable. With this approach, a customer does not need to choose between different types of sensors.

The process of interchanging the two chips is performed by placing the two chips on either façade of a plane that "flips" over (i.e., rotates 180 degrees) upon demand to obtain the requirements of the chosen chip type. This mechanism would fit behind an SLR's mirror and could easily be performed as long as the mirror is in the "up" position. In another embodiment, the chip exchange process can occur by sliding alternating chips into a sleeve from a single location and replacing the non-utilized chip(s) into the reserve compartment. In either event, the camera will detect the chip exchange and will automatically reprogram software functions and settings for the usable chip.

(10) Nano-grids for selected pixels on CCD or CMOS integrated circuits to optimize selective modifications of exposure, ISO and aberrations in digital photography

Digital sensors consist of arrays of pixels, arranged in rows, which behave as tiny buckets for converting photons to electrons. As the pixels fill up with light, they are able to discern slight differences in color and exposure and transfer the energy, in the form of electrons, to storage. Charge coupled devices (CCDs) have been the predominant form of digital sensor because they use a form of electronic charge which creates the behavior of a bucket brigade of transferring data, once the buckets in a row are filled up, to successive rows for digital data storage of the electronic charge sets. CMOS digital sensors may be structured with larger bucket pixels, which can increase the depth of the light captured and thus the latitude of light exposure that is stored. However, for the relatively larger buckets to provide increased photon capture capacity, it is necessary to control the width of the opening in the top and the width of the buckets so that the amount of light captured may be modulated.

The present invention introduces a key advance in the ability of digital sensors, particularly CMOS sensors, to modulate the size of the openings of the pixels. Specifically, the present system provides for a nano-grid, or a very small matrix of filaments, which fits over the sensor. The nano-grid is carefully calibrated to match the rows of pixels on the sensor so as to limit the amount of light that each of the buckets may receive. Use of the nano-grid allows a selective closing of the large buckets in order for photons to be restricted. Selective modification of specific pixels on the neutral grid makes it possible to identify specific sets of pixels to correct for various exposure or lens aberrations.

In this embodiment of the present system, data about a specific lens are provided to the camera in order to correct specific lens aberrations, while exposure data is used to modify image capture using nano-grids for optimum image performance.

Nano-grids may be selectively switched at different pixel sites, akin to continuously programmable field programmable gate array (CP-FPGA) semiconductors, which modify architecture in order to optimize effective operation by constantly manipulating the chip's gates.

Nano-grids may be used for specific image modes, for example, nocturnal imaging, which requires more time to read a sufficient amount of light. In this case, a specific software module may provide lens and exposure data to the camera, which then determine the precise composition of nano-grid correction to provide to specific sets of pixels on the digital sensor. In effect, nano-filaments move to positions to effectively block out the full capacity of the pixel buckets and thus change the pixel effects. With use of preset nano-grid positions for particular applications, the identification of specific vectors of nano-filaments is performed, and exposure adjustments are made on specific images in hardware.

The nano-grid is overlaid over the surface of the pixel architecture. The nano-grid is used not only in specific pre-set positions, but it also provides feedback to the post-capture system for analysis and repositioning to achieve the desired effects. One effect of the nano-grid is to manually expand or narrow the range of a set of pixel buckets; this process in turn effectively modifies not only the exposure range but also sharpness at high ISO, thereby dramatically reducing noise. Consequently, it becomes possible, by modifying the pixel bucket width and height, to obtain extremely sharp images with excellent contrast and tonal range even in poor lighting, a feat heretofore impossible.

The nano-grid performs these mechanical functions by moving the nano-filaments in an arc, like expandable windshield wipers. Though nano-grids are particularly useful in CMOS chips, they are also useful with CCDs. In fact, with the advent of nano-grids, CCD pixel size (and density in pixel-rows which will affect the overall sensor size) may be expanded and thus made substantially more versatile.

In a further embodiment of the present invention, multiple screens, or grids, would be placed over the digital sensor. The use of multiple nano-grids provides increased capacity to perform the function of closing off the pixel buckets and, in fact, to completely close off selected pixels to make the image effect completely dark. The combinations of nano-grids behave as multiple screens that move left and right to achieve the desired effect. Although there is a need to periodically calibrate the screens to effect their precise positions, this system will employ an electric charge to push the nano-filaments to the desired locations.

Nano-filaments move to block the space allowing photons to hit the pixel in order to limit the amount of light capacity available to the pixel. The complete darkening of the pixel will result in a total black color in the resulting image.

Exposure data feedback is provided to the digital sensor to effect the precise positioning of the nano-grid(s). In a further aspect of the present system, the camera's computer will anticipate the exposure data by statistically extrapolating from the pattern created by at least three data sets. A microprocessor (or ASIC) controlled nano-grid mechanism will use the feedback to anticipate specific nano-grid positions in order to optimize the exposure and corrective functions.

In one application of the nano-grid, the problem of vignetting in wide-angle lenses may be solved by activating nano-filaments in nano-grid(s) primarily in the corners to correct for the darkening from the limits of the optical aberrations, while still maintaining very low noise in a high ISO (low light) photographic situation. The use of the nano-grid would thus contribute to solving multiple problems.

Nano-grids will also be useful in accurately correcting for both color and exposure detail. In fact, with nano-grids, the capacity of digital sensors' range should be substantially increased, because the chips' pixel bucket sizes can be modulated. Therefore, not only will the lighting and color be accurate, but sharpness and optical aberrations will also be optimized, in ways not possible before.

(11) Integrated nano-grids in digital sensor

In a further embodiment of the system, nano-grids may be integrated into the digital sensor. In this form of the nano-grid, the nano-filaments are constructed *within* the pixel buckets in order to increase their accuracy and responsiveness. The nano-filaments mechanically move in various directions to perform the main operation of modulating light into their respective pixels. This method of organizing nano-grids and nano-filaments increases the rapidity of response to feedback. In effect, each pixel has a mask, or flexible lid, contained in it, which may open and close, to allow more or less light into the pixel bucket.

The integrated nano-filaments are activated by oscillation between positive and negative charges. In the context of a CMOS sensor, the transistor networks oscillate between positive and negative charges. This architecture allows a "push-pull" design of nano-filaments in which the negative charge "pulls" and the positive charge "pushes" the activation of the nano-filaments. This charge-enabled nano-grid (CENG) advantageously allows modulating gates (i.e., filaments) integrated into the pixel to reduce spaces between pixels, thereby allowing more pixels to be packed on the same surface area. The net benefit of the use of integrated CENG filaments is that specific sets of nano-filaments will produce specific effects on-demand and allow far more tonal detail than has been possible before.

In a further embodiment of the present system, sophisticated digital sensors may contain combinations of nano-grids that appear on top of the sensor as well as nano-grids that are integrated into the digital sensor. This combination will provide maximum latitude for processing the greatest effect available.

(12) Combinations of nano-grids and digital corrections applied to digital imaging system

Whereas it is possible to exclusively implement nano-grids to control the amount of light penetrating specific pixels, and it is possible to exclusively provide digital corrections as specified above regarding correcting optical or digital aberrations, a further embodiment of the present invention combines the two processes in order to optimize imaging.

Combining these two complex processes makes it possible to modify pixel capacity to maximize exposure latitude, to expand exposure modification and to apply digital correctives for optical and digital aberrations. Hence selective exposure far beyond the limits of present film or digital photography is made possible. The restrictions of film can thus be transcended by using

the present system, whereas use of a static and limited digital system would not be sufficient to facilitate these complex corrections.

The unique combinations of these processes also illustrate a complex system that provides feedback from both the environment and the photographer. The photographer may select preset exposure settings that will activate a range of options in both the nano-grids and the digital corrective system, while the lens aberration corrective system is automatically implemented. Once the camera detects specific conditions, such as a broad range of exposure latitude, from very bright to very dark, in the scene, it computes the precise number and location of nano-grids needed to modulate the pixels for optimum exposure with highlight and shadow detail and extreme sharpness, even in relatively low light. The dynamics of these multiple processes present trade-offs in selecting the best available set of selected modifications.

(13) Tri-well pixels

As indicated above, one of the key problems with current digital sensors involves dynamic range. There is a need to limit the scope of the space in the pixel well, into which light is captured, then converted into electrons. The challenge with current technologies is to balance details in shadow and highlight areas, particularly to acheive low noise at relatively high ISO speeds.

In addition to the concept of nano-grids, both in surface screen and integrated embodiments, as specified in (10) to (11) above, the present system introduces the notion of three side-by-side differentially-sized buckets within each pixel intended to optimize dynamic range for increased sensitivity. In the most common configuration, the three different-sized buckets are arranged with the largest bucket (in both width and height) in the center, with the second and third largest buckets on either side. The buckets are elliptical and concave in architecture to increase efficiency of fitting together in a round pixel structure. Their structures are semi-circular and elongated. The largest and tallest bucket will be tasked with maintaining the details in highlights, and the smallest will be tasked with maximizing the details in shadows, while the mid-sized bucket will be tasked with maintaining the middle range of exposure details. The pixel will have data from all three buckets available, but will select the data from one or more buckets depending on the exposure details.

The system is analogous to the high fidelity sound technology in speakers with crossovers, whose several frequencies are used by the tweeters, mid-range(s) and woofers; the

crossover point at which the frequency changes from one component to another can be modified based on the specific mechanics of each component.

In the case of the multiple buckets in a single pixel, the buckets are connected by filaments to a central grid which captures and stores the electrons. When the photographic scene displays increased light, image data from the larger buckets are selected to be recorded by the processor, while in cases of darkness and increased need for sensitivity, the smaller buckets are selected to be recorded; the mid-sized bucket is used in normal light situations of most cases. Further, this multi-aspect architecture can use pixels in varying positions on the sensor differently, particularly to facilitate processing far more dynamic range and to produce uniform tonal range in scenes that vary more than two or three stops. This novel multi-aspect model solves a number of key problems involving exposure dynamics in digital photography.

In another embodiment of the system, there may be more than three buckets in a pixel, so as to divide out the functions further and create even finer tonal continuity. In a further embodiment of the system, several pixels in a super-pixel allow red, green and blue colors to be segregated by each sub-pixel. This approach will be useful particularly in CCD semiconductors because of limits of this architecture, which require coupling circuitry between pixels to pass a charge between rows of pixels. In this case, outputs will vary between the micro-pixels to facilitate the differential processing required.

While cases of two side-by-side pixels might solve these exposure latitude problems, they represent an inadequate solution, much as a speaker with only two components limits the dynamic range output dramatically in contrast with a speaker with five components. This is similar to comparing a diode and a transistor.

(III) Digital System Improvements that Link Multiple Digital Corrections

(14) Auto pre-programmed modules for specific functions in digital imaging system

To process the functions specified in this integrated digital imaging system, it is necessary for automated pre-programmed modules to detect the specific lens type and the specific digital sensor(s) used to assess the appropriate corrections or alterations. The purpose of the pre-programmed modules is to access a preset library of (a) typical corrections of lenses, (b) typical scene types with appropriate exposure modes, (c) specific effects that may be selected and (d) specific sensor functions. It is important to match a particular lens to a particular sensor

type so that adjustments are calibrated to this pairing. The processing software is stored in either a microprocessor or an ASIC in order to process the images after they are captured by the sensor but before they are transferred to storage on a memory device.

In another embodiment, the system processes image corrections after the digital data is stored and constantly accesses the original stored data file in the production of a corrected file. This process allows for immediate data processing and storage which affords more time to accomplish specific corrective functions. There are thus cases when real-time correctives are neither necessary nor possible. Such increased processing capability may also facilitate a more complete corrective task.

In an additional embodiment, because similar correctives and effects may be provided to images that share the specific combination of lens and sensor, in order to accelerate the process of optimizing the images, batches of similar images may be processed together. This batch processing method may include the creation of duplicate images for each image captured, including a RAW image that contains no changes to the native image capture and a simultaneous auto-corrected image. The optimized image may be simultaneously compressed, to maximize storage capabilities, while the RAW image may be left uncompressed so as to maintain original detail.

(15) Apparatus and process for affecting pre-sensor optical and digital corrections in digital imaging system

Given the nature of light transmission, not all optical corrections are optimized by modification after the image is captured by the sensor. Though a range of important corrections and effects may be made after image capture, such as correction for optical or digital aberrations, there are several types of corrections that are required to be made before the light reaches the sensor. One example of this pre-sensor digital correction involves the use of a low-pass or anti-aliasing filter that resides in front of the digital sensor to minimize moiré and aliasing digital problems (although the use of this filter adversely affects image sharpness).

In the case of optical corrections, one class of filter that requires use before the digital sensor is the polarizing filter, because once light is captured on the digital sensor, the polarizing effect will not be available. Another type of correction that involves use of a filter or lens before the digital sensor is the close-up filter. This latter solution allows a lens's closest focusing plane to be closer to the front of a lens and has the effect of diminishing the rear plane of the depth of

field. The close-up filter may be optimized for use with floating rear-element group lenses which allow increasingly close focusing. In one embodiment of the system, specific pre-sensor optical filters may be used to provide polarization and close up corrections. The use of in-camera optical (circular) polarization would help standardize this valuable process and eliminate the need to maintain several external polarizer filters for each lens mount.

Since the present system entails an embodiment which uses nano-grids to perform specific exposure modifications before the light hits the digital sensor, it is possible to use these nano-grids for the applications of polarization and close-up filter. These filtration capabilities occur between the lens and the digital sensor.

In order to optimize the use of pre-sensor filtration, an image is initially tested and analyzed before the optimized corrections are activated and the pre-sensor changes are made. This process is analogous to the use of automated flash photography in which a feedback mechanism is provided; a scene is evaluated, and the initial flash data analyzed and modified to correspond to the correct exposure before a final flash is produced.

Because the camera system processes post-capture data, in order to optimize images for optical and digital problems, as well as continuously makes changes to pre-sensor filtration, multiple ASICs work in parallel to make the conversion of the image after capture. The use of parallel ASICs to perform specific correction processes solves the problem of capturing images and making post-capture corrections while simultaneously adapting the pre-sensor filtration system.

As an alternative embodiment of the system, a microprocessor (and software) may perform specific pre-sensor adjustments while the ASIC(s) performs specific corrective functions. In another embodiment, the ASIC(s) may perform the specific pre-sensor adjustments while a microprocessor (and software) will perform the specific corrective functions.

(16) Integrated digital imaging system for optical and digital corrections with feedback dynamics

Because the present system consists of, and uses, complex sub-systems, including an auto-focus mechanism, an auto-exposure mechanism, a shutter mechanism, an automatic flash mechanism, a digital sensor mechanism, a digital processing mechanism and a digital storage mechanism, it is possible to realize interaction dynamics that contain feedback. The interactive process of operating these sub-systems involves a learning progression. The image is analyzed,

solutions are tested and an optimal solution is selected and implemented, all in real time. By choosing a specific logic vector in a decision tree involving an initial variable, the process begins again with another key variable in real-time until the final image is captured and optimized.

In order to accomplish these complex processes, specific variables, such as aperture data, shutter speed data, lens data, digital sensor data and subject type are registered and analyzed by the camera. As environmental data changes, the camera mechanisms adapt to the environmental and the photographer's situation.

In order to accelerate these processes, the camera learns to anticipate the user's behaviors, the user's preferences and the subject's behaviors. By providing user-adjusted setting modifications for optical and digital corrections, the camera establishes a reference point for processing rapid image changes. In particular, the camera's software will analyze trends in the user's pattern of behaviors and preferences as well as pattern changes in the subject's behaviors. Anticipation processes are programmed into the autofocus and automated flash systems because of the extremely rapid reaction-time requirements of these specific mechanisms.

In one embodiment of the system, a method of processing a chain of rapid image captures is to employ computer-caching techniques in which a first image is processed in a normal way while later images are processed in an accelerated way. This is possible because the first image provides data to the system to analyze; these data then allow the system to anticipate further similar images and to use similar auto-focus and auto-exposure data. The optical and digital corrections are performed in a batch fashion by applying similar changes to near-identical image problems in order to dramatically accelerate the processing speed of a chain of images. This caching and anticipation approach is very useful in fast-paced action photography.

Another embodiment of the process of rapidly capturing a chain of images in sequence employs multi-threading techniques. Dividing the functions between specific subsystem ASICs allows multiple corrections to be performed in a parallel cascade for efficient task completion. One advantage of breaking down functions to specific processors is the acquired ability to start on one function and, while the system is in the process of completing a task, to begin other tasks. This process eliminates the lag between the specific subsystems.

(17) Adaptive user pattern learning with user-programmable functions in digital imaging system

In order to optimize its functions, the camera needs to learn about the user's preferences. When the user uses the camera, the camera evaluates the use patterns. Since the camera is programmed with a database of common user patterns, it can identify common uses and anticipate common uses of similar users by employing a "collaborative filtering" mechanism (i.e., if you like this camera setting, you should like this other setting because similar users who have liked the first setting have also liked the second setting). By anticipating common uses of each camera user, the camera optimizes its functions for each use and for each user. In effect, the camera's learning of user preferences is a sort of guided process of experimentation. Evolving algorithms learn about the user from actual use patterns.

One positive effect of this learning process of the camera about the user's patterns of behavior is that the filtration process becomes adaptive. The camera builds an initial map of the user's preferences from the user's actual selections. From the starting point of common types of personal selections, the camera uses standard templates of main types of uses that are fulfilled for each user's applications. For instance, if a photographer typically takes portraits with a traditional portrait lens, the camera will be aware of this and will activate filtration processes that are optimal for this type of portraiture photography, such as instilling limited depth of field on a subject and out-of-focus foreground and background. Contrarily, if landscape images are selected, depth of field will be increased substantially and the lens focused on either infinity or a medium point depending on the specific type of subject matter. The camera builds a model for each user based on the accumulation of experience.

In order for the camera to learn about the preferences of a specific user, the camera must adjust to each particular user, much as each individual identity must log onto a computer network privately.

Since the dynamics of the combined subsystems are complex, and adaptive, it is necessary that automated adjustments be interactive. Once detection of the lens type, the sensor type, the exposure settings, the user and the subject is made, optical and digital distortions are identified and specific combinations of corrections are applied both before and after the digital sensor in order to optimize the image. All of this is accomplished in less time than the blink of an eye.

(18) Software privacy function in digital imaging system

Because digital camera systems are able to use software and wireless mechanisms for their operation, it is possible to activate aspects of the camera remotely. Conversely, it is possible to disable operations of the camera remotely.

The present invention embodies a capability to externally disable the camera remotely in specific locations that require privacy, such as secret government areas (courthouses), private homes or businesses that are image-free zones. In these cases, a signal from an external source is provided to disable the shutter from firing. This black-out capability will allow external control of access to specific sites. As a condition of access, only a camera with this feature may be admitted to public buildings, so that even if the camera is permitted to operate, permission is only conditional. For instance, the owner of the building may allow the camera to function only in a specific set of rooms but not in others. Cameras without this feature may not be allowed in private spaces where control must be externally restricted.

This blocking feature will require the addition of specific blocking software, which may be automatically downloaded as one enters specific buildings. Similarly, in order to be granted permission to access the camera, or specific functions of the camera, the downloading of a "key" may be required.

Moreover, a further embodiment of the system may make it necessary to download software keys to get access to filtration capabilities in the camera in order to obtain optimum images. For example, the user may be required to pay a fee to download software in real time that will permit her to access a particular function in the camera to obtain a critical image. A spectrum of quality and complexity in filtration capabilities may be made obtainable for a range of fees on-demand. Therefore, the external downloading of software for the camera need not be limited to a black out function.

(IV) Dynamic Digital Imaging System Improvements that Apply to Zoom Lenses and Video Imaging

(19) Dynamics of zoom lens corrections in digital imaging system

Whereas the optical aberrations of prime (fixed focal length) lenses were discussed above, the modulation of optical aberrations of zoom lenses is another problem to consider. As a wholly different species of lens, zoom lenses have become extremely complex optical mechanisms consisting of multiple groups of lens elements. The general problem with zoom

lenses is the trade-off that must be made: To minimize the distortions of the widest possible focal length, distortions become maximized at the longest possible focal length, and vice-versa. Consequently, zoom lens architecture is inherently compromised on image quality. Over the years, lens designers have developed lens formulas that have dramatically improved image quality and that compete with typical prime lenses. As an example of this evolution in quality, the class of 70-200 f/2.8 35mm zoom lenses, now in their sixth generation, has supplied substantial improvements over earlier telephoto zooms. However, in general, zoom lenses have more aberrations than primes and thus require increased optical corrections. The need to solve the problem of zoom lens aberration correction is accentuated by their increased use in photography because of their simplicity and versatility.

The dynamics of the zooming process present specific difficulties for the purposes of correcting optical aberrations in digital imaging systems. With fixed-focal length lenses, the camera can detect the lens and provide an immediate consistent modification for a varying range of apertures. In the case of zooms, however, where the focal-length is not fixed, the adjustments must correlate to the changes in the focal length. In effect, this condition presents a continuous resampling process. When combined with changing scenes, the zooming process requires far faster responses to changing inputs by the camera system. This process resembles the tracking of a kaleidoscope's changing image structures as the wheel on the device is constantly turned.

In order to solve the problem of distortion at the wide-angle part of select zoom lenses, manufacturers have been using aspherical elements which are complex shapes that require special production techniques. On the other hand, in order to solve the problem of chromatic aberration in select telephoto lenses, manufacturers have used extra low dispersion glass elements, particularly at the front of the zoom lens. Since there are generally three main classes of zoom lenses – wide-angle to wide-angle, wide-angle to telephoto and telephoto to telephoto – aspherical elements have been used in wide-angle zoom lenses, while extra low dispersion glass has been used in the telephoto zoom lenses and both kinds of lens elements have been included in the wide-angle to telephoto zoom lenses.

The changing focal lengths of zoom lenses add a variable to the complex set of variables of the interacting sub-systems in the digital imaging system. The digital camera system must therefore track the movement of the changes in the focal lengths in zoom lenses and continuously make modifications to the varied optical aberrations in these types of lenses.

Unlike in fixed focal length lenses, the aberrations change at different focal lengths in zoom lenses, and the camera must track these changes.

The present system is designed to make the corrections to these changing aberrations in zoom lenses by noting the changed focal length at specific times of each lens. For a fixed focal length lens, the camera refers to a database of information to provide information to correct specific types of aberrations; for a zoom lens, the camera's database contains multiplex information for each focal length in each respective zoom lens type. This is as if each zoom lens contains a combination of multiple lenses of specific focal lengths. When the zoom is moved to a new focal position, the camera reads the lens as a specific focal length and makes corrections to aberrations based on this specific setting. Although the camera reads the zoom lens at a specific moment in time and adjusts the necessary modifications to correct for aberrations at that specific focal length at that time, overall the zoom lens requires the camera to rapidly make these adjustments.

Since zoom lenses employ dynamic processes of change, it is possible to track a moving subject in real-time by changing focal length from a stationary vantage. These changed focal length positions are tracked by the auto-focus system, but also by the auto-exposure system in the camera. The present system thus allows for zoom tracking in order to anticipate the direction of zoom lens changes, much as the focus on the moving subject involves focus tracking mechanisms. These systems use fuzzy logic and evolutionary algorithms to anticipate the movement of the subject and thus of the focal length change of zoom lens. In this way it is possible to accelerate the lens aberration correction process using zoom lenses.

Because the zoom lenses typically increase aberrations precisely because of the lens design compromises, these types of lenses are ideally suited to the present digital imaging system. The present system allows the zoom lens to be used at high quality without needing to stop down the aperture, thereby resulting in superior photographic opportunities.

(20) Dynamic changes in video corrections of digital imaging system

While the zoom lens presents the need to provide a dynamic solution to the process of making corrections to optical aberrations, video photography provides another case of a process that requires dynamic solutions. The same principles that apply to still photography apply to video; auto-focus variability, aperture and depth-of-field variability aspects, shutter speed variability aspects, differences in lens focal length and artificial lighting variability suggest that

video be viewed as merely a very rapid (30 to 60 frames per second) application of still photography. Nonetheless, video presents new classes of dynamic problems, most notably regarding the matter of tracking changing subjects in real time.

The process of shifting subject positions, even if the camera is stationary, presents a change of multiple variables that require the automated subsystems (auto-focus, auto-exposure, auto-flash, etc.) to be integrated. Feedback is presented by subjects in the external environment with changing focus and exposure variables. In these cases, even with a modulating shutter speed, the three main variables of change are a zoom lens to continuously change the focal length, auto-focus to track a subject and aperture modifications to continuously change depth-of-field.

The unique dynamics of these complex sub-systems presents particular challenges for a digital imaging system to produce rapid results with the use of advanced ASICs and microprocessors. By incorporating techniques that track objects with advanced auto-focus mechanisms, anticipate zoom lens changes and predict optimal exposures as well as make automatic corrections to both optical and digital aberrations in real time, the present system continuously optimizes the video imaging process.

(21) "Stationary-scene object-motion" caching process, with application to video, in digital imaging system

Because video imaging processes employ full motion activity, particularly of subjects in the environment, tracking a subject in a video system is problematic. Once a subject is identified and selected, the subject is automatically tracked with auto-focus and auto-exposure mechanisms by a zoom lens apparatus. There is a particular need to identify and track a subject within a broad stationary scene.

The present system accomplishes this task by using anticipatory object-trajectory tracking. The parts of the stationary scene that are not being tracked are cached. In other words, precisely because the background of the scene is stationary, this part of the scene is not tracked for focus or exposure. On the other hand, the object in motion is identified and tracked by subtracting the extraneous data of the stationary scene. Multiple objects are tracked by comparing data about these combinations of objects and their relations and determining the appropriate exposure and focus settings.

While Monte Carlo processes use random settings to self-organize an initial map, which are useful as a baseline for the purpose of anticipating tracking data sets, the present system subtracts the known information about the specific object(s) being tracked from the stationary background in the environment. In other words, the background data is "blanked out" in a caching process while the main subject(s) are tracked. By so using these techniques, the camera system can efficiently calculate the modifications needed to optimize the video scene.

In a further embodiment of the system, a chip-set is enabled in video display devices (i.e., video monitors) to implement select corrections for optical and digital distortions. The user may modify settings for automating the process of achieving optimum video images.

(V) Digital Image Networking

(22) Network coordination of fixed sensor grid to track multiple objects in digital video imaging system

While the previous discussion has focused on employing a single camera to capture images, the present system is also useful for networking sensors in a sensor grid in order to track multiple objects. Specifically, the present system may be used in surveillance and reconnaissance situations to track objects over time. Using a grid of image sensors with overlapping range parameters makes it possible to organize a complex network of sensors for surveillance activities.

After selecting specific objects to track, the system follows the objects as they move from location to location, appropriately modulating the focus, the lens focal length, the ISO and the exposure settings. As the subject moves from one section of a grid to another, the sensors are coordinated to "hand off" the object to other sensors on the grid, much like a cellular phone network hands off calls between cells.

In another embodiment of the present system, the cameras in the network may be mobile instead of stationary in a fixed sensor grid. In this case, self-organizing aspects of the mobile sensor grid track mobile objects in real time. One application of this complex system, which draws on earlier work in collective robotics, is in cinematography, which requires multiple transportable perspectives of mobile subjects. The complex dynamics of a mobile sensor network provides complex feedback in this manifestation of the present system.

(23) Automatic wireless off-porting of back-up images to external data bank

Because the present system uses digital files, it is possible to move these files to an external site for storage. The present system has capabilities to off-port images to an external data bank automatically. This feature is valuable in order to preserve on-board storage capability.

Whether implemented in a local area network (LAN) or a wide area network (WAN), by using a built-in wireless router, the present digital imaging system may be set to send data files directly and automatically to hard-drive storage either in a device in the same room or uploaded to the Internet for storage around the world. This capability is critical for managing massive files of large sensor data sets and preserving valuable in-camera storage space. When automatically sending data files to a nearby computer, the computer may act as a data-port relay to automatically resend the images to an Internet site for storage. The system will maintain the option of keeping some images in the camera and sending duplicate copies of digital files of images to another site for storage as a backup. This automatic back-up process provides insurance for the photographer.

In another embodiment of the system, just as image files are off-loaded to external storage, software files are periodically downloaded to the camera in order to update the camera settings and the database system. For example, as the camera manufacturer provides new lenses for the camera, it becomes necessary to load new updated settings to accommodate corrections for the new lenses. Similarly, as the camera requires new software updates with improved algorithms to further optimize the corrective functions of both the optical and digital mechanisms, the camera will automatically accept these. This feature is particularly important to both manufacturer and user because the ability to update software capability periodically will protect a user from needing to upgrade major hardware such as with a lens replacement.

(24) Image organization system

The present digital imaging system does not merely allow for the storage of image data files on external storage. Because of the problems of protecting storage and the need to make multiple back-ups in the digital sphere, it is also necessary to store digital image files in multiple database locations. The images are organized in a main database by various criteria, such as time, location, subject-type, etc., and then rerouted to various locations around the world for safe storage. While specific sets of images may be stored together, the need to identify the locations is less important than the need to have control of the main database list which identifies the

locations.

In order to maintain security, the digital imaging files may periodically be rotated randomly between locations. Only the main database list, which is constantly updated, maintains information on their location. In fact, specific digital bits of a single image may be maintained at different locations in order to maintain further security. Thus, on many computers around the world bits of each image may be stored, and continuously rotated, with constantly updated registries maintaining their complex hybrid whereabouts. These rotation storage functions are performed by a randomizer logic engine.

In a further embodiment of the present system, once the digital files are off-loaded from the camera system to external storage, specific images may be automatically identified and further specific corrections automatically provided.

In yet another embodiment of the system, the images that are off-loaded from the camera to the external storage system are organized according to various criteria, such as accuracy of focus or exposure or quality of image type, in order to be automatically prioritized. The camera, with the assistance of an initial setting of user priorities, will automatically order new images with a higher or lower priority relative to other images and camera settings. Thus, at the end of a day, the images may be displayed in an order preferred by the user. Lesser images will be automatically routed to a lower position as they do not meet specific criteria, and better images will be routed to a relatively higher position in the organization of files. This feature of automatically assisting in the organization of the digital image files is a very useful one which will save photographers time.

(25) Wireless digital image system automatically generating prints from image capture

The present digital imaging system not only automatically off-loads digital image files to remote locations for storage; the system also will allow one to photograph an image (or sequence of images) in one location (i.e., Paris) and instantly print it in another location (i.e., Los Angeles) for publication in real time. In addition, an image may be captured by the camera and instantly uploaded to a pre-programmed Web site for publication by using wireless technologies. In addition, it is possible to automatically print the digital image file anywhere in the world virtually the moment the image is taken. This system makes this instantaneity particularly possible precisely because the image corrections are automated in-camera. Since there is no

need in most cases to further edit the image files, they are thus generally ready for immediate release.

General Architecture and Dynamics

Fig. 1 illustrates the overall structure of the system. Object data (100) in the domain of objects being photographed by the camera constantly change. In some cases, the lighting changes, while in other cases, the positions of the objects change. At 120 the flash will artificially light the objects. Flashes may be either on the camera or remote from the camera. A camera sensor (130) will detect external data changes. An optical lens (110) feeds analogue imaging data to the digital sensor(s) (175 and 180). In some cases, a mirror (170) will swivel in order to directly input imaging data to the digital sensor after the shutter (150) is fired. In some cases, a filter (160) stands between the lens and the digital sensor(s). A digital signal processor (DSP) (195) is connected to at least one sensor (A or B). A database (190) is connected to at least one sensor (A or B) as well. The digital sensors are connected to an ASIC (195) and/or a microprocessor (193) in order to process the image and control the camera. The digital image data is passed from the digital sensor to either the ASIC or microprocessor and then stored in memory (197). The presence or absence of specific elements of this mechanism is not required for the correct functioning of this system. Consequently, a number of the drawings contained herein will focus only on specific sub-assemblies of the overall digital imaging system mechanism.

The present invention is intended to operate with a spectrum of camera types. These camera categories include digital still cameras without a mirror mechanism or without an optical interface. The present system applies to cameras with single lens reflex mechanisms. In addition, the present system applies to video cameras, both with or without mirror mechanisms, including camcorders. Finally, many of the functions disclosed in the present system are integrated into specific imaging sensors. The system applies to image sensors that are integrated with complex system functions, including those described herein, with "system on a chip" (SoC) capabilities in a single microelectronic integrated circuit. The invention also applies to networks of sensors, networks of cameras or integrated networks of both sensors and cameras.

Fig. 2 describes digital image signal processing. After an analog signal (200) is captured, it is converted to a digital signal by an analog-to-digital converter (210). The signal is then

forwarded to the digital signal processor (220) and filtered (230). The digital signal is then stored in memory (240).

In fig. 3, the correction to the optical vignetting problem is shown. In vignetting, the lens (300) makes the edges of the image significantly darker as the light falls off, a phenomenon particularly prominent on wide angle lenses. As represented here, the concentric circles of filtration correction are darker in the middle (310) of the image in order to counteract the vignetting effect. The overall image aperture is reduced from one half to two stops in order to compensate for the maximum light fall off depending on the amount of vignetting effect from each lens type.

Fig. 4 shows a list of several different wide angle lenses in a database. In the 35mm domain, the 14mm (400), 20mm (410), 24mm (420), 28mm (430) and 35mm (440) lenses, each with f/2.8 apertures are listed in the database. Each lens type presents a distinct formulation involving different sets of optical data that require different aberration corrections.

The digital corrective process is described in fig. 5. After a specific lens type is identified (500) and a database is referenced (510), the lens type is matched with the specific optical aberrations (520). The digital filter then applies a correction to specific optical aberrations (530). As an example, the vignetting effect is corrected by gradually darkening the center of the image in concentric rings (540).

Fig. 6 shows the database configuration of several different types of 24mm f/2.8 lenses (600 to 630) with different optical configurations. Each lens type has a different set of manifestations of optical aberrations including vignetting (640), spherical aberration (650), pin cushion distortion (660), barrel distortion (670) and comatic aberration (680). For each lens, there will be a unique combination of optical aberrations compared to each lens type from different optical configurations. The database is accessed to provide the multi-objective optimization solution for correcting several different optical aberrations for each specific lens formula.

In fig. 7, after a camera captures an image (700) and uses a digital sensor to create a digital file (710), the digital file is forwarded to the digital signal processor semiconductor (720). The DSP applies the filtration (730) to correct the optical aberrations from the lenses. The revised digital file is then sent to storage (740).

Digital filtration is performed by employing the DSP hardware as well as specific software in order to attain specific aberration corrections. In an optical filter, which typically sits at the front of a lens and performs a single function of modifying the optical characteristics of the lens, the electronic filter will process the image after it is converted from an analogue representation to a digital signal. Common digital filters include a low pass filter or anti-aliasing filter. In most cases digital imaging filtration is a discrete time application and is processed in a time-signal sequence.

One example of a digital filtration process is a fast Fourier transform (FFT). The digital signal is modified by applying an algorithm to extract the frequency spectrum. The original function is then reconstructed by an inverse transformation of the original signal. The signal can be manipulated to perform various conversions. This process is used to sharpen or soften an image. For instance, by differentiating the frequency spectrum, the high frequency can be emphasized by limiting the low frequency, as in a high pass filter. Digital filtration is typically performed by the DSP after the image is captured and before the image file is stored. However, in the present system, there is some filtration before the digital sensor that captures the image as well as some filtration processing after the sensor sends the file to the DSP.

In order to accelerate the filtration process, the digital file will be broken into parts, with each part processed simultaneously. Filtering a one-dimensional image will treat data from each column of a digital sensor separately. When the data is treated like a two dimensional image, the data file may be treated with different techniques. For instance, different quadrants of the image may be analyzed and filtered separately. In addition, the highlights and the shadows in the varied frequency range may be analyzed and filtered separately as well. Similarly, a two dimensional image file may be analyzed by starting in a corner and working in each contiguous quadrant in a circular (clockwise or counterclockwise) order. Further, the filtration process may begin in the corners and work inwards or begin in the center of the image and work outwards. For instance, in wide angle lens filtration to correct optical aberrations, the outer edges will be the most prominent distortions that will require the most corrections; therefore, the filtration process will work by starting on the corners first.

The present invention also addresses the multi-functional corrections in an image by applying multiple simultaneous techniques. This is done either by performing a sequential

filtration process or a simultaneous filtration process. In either case, the image is re-filtered to make more than one pass in order to correct different types of aberrations.

Different types of aberrations require different types of filtration. In the case of pin cushion distortion and barrel distortion, which are inverse appearing aberrations, the filtration process will adjust the edges of affected digital files captured with wide-angle lenses. The optimized images will be accessed by the database and compared to the actual image files. The filtration will be applied to each image file to closely correct the distortions bit by bit. In effect, the corrected digital images will be reverse engineered to discover the unique distortions as they establish a pattern by comparing the input digital images and the database of optimized images. The digital image correction will be applied once the aberration is assessed.

Each lens provides data to the camera microprocessor and DSP about its unique characteristics. The lens is pre-programmed with aberration data pertaining to that lens type and even to each particular lens (ascertained through a testing process). The lens then provides this specific data to the camera for processing of optical aberrations. In one additional embodiment, the lens will also contain software to correct its aberrations that will also be sent to the camera processors in order to be applied to specific digital file filtration. As information and techniques are made available, new software to ascertain and correct each lens's unique optical aberrations will be forwarded to the camera and stored in the lens, thereby providing an upgrade path to continuously improve the optical qualities of lenses by employing a sort of after-manufacture digital correction.

Fig. 8 shows the process of selecting filtration settings. After the user selects the specific filtration settings (800), the user marks the specific filtration setting and accepts the setting (810). The user may continue to select multiple settings. When the user has selected all preferences (820) and accepts the settings the user returns to the main menu.

In Fig. 9 varied depth of field optimization at different apertures is described. In the first drawing, the object (930) has a depth of field (940) that has a broad range of clarity around the object. The camera (900) evaluates the distance data (920) and the object to establish an optimal depth of field range between f/8 and f/11. In the second drawing, the object (980) has a narrower depth of field range (990) based on distance data (970) and object data from the camera (950) to determine an optimal depth of field range between f/2.8 and f/5.6. The camera's automatic alteration of the aperture to narrow the depth of field is based on a range of factors, including the

focus on the object, the object's motion, the distance to the camera, shutter speed constraints and the light on the object. Modulating aperture automatically in the camera provides a blurring of the background and the foreground so that the object can stand out without distraction.

Exposure optimization using digital correction is shown in fig. 10. After the camera assesses an object's distance from the camera (1000) and identifies the optimal aperture of the image to maximize the dynamic range (1010), the aperture is either increased (1020) or decreased (1030) and the correction applied (1040).

In-camera special effects filtration is illustrated in fig. 11. Once the image exposure is assessed by using the camera exposure meter (1100), the camera corrects the image by either underexposing the image by one third stops to one stop if the image is overexposed (1110) or overexposing the image by one third stops to one stop if the image is underexposed (1120). The camera finally takes a picture and stores the image (1130).

Fig. 12 shows the selective in-camera filtration of specific objects. After the camera identifies specific objects (1200), the camera assesses distance to the objects (1210). This is done by sending out an infrared light signal, bouncing it off the object, and measuring the distance data from the camera to the object. The camera isolates the objects on a one-dimensional Euclidian plane (1220) and then selects the optimum aperture to isolate objects and to blur the background and foreground (1230). The camera tracks the motion of objects (1240) and activates a digital sensor (1250) thereby capturing the image. The image data is sent to a post-sensor processor (1260) where the camera applies specific filtration only to the designated objects (1265) and stores the file in memory (1270). Alternatively, the camera will apply specific filtration only to the background (not to the objects) (1275) and then stores the file in memory (1280). The effect of only applying filtration to an object or to its background is to isolate the subject. The type and degree of special effects, which are selected by user-adjustable in-camera software, will be determined by the user's palate of filtration choices.

Image exposure adjustment using in-camera filtration is described in fig. 13. Once the camera assesses a two stop difference in parts of the image (1300), the camera's microprocessor accesses the database of similar scenes (1310) and then selects the optimal metering for the image and the user activates the digital sensor (1320), capturing an image. The camera provides the filtration to part of the image by adjusting the exposure in the processor (1330) and then stores the image (1340). In scenes such as sky on top, a neutral density filter is often required to

remove the two stop difference between the bright top of the image and the darker bottom of the image. By reducing the brightness at the top, the exposure is evened out. By using the present system, this process is accomplished in the camera.

In-camera special effects filtration is described in fig. 14. After a user selects a special effects filtration technique (1400), the camera assesses image meta-data (1410), analyzes image data (1420) and the user captures the image (1430). The camera's post-capture processor applies special effects filtration technique to part of the image (1440) and the camera stores the image in memory (1450).

Digital correction for sensor dust is described in fig. 15. The pattern of dust on the pixels of a digital sensor (1500) is assessed. The specific pixels that are obscured by the dust are identified (1510) and a map is built of a digital sensor pixel frame by comparing information from at least two image samples to identify obscured pixels (1520) and the camera takes an image (1530). Information from pixels that are adjacent to dust-affected pixels are used to interpolate data on affected pixels (1540) and image data is processed and stored in memory (1550).

Fig. 16 shows an ASIC array in a digital imaging system. Once the digital sensor (1620) captures an image, the digital file is sent to multiple application specific integrated circuits (1630, 1640, 1650 and 1660) for processing of several digital signals simultaneously. In one embodiment of the invention, each ASIC corrects a single optical aberration. In another embodiment, the ASICs will divide the digital file and perform specific functions on parts of the image file and reunite the file before storing the completed image in memory (1670).

In fig. 17, the camera is illustrated with multiple interchangeable digital sensors. The CCD (1720) is shown in the forward position capturing the digital image in this drawing. However, the CMOS (1730) digital imaging sensor may swivel around (1740) to replace the position of the CCD in order to be used to capture the image. The image is then processed (1750) and stored in memory (1760). The advantages of interchanging the digital sensors are to have the opportunity to benefit from the strengths of each sensor type without sacrificing the weaknesses of either. In some cases, the scene will be optimized for the exposure range of a CMOS digital sensor, while at other times, the scene will be optimized for the detail of the CCD.

In fig. 18, the nano-grid (1820) appears in front of the digital sensor (1830). The lens will send analog image data to the sensor through the nano-grid. Once the digital data from the

sensor is processed (1840) it is sent to memory (1850). Fig. 19 shows a nano-grid (1900). Nanofilaments are shown at 1920. The modulation effects of the nanofilaments are shown at 1910. Nanofilaments will change their position in order to allow more or less light through the system. Nano-grids fit before, or in some cases, adjacent to and on top of the digital sensor. Nano-grids behave as adjustable screens and may be used to polarize light between the lens and the digital sensor. Nano-grids are activated by electrical charge pulses sent to nanofilaments.

In fig. 20, the feedback loop connecting the processor and the nano-grid is shown. Analog optical data passes through the nano-grid (2020) to the digital sensor (2030) to the processor (DSP) (2040). A feedback loop (2050) is created by analyzing the data at the processor and modulating the performance of the nano-grid. For example, the image may be very bright initially, but the DSP will require that the image needs to be darker in order to be properly exposed. In this case, it will activate the nano-grid to modulate its grid structure in order to darken the image so as to let less light through the filaments by adjusting the filament structure. Once properly exposed, the camera will capture a digital image and send the file to memory (2060) for storage.

In fig. 21, a tri-pixel architecture is described. The large (deeper) oval bucket in the center (2110) will capture highlight exposure, the medium sized oval bucket at the right (2120) will capture a normal exposure range and the small (shallower) oval bucket at the left (2130) will capture the shadow exposure range. These three separate wells are contained within each pixel. In most cases, a pixel well is like a bucket, capturing light data and passing the data sets to the digital processor. By splitting the exposure range into three distinct wells within each pixel, the data is more accurately captured and organized in order to accommodate the broader range of exposure data. This system will be able to increase the range of digital imaging up to four stops, from the typical two stops. By maximizing the range of exposure data, the image collection will display more tonal range that is more associated with films' broader exposure range.

Fig. 22 shows the pre-programmed module for in-camera functionality. After the camera detects the lens type and the sensor type (2200), the camera focuses on an object (2210) and the processor accesses the library of scene and filter types (2220). The user pre-selects specific in-camera modifications (2230) and activates the camera to capture an image (2240). The processor makes filtration adjustments after the sensor takes the image (2250) and the image file is stored (2260) in memory.

Much like the nano-grid that is present before the digital image sensor, the pre-sensor modification to an image is shown in fig. 23. An optical filter (2320) such as a polarizer filter is shown in a position between the lens and the digital sensor (2340). The image is captured and the optical filter is activated by the processor (2350), which determines whether to activate the filter after analyzing a particular scene. Other filtration (2330), such as the use of the nano-grid, is also interchangeable with the optical filter in a position before the digital sensor. In another embodiment of the present invention, the filter assembly is sequential, with both, or multiple, filters being activated in order so as to obtain the maximum filtration effect. The DSP will compute the optimal combination of filtration resources based on the available resources in the camera. In another embodiment, the optical filter assembly will fit out of the line of sight between the lens and the digital sensor and will be activated by the DSP on-demand to swing into the optical image path much like a mirror mechanism.

Fig. 24 shows the integration of optical and digital corrections with feedback. Once the camera meters a scene (2400), the camera auto-focuses and obtains distance data to the object (2410), analyzes the lens data, the aperture data and the shutter speed data and accesses the library of images (2420). The camera assesses the optical aberrations (2430), activates the digital filters to correct aberrations (2440) and takes the picture (2450). The camera analyzes the image and optimizes the image using the processor (2460). This is performed by comparing the image data to the library of images and assessing the needed filtration required to optimize the image. The image is then stored in memory (2470).

The interactive feedback mechanism of integrated correction is described in fig. 25. After an analysis of the initial image (2500), the identification of optical aberrations (2510) is made. The camera's database is accessed to retrieve the corrections (2520) and the interactive feedback mechanism is activated (2530). Corrections to filters are applied before the sensor captures the next image (2540). In addition, correction to the image signal via the DSP is made after the sensor data is captured (2550) and the image is stored in memory (2560).

The adaptive user pattern learning process is shown as images are processed in fig. 26. A batch of images (2600, 2610, 2620 and 2630) is shown. The first image is processed (2640) and data from image 1 is analyzed and metadata is mapped (2650). Image 2 is then analyzed and its metadata is compared to the image 1 metadata (2660). Similar metadata in images 1 and 2 programmed in the processor (2670) and image 2 is rapidly processed by using similar metadata

from image 1 (2680). Images 3 and 4 are analyzed and their metadata are compared to image 1 and rapidly processed (2690).

In fig. 27, the feedback process of filtering images is shown. After the camera analyzes the user behaviors, user preferences and subject behaviors (2700), the camera's processor analyzes trends in the pattern of user behavior and preferences and creates a map (2710). The camera's processor anticipates the user behavior and subject behavior (2720) by applying evolutionary computation and fuzzy logic algorithms. The camera's processor then applies a collaborative filtering process to a new image (2730) and the user takes and optimizes the image (2740).

Fig. 28 shows a software privacy function in a digital imaging system. The camera automatically downloads software as it enters a building or specified area (2800). The camera's features are deactivated in specific locations by the software (2810) while allowing the camera to perform specific camera functions by accessing software keys (2820). The camera then performs specific functions (2830) that are available in the restricted area while other specific functions are disabled (2850).

In fig. 29, the dynamics of zoom lens corrections are described. After a lens detects a zoom lens type (2900), the camera detects a particular focal length setting of the zoom lens (2910) and accesses a data library in the database to modify aberrations to optimize the zoom lens at a specific focal setting (2920). The camera applies a correction to a lens setting (2930) and continuously tracks the lens changes in the lens focal length (2940). The camera then applies the changed corrections to the changed focal lengths in the zoom lens (2950) and analyzes patterns of the user and subject behaviors (2960). Using fuzzy logic and evolutionary computation, the camera anticipates behaviors and rapidly optimizes image corrections by applying digital filtration (2970).

Fig. 30 shows object tracking in the dynamic changes of video corrections. An object moves from position 1 (3010) to position 6 (3060) in sequence. The camera (3000) is stationary, yet it records the object's motion as it is moving within the field of vision.

In fig. 31, object tracking is described. Once the camera tracks an object with auto-focus mechanisms and supplies distance information (3100), it tracks the user's zoom lens use patterns, anticipates the focal length changes (3110) and, using evolutionary computation and fuzzy logic

algorithms, predicts optimal exposures (3120) and captures images in real time, continuously tracking the object (3130).

Fig. 32 shows the caching process of a moving object in a stationary scene. After the main objects are tracked by the camera (3200), the background of a stationary scene is cached in the camera (3210). The camera subtracts the data about objects from the background of the scene (3220). The background scene is then "blanked out" and cached in memory (3230) and the main objects are optimized by applying digital filters.

Fig. 33 describes the network coordination of a fixed sensor grid tracking multiple objects. The object in motion is represented in positions A through D (3370, 3380, 3390 and 3395). The fixed sensors are at positions 1-6 (3300, 3310, 3320, 3330, 3340 and 3350). The image data is fed remotely into the central imager (3360). The sensors track the object by taking image data at each fixed sensor position in the network. As the object moves through the field of the network, each sensor records the object.

In fig. 34, wireless communication features of the digital imaging system are described. The camera (3400) sends digital image data files wirelessly to a computer (3410). Files are also uploaded from the camera to the Internet in accessible locations (3450), while software files are downloaded from the Internet to the camera, both automatically and through manual intervention. Files are automatically downloaded if the user sets the camera to receive automated software updates. One advantage of loading files automatically to the Internet is that the images are then automatically published (3460) at a remote location, or locations, for viewing.

Fig. 35 describes an image organization system. After images are captured by the camera (3500), the image files are organized according to metadata in an external computer database (3510). The image files are then sorted by category and sent to the database of a distributed network (3520) for off-site storage.

Reference to the remaining portions of the specification, including the drawings and claims, will realize other features and advantages of the present invention. Further features and advantages of the present invention, as well as the structure and operation of various embodiments of the present invention, are described in detail below with respect to accompanying drawings.

It is understood that the examples and embodiments described herein are for illustrative purposes only and that various modifications or changes in light thereof will be suggested to persons skilled in the art and are to be included within the spirit and purview of this application and scope of the appended claims. All publications, patents, and patent applications cited herein are hereby incorporated by reference for all purposes in their entirety.

WHAT IS CLAIMED IS:

1. A digital imaging system comprising:
A digital camera mechanism, an optical lens mechanism, a digital sensor, a microprocessor, an application specific integrated circuit, a digital signal processor, system software, a database management system and a memory storage sub-system;
wherein the optical lens mechanism is a fixed focal length;
wherein the aberrations from the optical lens mechanism are corrected by applying digital filtration by using the application specific integrated circuit and digital signal processor;
wherein a microprocessor is used to provide digital and optical data to the digital signal processor;
wherein the system software is organized to identify specific optical aberrations and to access the database to identify specific corrections to the aberrations;
wherein the system software forwards the data file from the digital sensor to the digital signal processor;
wherein the digital signal processor selects a specific procedure to optimize the image and corrects the aberrations and;
wherein the modified digital file consisting of the digital data optimized from the aberrations that are corrected from the original optical image is stored in memory.

2. A digital imaging system comprising:
A digital camera mechanism, an optical lens mechanism, a digital sensor, a microprocessor, a digital signal processor, an application specific integrated circuit, system software, a database management system and a memory storage sub-system;
wherein the optical lens mechanism is a fixed focal length;
wherein image depth-of-field is optimized by forwarding the digital file from the digital sensor to the microprocessor;

wherein system software accesses a database to determine the optimal aperture by comparing the distance data to similar images in the database;
wherein a microprocessor is used to provide digital image data to the digital signal processor;
wherein the digital signal processor optimizes the digital file aperture setting by comparing it to the database data;
wherein the microprocessor adjusts the camera's aperture setting;
wherein the digital sensor captures the image and the application specific integrated circuit forwards the image data file to the digital signal processor to make modifications to the digital file and;
wherein the digital file is stored in memory.

3. A system as claimed in claim 1 in which the type of filtration applied by the digital signal processor are special effects;
wherein the data file is forwarded from the digital sensor to the digital signal processor by an application specific integrated circuit;
wherein the digital signal processor applies a fast Fourier transform to the digital file in order to satisfy a user specified special effects function;
wherein the digital signal processor modifies the digital file by applying the special effects function and;
wherein the digital file is stored in memory.

4. A system as claimed in claim 1 in which the type of filtration applied by the digital signal processor are applied only to specific objects;
wherein the digital file is forwarded from the digital sensor to the microprocessor and to the digital signal processor;
wherein the digital file is analyzed by the microprocessor to separate specific objects in the image using the differentiation of the depth-of-field;
wherein the digital signal processor applies filtration only to specific objects in the image and;

wherein the digital signal processor forwards the modified digital file to storage in memory.

5. A digital imaging system comprising:
A digital camera mechanism, an optical lens mechanism, a digital sensor, a microprocessor, a nano-grid mechanism, a digital signal processor, system software and a memory storage sub-system;
wherein the nano-grid mechanism is between the optical lens mechanism and the digital sensor;
wherein the nano-grid mechanism is comprised of an array of nano-filaments;
wherein the nano-grid mechanism receives an electrical signal from the microprocessor and modifies its filament structure by modulating the filaments;
wherein the nano-grid mechanism performs a function to provide filtration to the image before the digital sensor captures the image;
wherein the image is captured by the digital sensor and the digital image file forwarded to the digital signal processor and;
wherein the digital file is stored in memory.

6. The system of claim 1;
wherein the digital sensor contains a tri-pixel configuration;
wherein three differentiated sub-pixels in each pixel in which one of the sub-pixels is in the center of the pixel and is the largest and deepest of the sub-pixels;
wherein the other two sub-pixels are smaller than the center sub-pixel and are on the sides of the center sub-pixel;
wherein the sub-pixels forward image data to the filament on each row and;
wherein each row forwards the image data to the digital signal processor.

7. The system of claim 1 comprising:
wherein the lens type is a zoom lens and;
wherein the lens focal length alternates from specific fixed focal length lens settings in a succession of steps and;

wherein optical aberrations are corrected with digital filtration to modify multiple images from different focal lengths in a succession of data files.

8. The system of claim 1:
wherein the imaging system is integrated into a video camera.

9. The system of claim 1;
wherein the system uses a video camera to capture moving objects;
wherein the type of filtration applied by the digital signal processor is applied to specific moving objects;
wherein the digital image that is captured is forwarded from the digital sensor to the microprocessor and to the digital signal processor;
wherein the digital file is analyzed by the microprocessor to separate specific objects in the image using the temporal differentiation of caching in which successive images share geometric elements;
wherein the digital signal processor applies filtration only to a specific continuous object that is isolated and is in motion and;
wherein the digital signal processor forwards the modified digital file to be stored in memory.

10. The system of claim 1;
wherein a network of digital imaging sensors is linked together in a fixed structure;
wherein the network is coordinated to track specific objects that are within its collective field of vision;
wherein the network captures images of objects using the digital imaging sensors;
wherein the individual digital imaging sensors forward the imaging data to a central digital signal processor and;
wherein the imaging data file is forwarded to storage in memory.

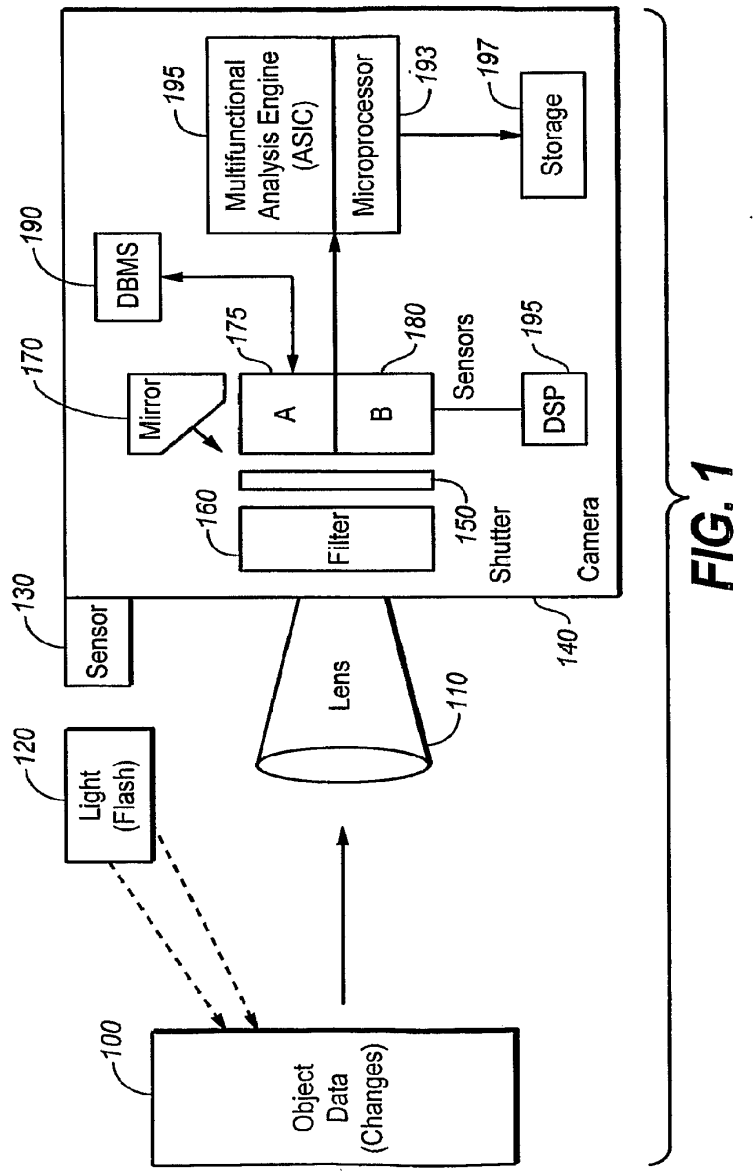


FIG. 1

EX1002 - Page 809

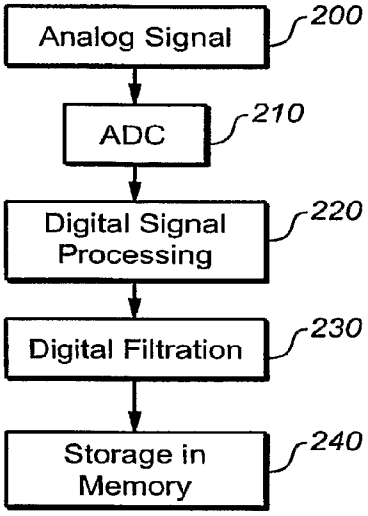


FIG. 2

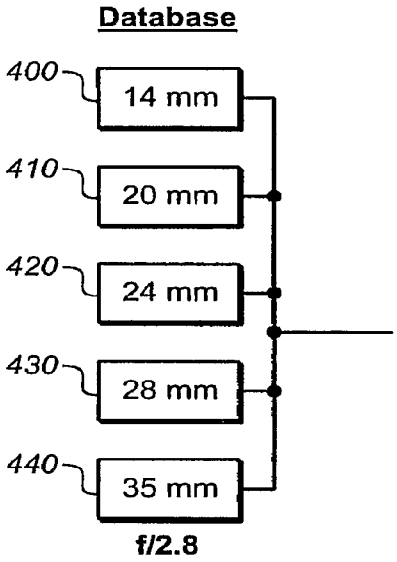


FIG. 4

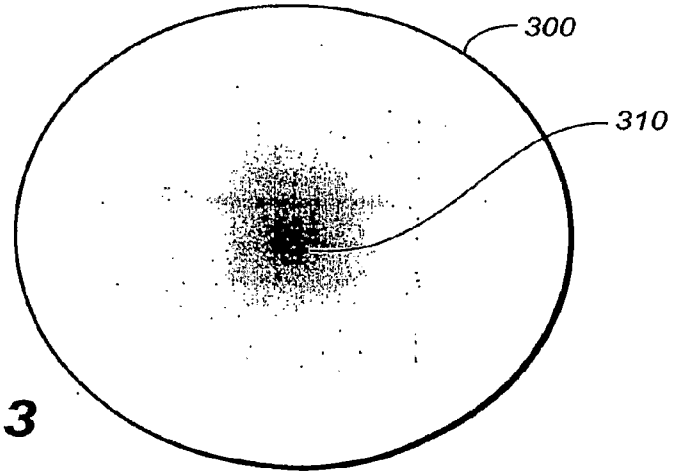


FIG. 3

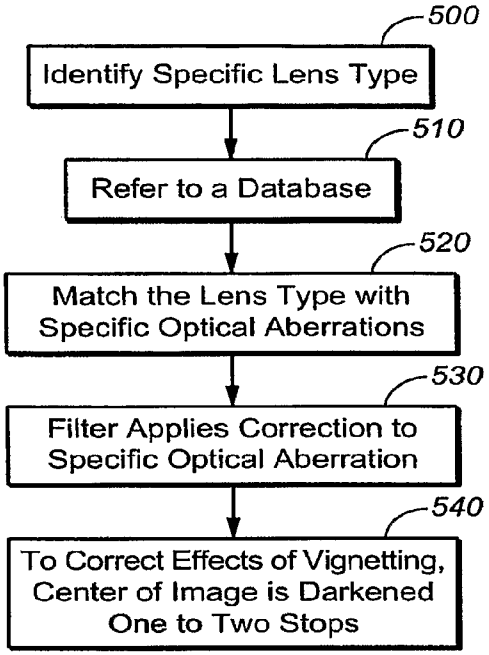


FIG. 5

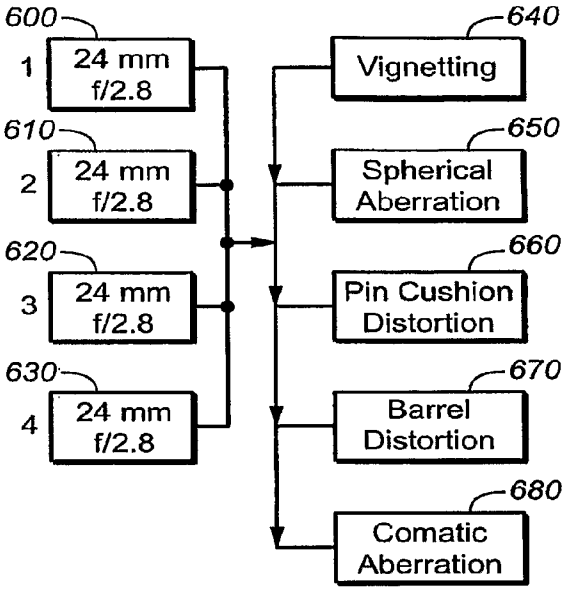


FIG. 6

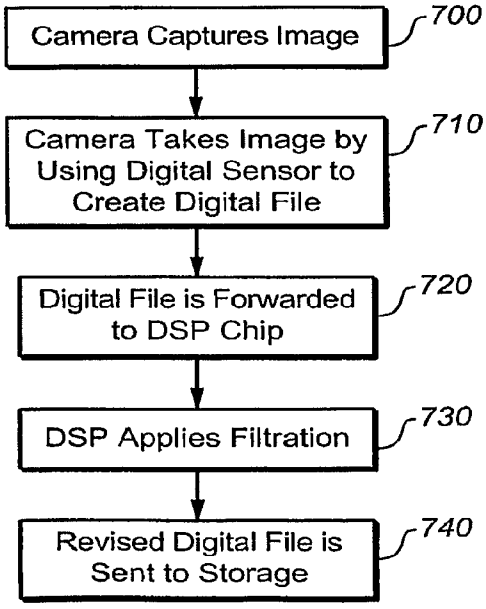


FIG. 7

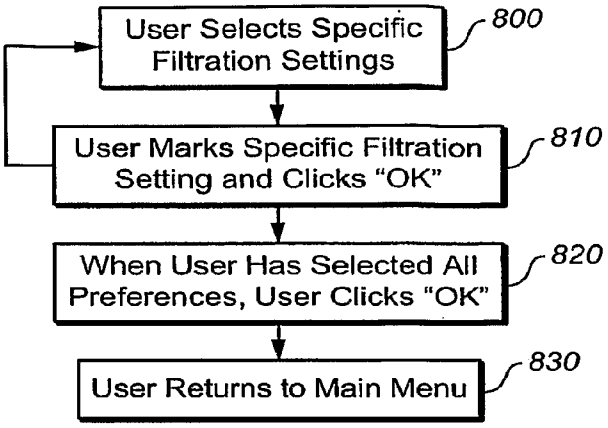

User Selects Specific Filtration Settings
800
User Marks Specific Filtration Setting and Clicks "OK"
810
When User Has Selected All Preferences, User Clicks "OK"
820
User Returns to Main Menu
830

FIG. 8

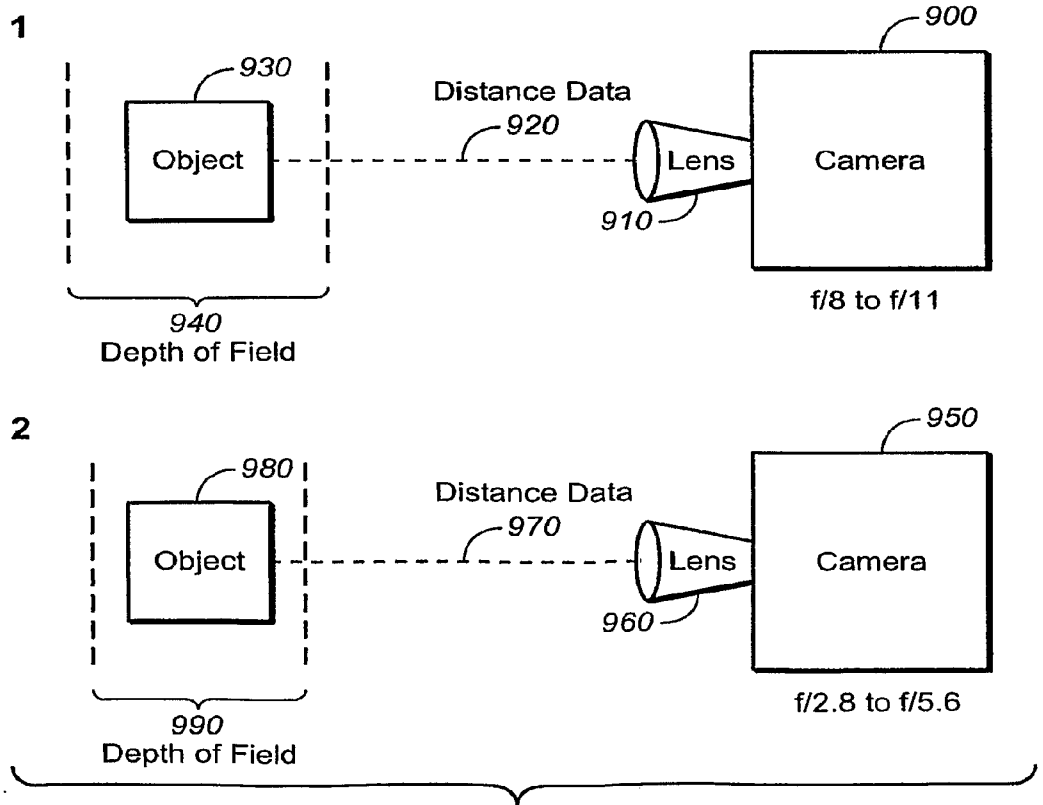

1
900
930
Object
Distance Data
920
Lens
Camera
910
f/8 to f/11
940
Depth of Field
2
950
980
Object
Distance Data
970
Lens
Camera
960
f/2.8 to f/5.6
990
Depth of Field

FIG. 9

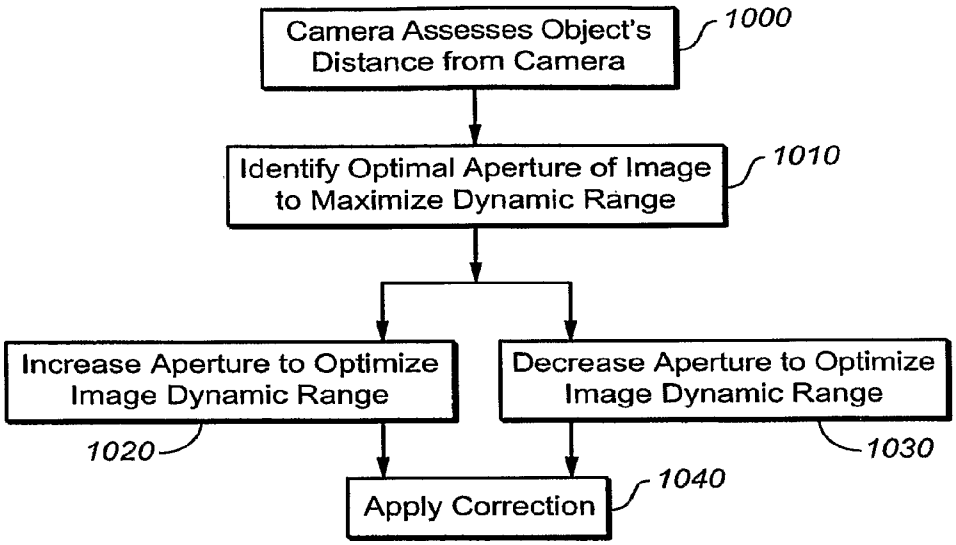

Camera Assesses Object's Distance from Camera
1000
Identify Optimal Aperture of Image to Maximize Dynamic Range
1010
Increase Aperture to Optimize Image Dynamic Range
1020
Decrease Aperture to Optimize Image Dynamic Range
1030
Apply Correction
1040

FIG. 10

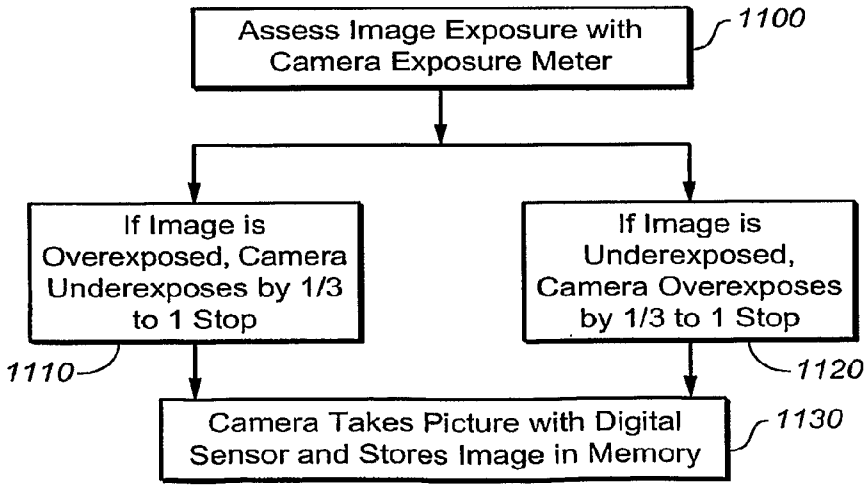

Assess Image Exposure with Camera Exposure Meter
1100
If Image is Overexposed, Camera Underexposes by 1/3 to 1 Stop
1110
If Image is Underexposed, Camera Overexposes by 1/3 to 1 Stop
1120
Camera Takes Picture with Digital Sensor and Stores Image in Memory
1130

FIG. 11

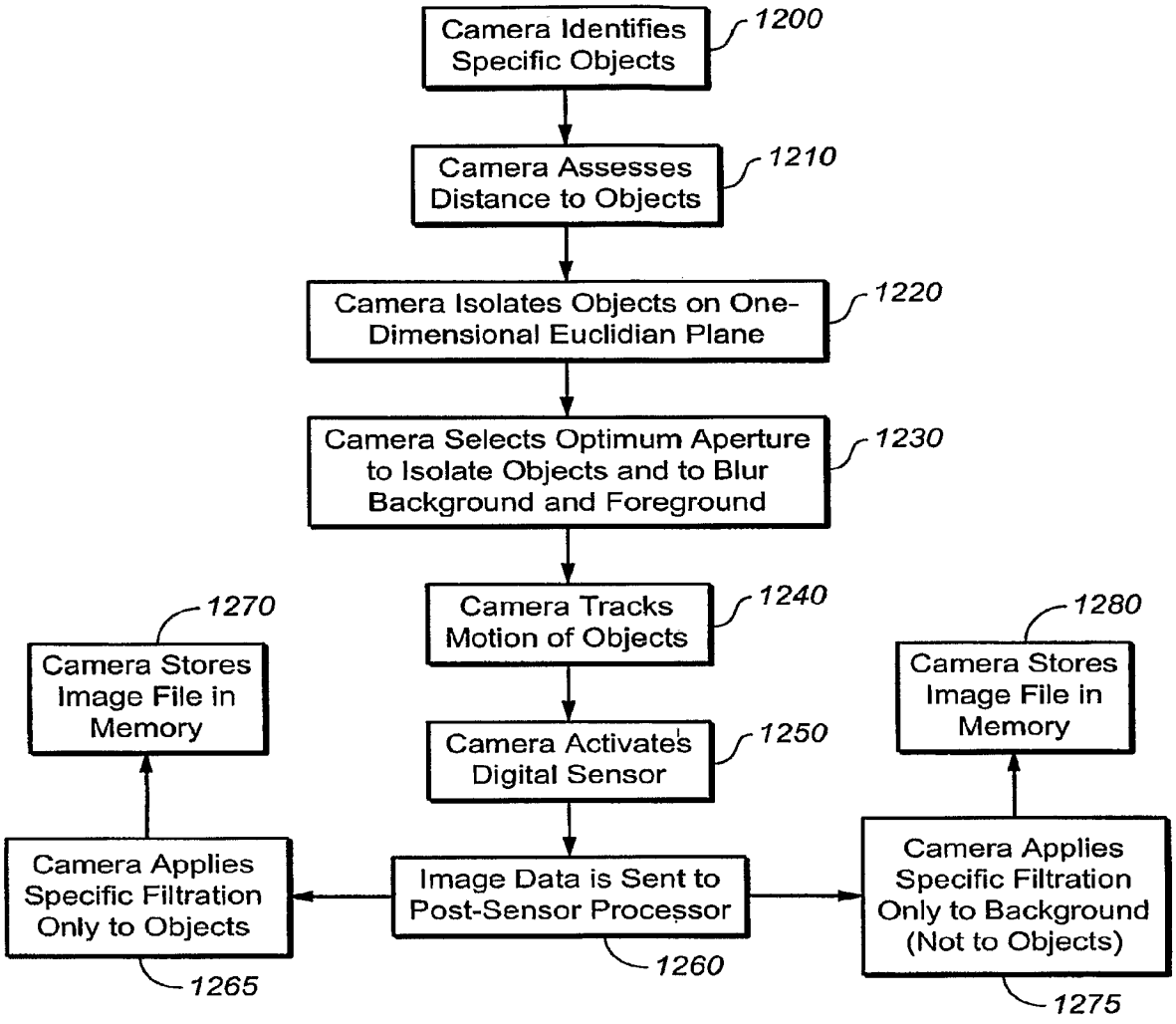

Camera Identifies Specific Objects
1200
Camera Assesses Distance to Objects
1210
Camera Isolates Objects on One-Dimensional Euclidian Plane
1220
Camera Selects Optimum Aperture to Isolate Objects and to Blur Background and Foreground
1230
Camera Tracks Motion of Objects
1240
Camera Activates Digital Sensor
1250
Image Data is Sent to Post-Sensor Processor
1260
Camera Applies Specific Filtration Only to Objects
1265
Camera Stores Image File in Memory
1270
Camera Applies Specific Filtration Only to Background (Not to Objects)
1275
Camera Stores Image File in Memory
1280

FIG. 12

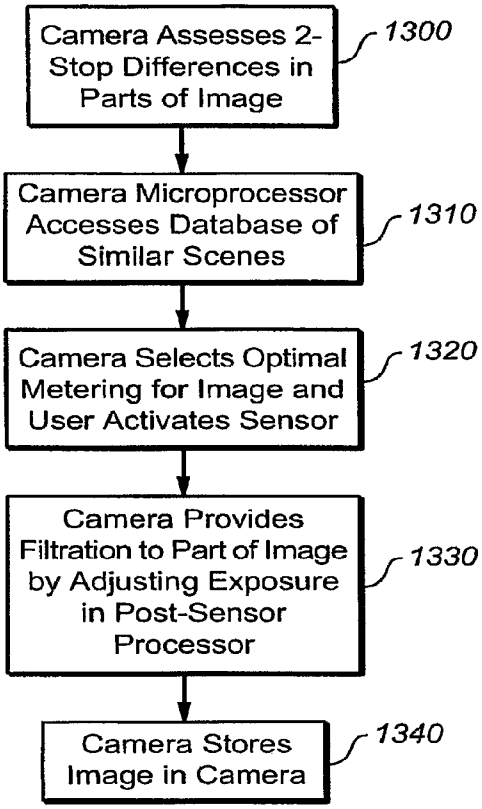

Camera Assesses 2-Stop Differences in Parts of Image
1300
Camera Microprocessor Accesses Database of Similar Scenes
1310
Camera Selects Optimal Metering for Image and User Activates Sensor
1320
Camera Provides Filtration to Part of Image by Adjusting Exposure in Post-Sensor Processor
1330
Camera Stores Image in Camera
1340

FIG. 13

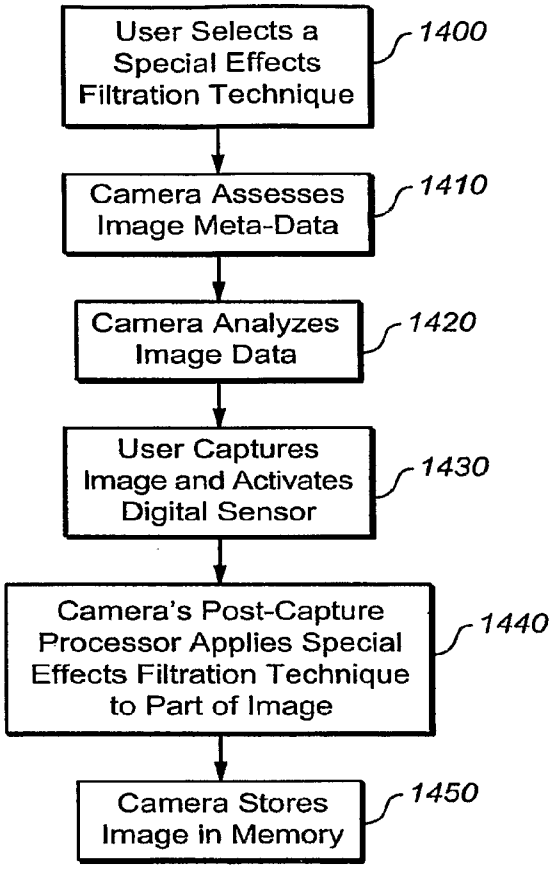

User Selects a Special Effects Filtration Technique
1400
Camera Assesses Image Meta-Data
1410
Camera Analyzes Image Data
1420
User Captures Image and Activates Digital Sensor
1430
Camera's Post-Capture Processor Applies Special Effects Filtration Technique to Part of Image
1440
Camera Stores Image in Memory
1450

FIG. 14

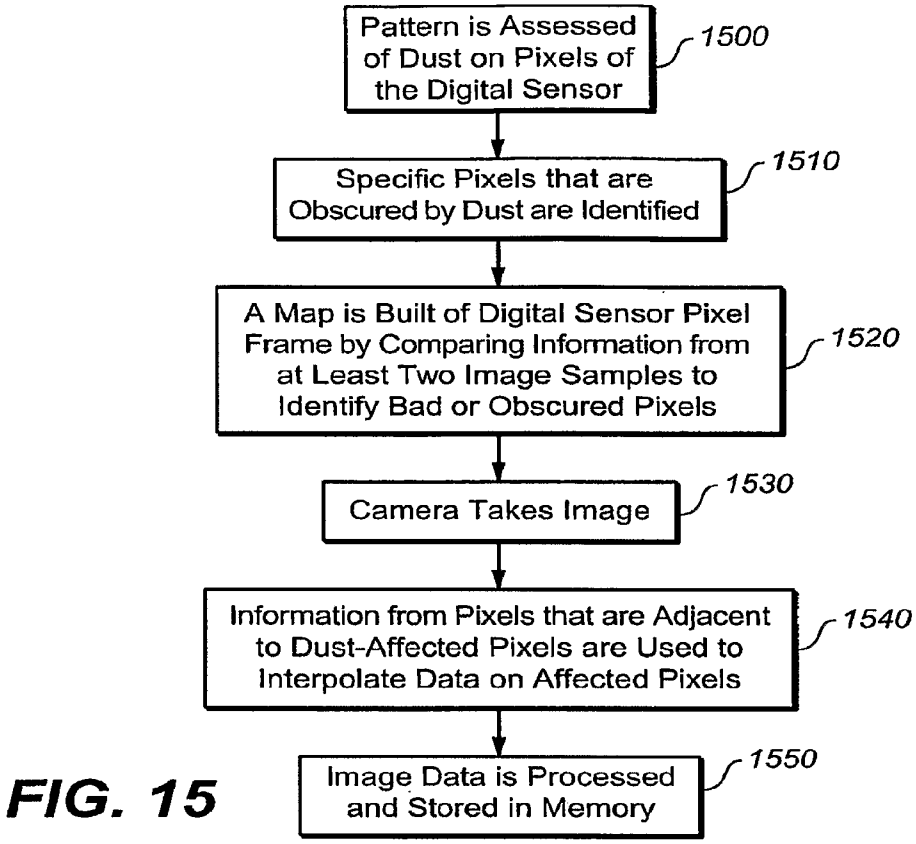

Pattern is Assessed of Dust on Pixels of the Digital Sensor
1500
Specific Pixels that are Obscured by Dust are Identified
1510
A Map is Built of Digital Sensor Pixel Frame by Comparing Information from at Least Two Image Samples to Identify Bad or Obscured Pixels
1520
Camera Takes Image
1530
Information from Pixels that are Adjacent to Dust-Affected Pixels are Used to Interpolate Data on Affected Pixels
1540
Image Data is Processed and Stored in Memory
1550

FIG. 15

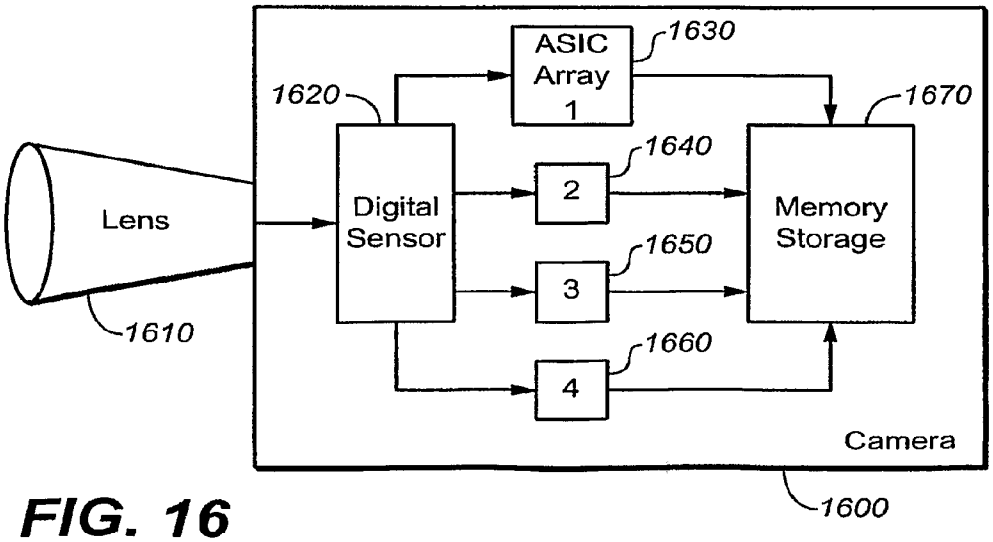

ASIC Array 1
1630
1620
1670
1640
Lens
Digital Sensor
2
Memory Storage
1650
3
1610
1660
4
Camera
1600

FIG. 16

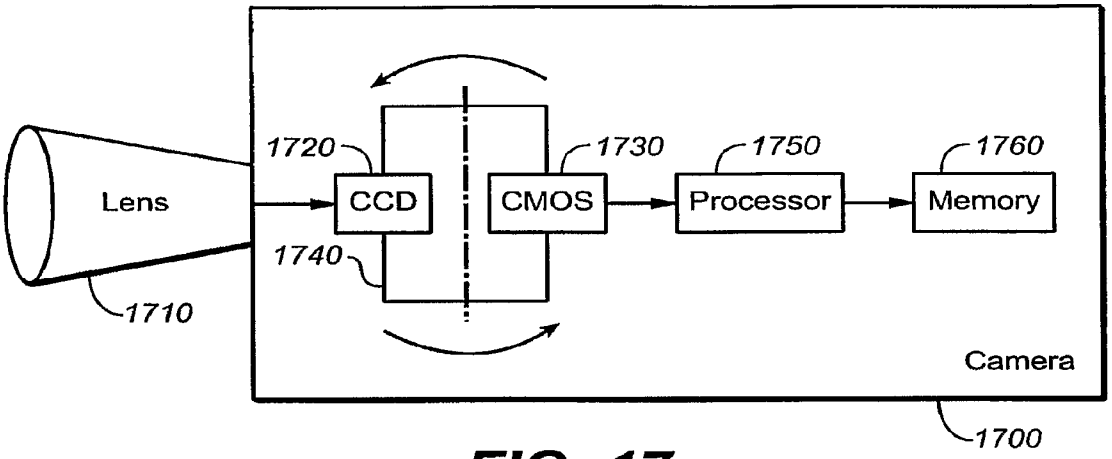

Lens
1710
1720
CCD
1740
1730
CMOS
1750
Processor
1760
Memory
Camera
1700

FIG. 17

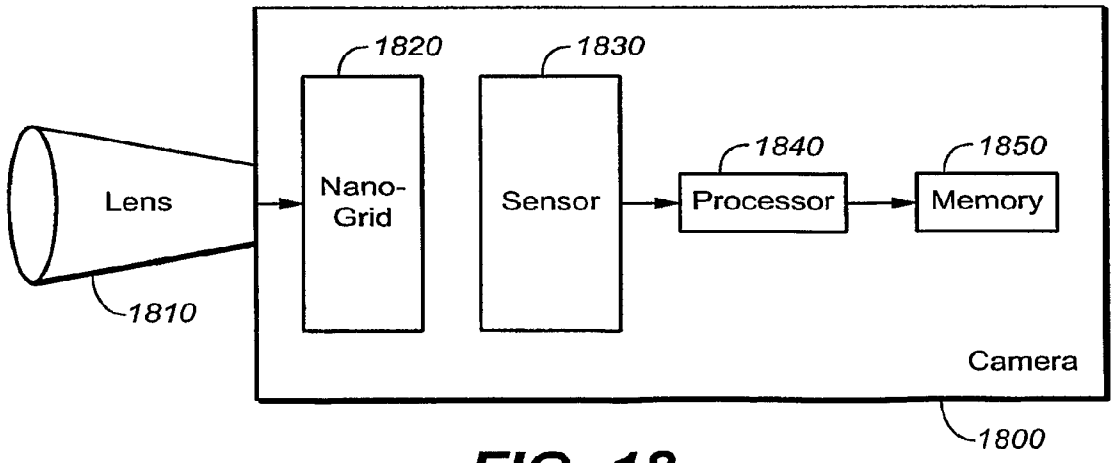

Lens
1810
1820
Nano-
Grid
1830
Sensor
1840
Processor
1850
Memory
Camera
1800

FIG. 18

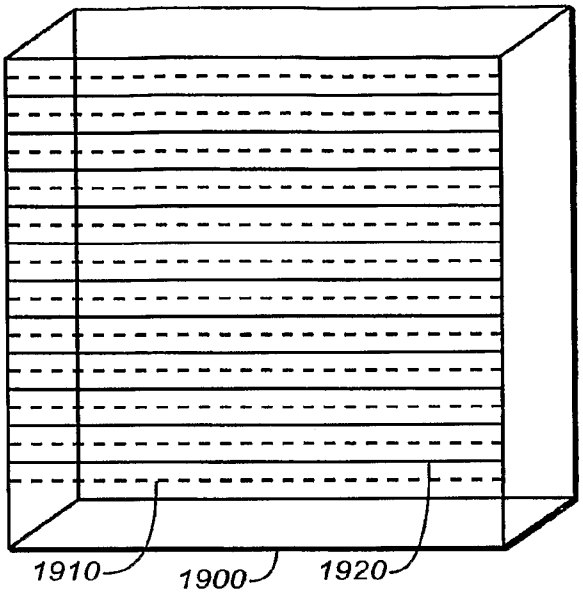

1910
1900
1920

FIG. 19

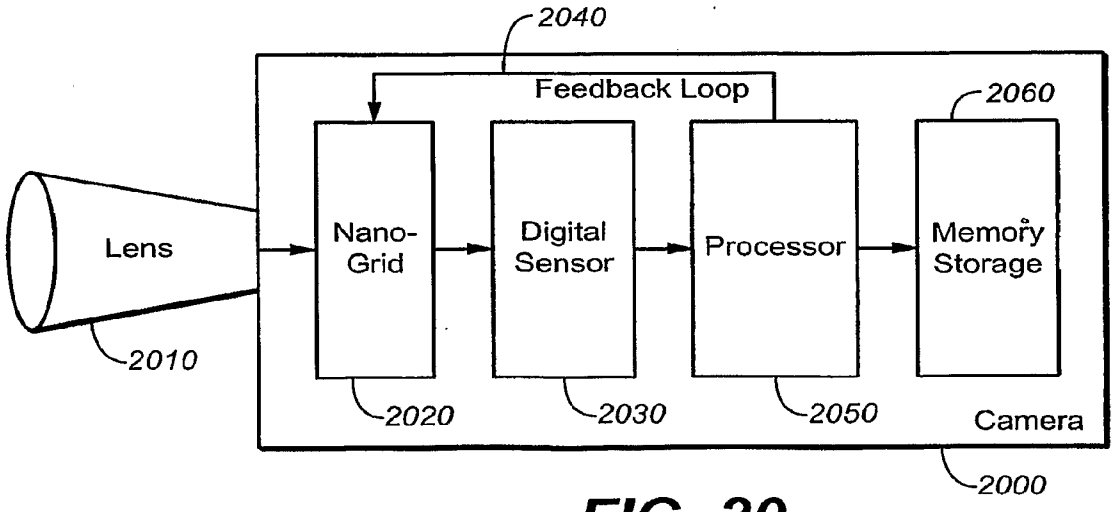

2040
Feedback Loop
2060
Lens
Nano-Grid
Digital Sensor
Processor
Memory Storage
2010
2020
2030
2050
Camera
2000

FIG. 20

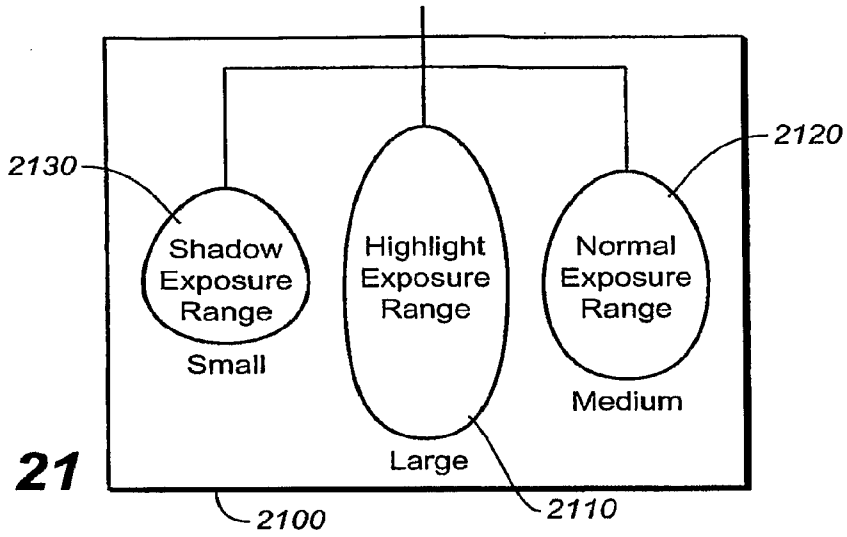

2130
2120
Shadow Exposure Range
Small
Highlight Exposure Range
Large
Normal Exposure Range
Medium
2100
2110

FIG. 21

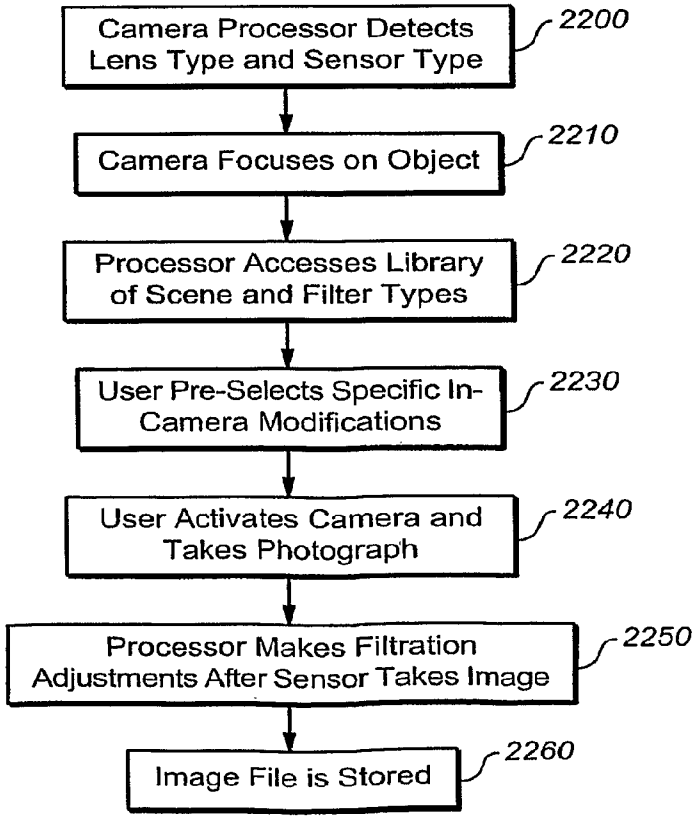

Camera Processor Detects Lens Type and Sensor Type
2200
Camera Focuses on Object
2210
Processor Accesses Library of Scene and Filter Types
2220
User Pre-Selects Specific In-Camera Modifications
2230
User Activates Camera and Takes Photograph
2240
Processor Makes Filtration Adjustments After Sensor Takes Image
2250
Image File is Stored
2260

FIG. 22

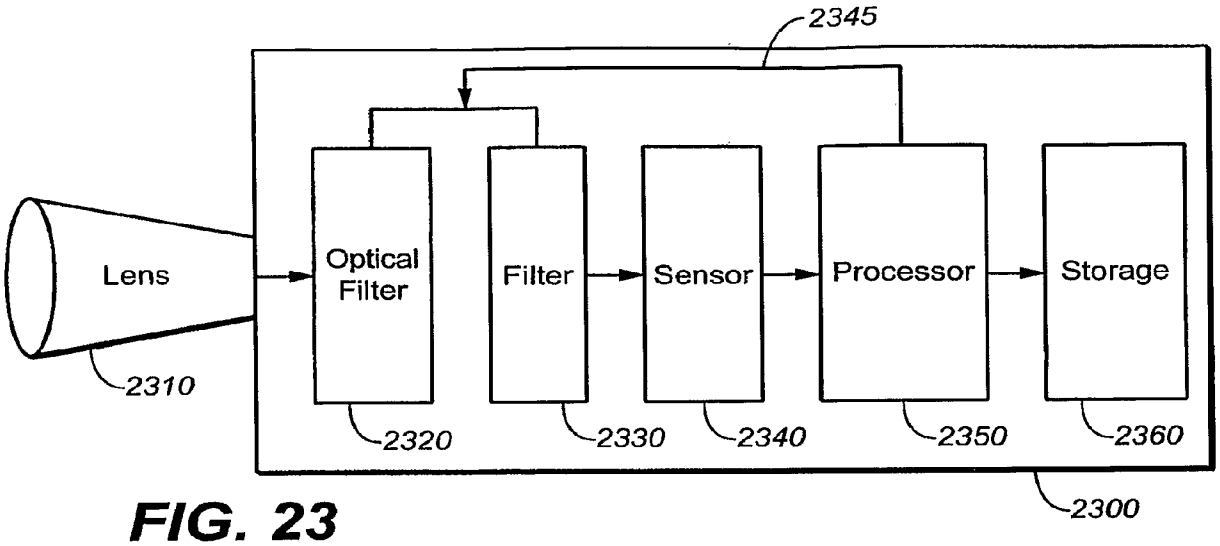

2345
Lens
Optical Filter
Filter
Sensor
Processor
Storage
2310
2320
2330
2340
2350
2360
2300

FIG. 23

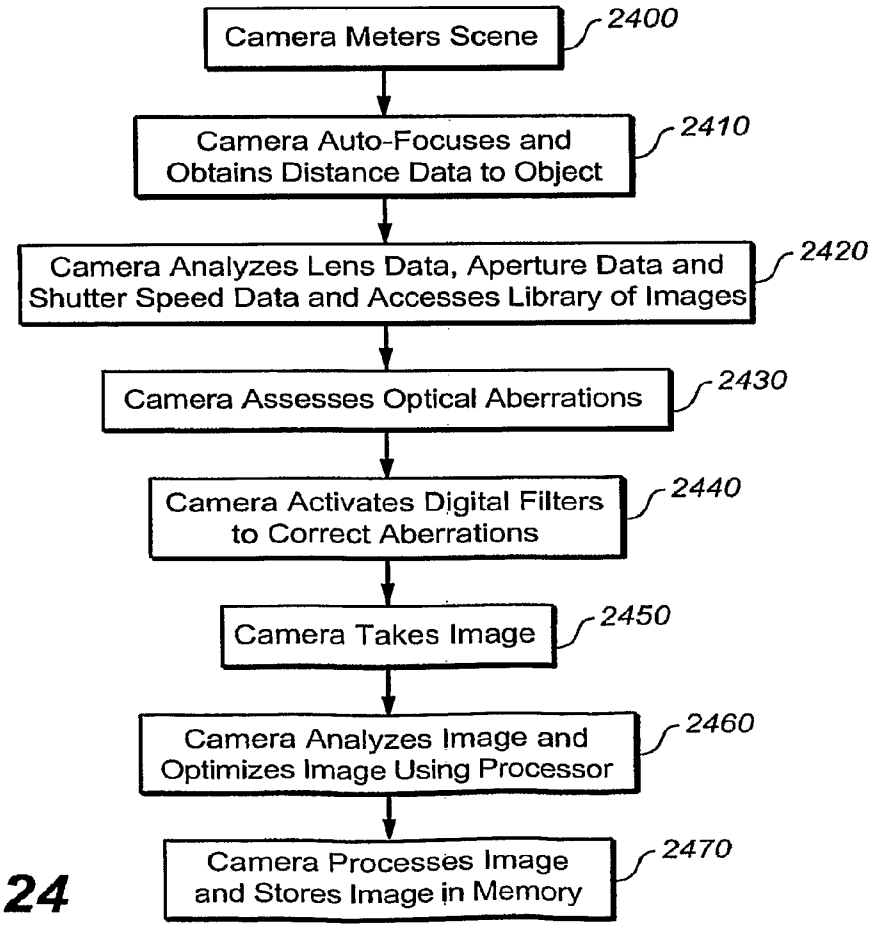

Camera Meters Scene
2400
Camera Auto-Focuses and Obtains Distance Data to Object
2410
Camera Analyzes Lens Data, Aperture Data and Shutter Speed Data and Accesses Library of Images
2420
Camera Assesses Optical Aberrations
2430
Camera Activates Digital Filters to Correct Aberrations
2440
Camera Takes Image
2450
Camera Analyzes Image and Optimizes Image Using Processor
2460
Camera Processes Image and Stores Image in Memory
2470

FIG. 24

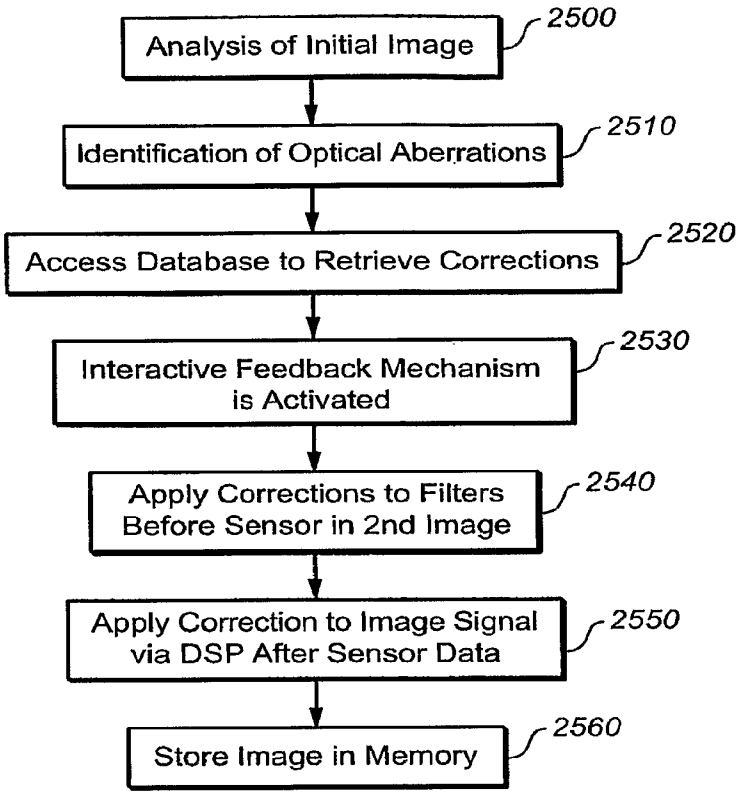

Analysis of Initial Image
2500
Identification of Optical Aberrations
2510
Access Database to Retrieve Corrections
2520
Interactive Feedback Mechanism is Activated
2530
Apply Corrections to Filters Before Sensor in 2nd Image
2540
Apply Correction to Image Signal via DSP After Sensor Data
2550
Store Image in Memory
2560

FIG. 25

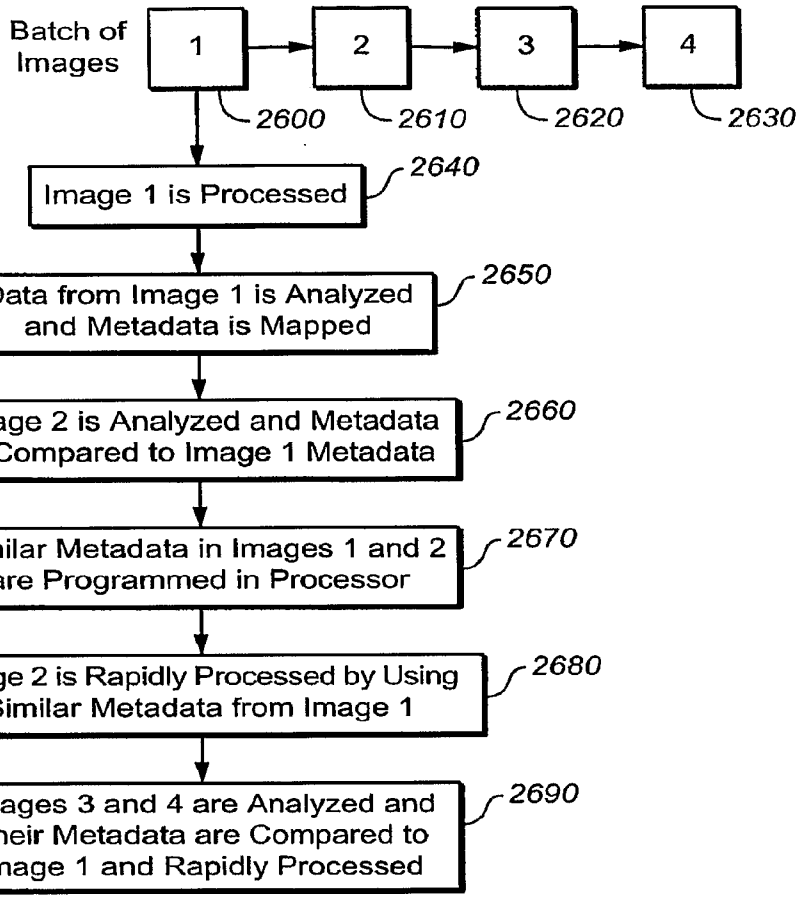

Batch of Images
1
2
3
4
2600
2610
2620
2630
Image 1 is Processed
2640
Data from Image 1 is Analyzed and Metadata is Mapped
2650
Image 2 is Analyzed and Metadata is Compared to Image 1 Metadata
2660
Similar Metadata in Images 1 and 2 are Programmed in Processor
2670
Image 2 is Rapidly Processed by Using Similar Metadata from Image 1
2680
Images 3 and 4 are Analyzed and Their Metadata are Compared to Image 1 and Rapidly Processed
2690

FIG. 26

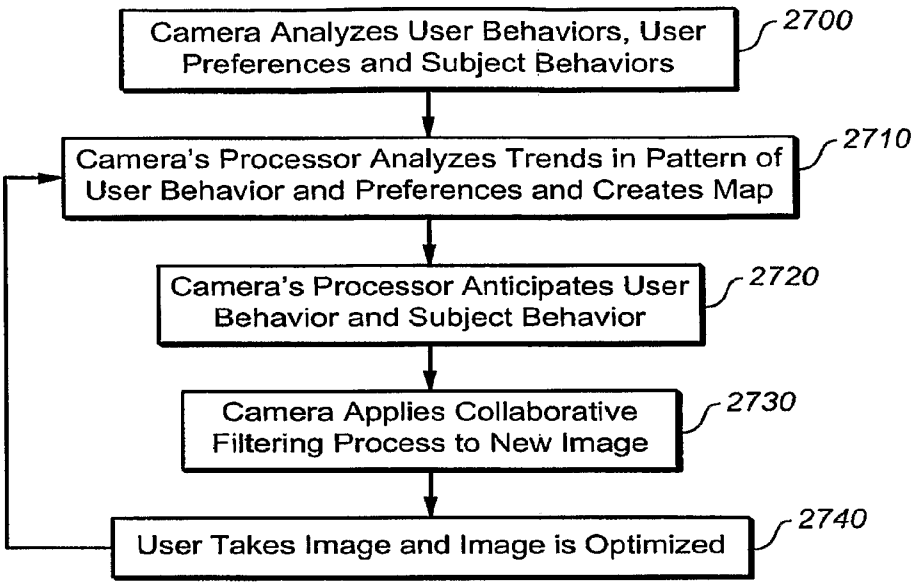

Camera Analyzes User Behaviors, User Preferences and Subject Behaviors
2700
Camera's Processor Analyzes Trends in Pattern of User Behavior and Preferences and Creates Map
2710
Camera's Processor Anticipates User Behavior and Subject Behavior
2720
Camera Applies Collaborative Filtering Process to New Image
2730
User Takes Image and Image is Optimized
2740

FIG. 27

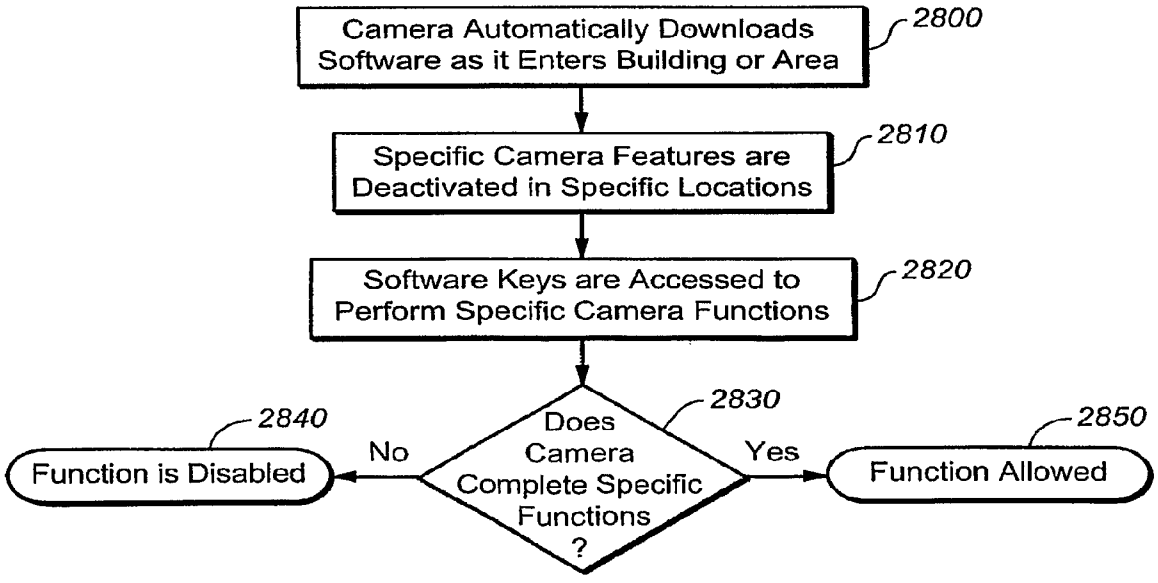

Camera Automatically Downloads Software as it Enters Building or Area
2800
Specific Camera Features are Deactivated in Specific Locations
2810
Software Keys are Accessed to Perform Specific Camera Functions
2820
Does Camera Complete Specific Functions ?
2830
No
Yes
Function is Disabled
2840
Function Allowed
2850

FIG. 28

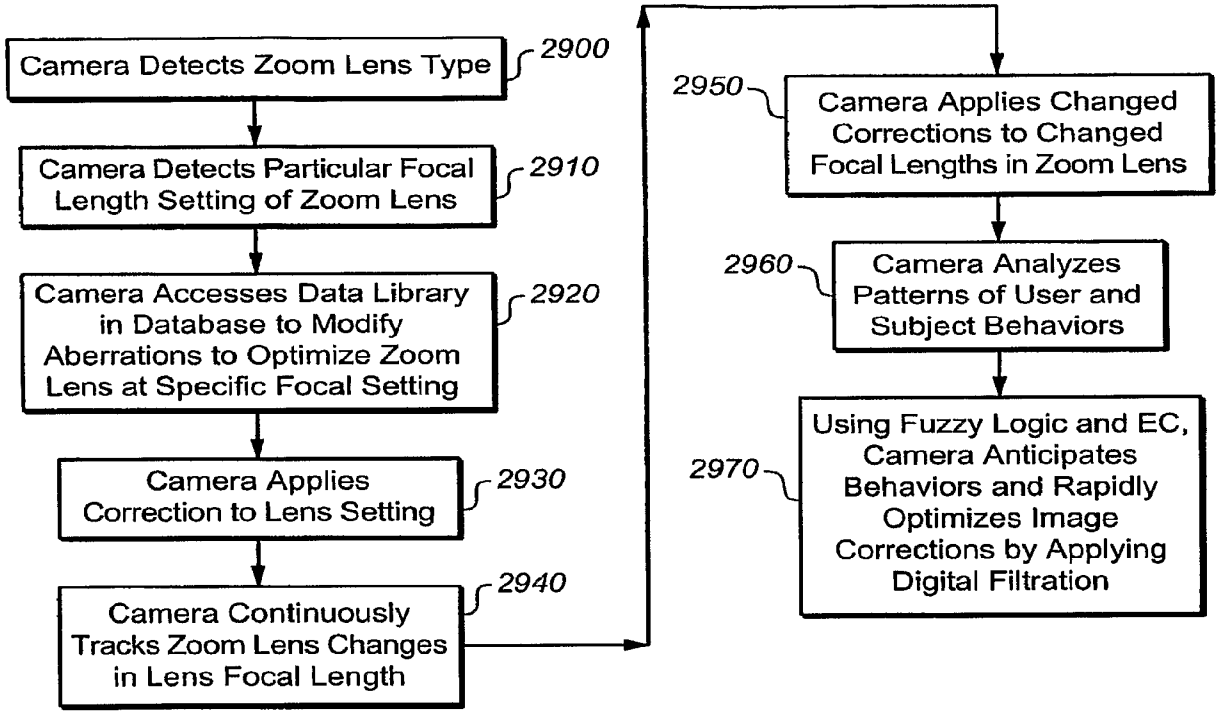

Camera Detects Zoom Lens Type
2900
Camera Detects Particular Focal Length Setting of Zoom Lens
2910
Camera Accesses Data Library in Database to Modify Aberrations to Optimize Zoom Lens at Specific Focal Setting
2920
Camera Applies Correction to Lens Setting
2930
Camera Continuously Tracks Zoom Lens Changes in Lens Focal Length
2940
2950
Camera Applies Changed Corrections to Changed Focal Lengths in Zoom Lens
2960
Camera Analyzes Patterns of User and Subject Behaviors
2970
Using Fuzzy Logic and EC, Camera Anticipates Behaviors and Rapidly Optimizes Image Corrections by Applying Digital Filtration

FIG. 29

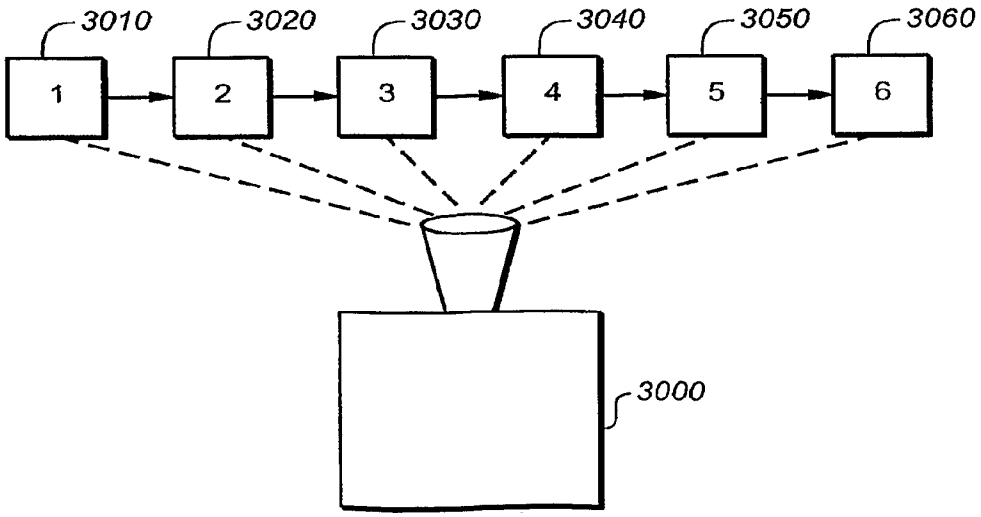

3010
3020
3030
3040
3050
3060
1
2
3
4
5
6
3000

FIG. 30

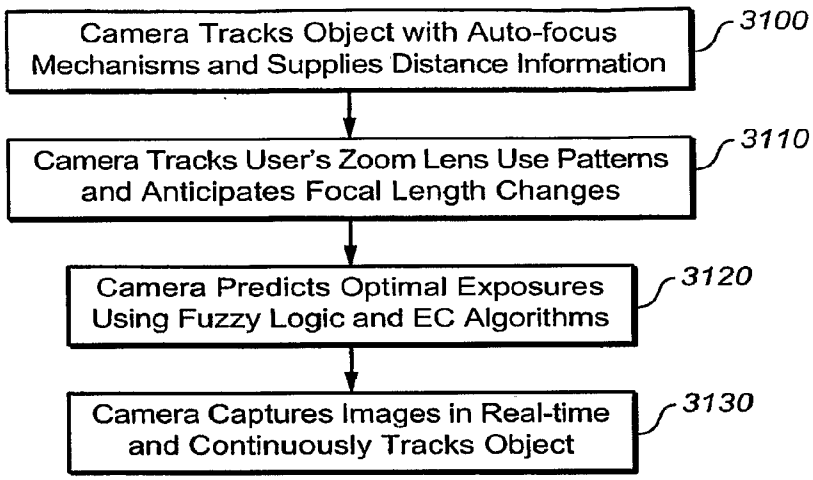

Camera Tracks Object with Auto-focus Mechanisms and Supplies Distance Information
3100
Camera Tracks User's Zoom Lens Use Patterns and Anticipates Focal Length Changes
3110
Camera Predicts Optimal Exposures Using Fuzzy Logic and EC Algorithms
3120
Camera Captures Images in Real-time and Continuously Tracks Object
3130

FIG. 31

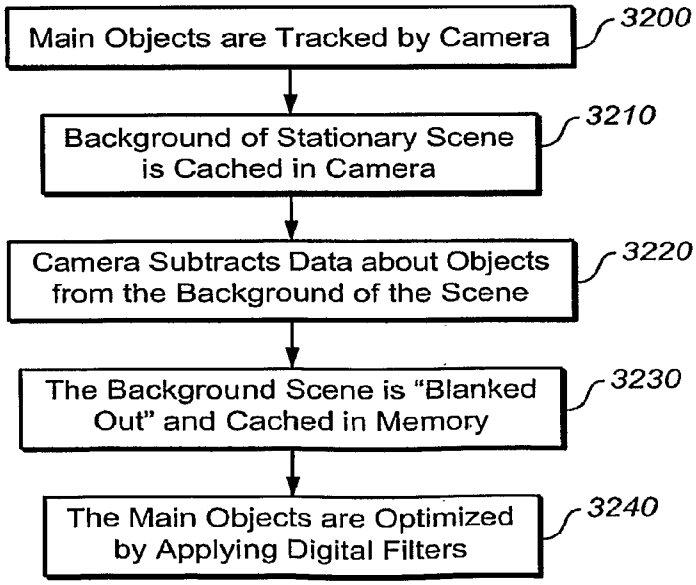

Main Objects are Tracked by Camera
3200
Background of Stationary Scene is Cached in Camera
3210
Camera Subtracts Data about Objects from the Background of the Scene
3220
The Background Scene is "Blanked Out" and Cached in Memory
3230
The Main Objects are Optimized by Applying Digital Filters
3240

FIG. 32

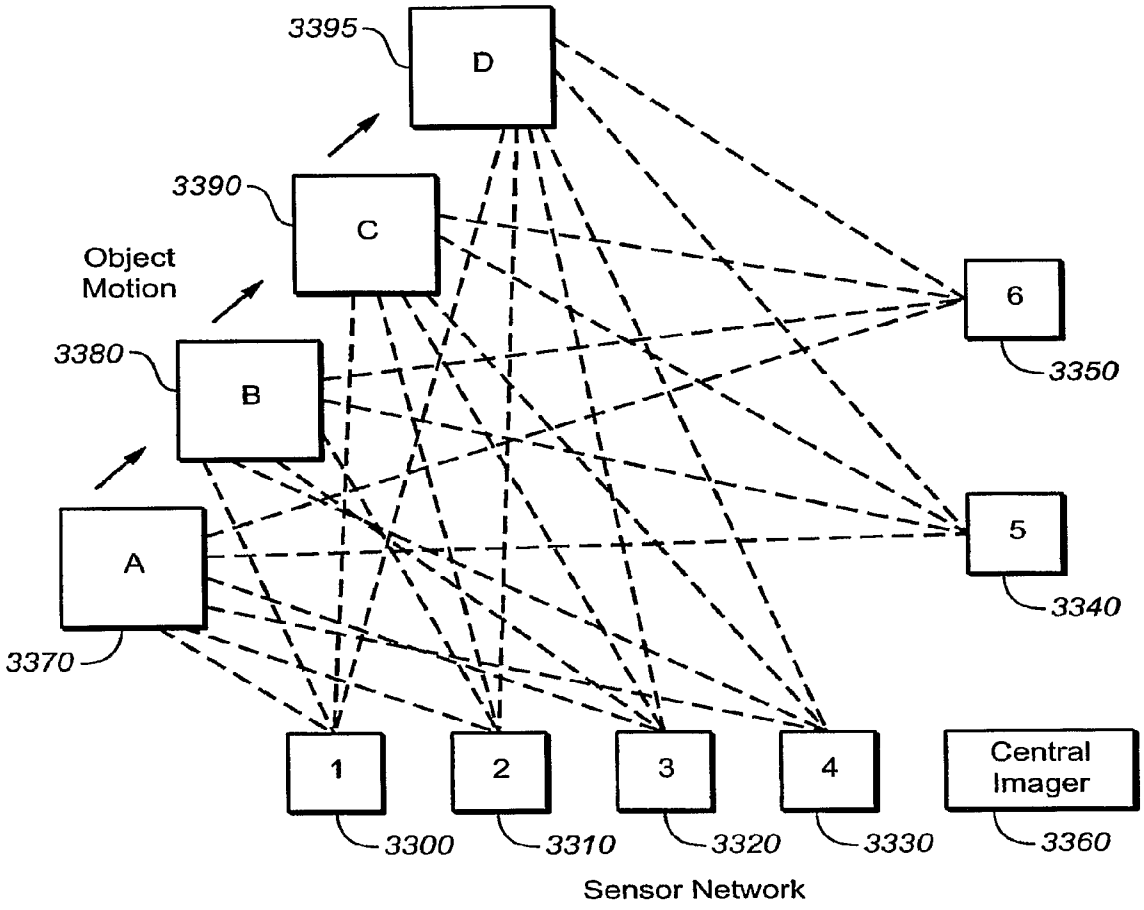

3395
D
3390
C
Object
Motion
3380
B
A
3370
6
3350
5
3340
1
2
3
4
Central
Imager
3300
3310
3320
3330
3360
Sensor Network

FIG. 33

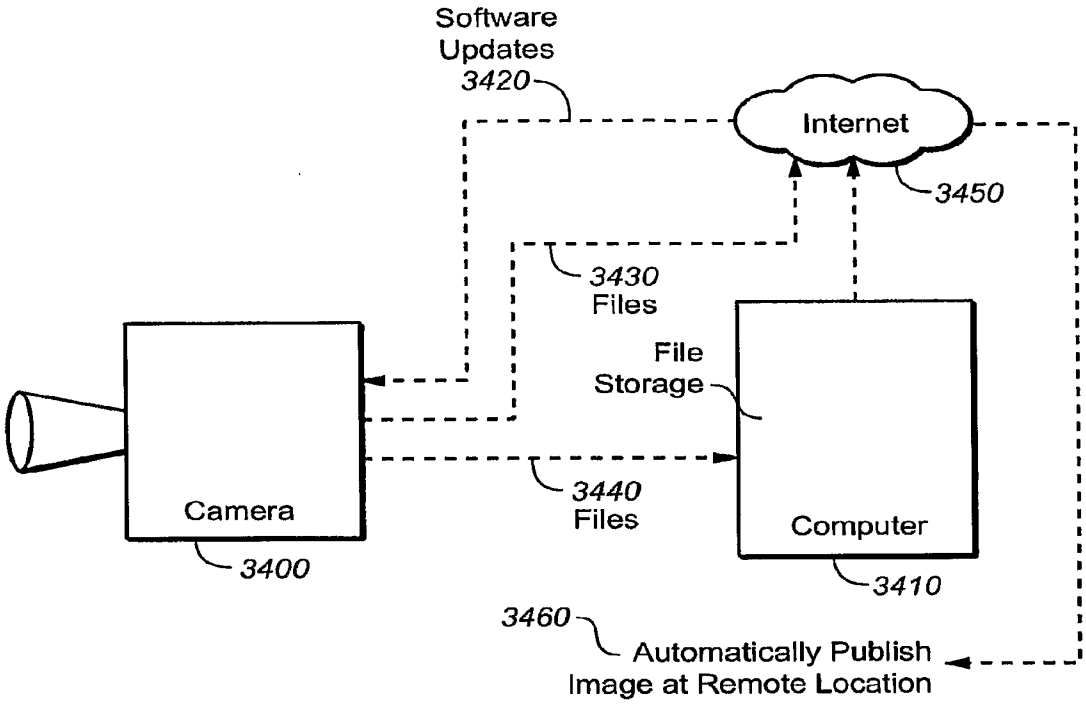

Software
Updates
3420
Internet
3450
3430
Files
File
Storage
Camera
3400
3440
Files
Computer
3410
3460
Automatically Publish
Image at Remote Location

FIG. 34

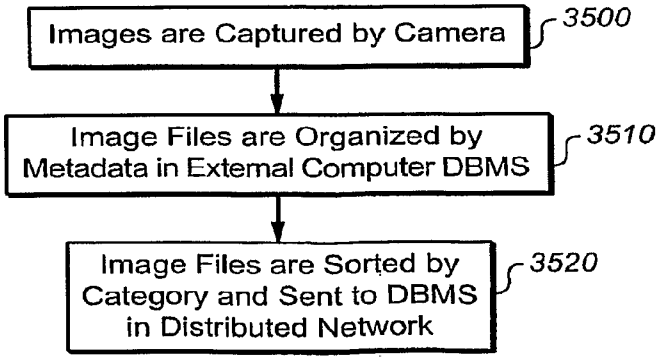

Images are Captured by Camera
3500
Image Files are Organized by
Metadata in External Computer DBMS
3510
Image Files are Sorted by
Category and Sent to DBMS
in Distributed Network
3520

FIG. 35

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION CONCERNING
SUBMISSION OR TRANSMITTAL
OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

To:

SOLOMON, Neal
P.O. Box 21297
Oakland, CA 94620
ETATS-UNIS D'AMERIQUE

Date of mailing *(day/month/year)* 19 September 2007 (19.09.2007)	
Applicant's or agent's file reference	**IMPORTANT NOTIFICATION**
International application No. PCT/US2007/015544	International filing date *(day/month/year)* 07 July 2007 (07.07.2007)
International publication date *(day/month/year)* **Not yet published**	Priority date *(day/month/year)* 11 July 2006 (11.07.2006)
Applicant SOLOMON, Neal	

1. By means of this Form, which replaces any previously issued notification concerning submission or transmittal of priority documents, the applicant is hereby notified of the date of receipt by the International Bureau of the priority document(s) relating to all earlier application(s) whose priority is claimed. Unless otherwise indicated by the letters "NR", in the right-hand column or by an asterisk appearing next to a date of receipt, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).

2. *(If applicable)* The **letters "NR"** appearing in the right-hand column denote **a priority document which, on the date of mailing of this Form, had not yet been received by the International Bureau** under Rule 17.1(a) or (b). Where, under Rule 17.1(a), the priority document must be submitted by the applicant to the receiving Office or the International Bureau, but the applicant fails to submit the priority document within the applicable time limit under that Rule, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

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DIGITAL IMAGING SYSTEM

Field of the Invention

The present invention pertains to imaging systems. The invention presents electronic methods to optimize optical processing, the digital capture of light and post-capture image organization of digital data sets. The system may be used in any device that captures, records, replicates, scans, reproduces, accesses, organizes, modifies, edits or stores images digitally. The invention applies to any imaging system that includes interaction between optics, digital image sensors, post-capture integrated circuits and digital storage components. The system includes self-organizing apparatus for optical image collection, electronic organization and optimization of digital data using integrated circuits and software applications. The system applies to consumer and professional still and video photography, including cinematography, to the processing of images with digital sensors, and to copying and scanning technologies. The system also applies to complex grids of multiple video cameras and satellites for surveillance and reconnaissance.

Background of the Invention

The history of photography in the twentieth century is a story of finding solutions for optimizing optical problems. The main challenges have involved improving lens configurations to optimize image quality for film capture. As an example of this, lens aberrations have been reliably corrected by creating aspherical lens elements in wide-angle lenses and by creating apochromatic lens elements in telephoto lenses. The use of lens element coatings has also improved optical quality. Similarly, the evolution of zoom lenses has included improvement in optical quality via the combining of complex optical element configurations; as the optical

quality of zoom lenses improved dramatically, their simplicity and utility led them to dominate lens sales. Complex computer-aided design (CAD) software has been used to test a broad range of possible lens configurations so as to optimize the optical performance in terms of clarity and contrast of each lens type, as much as optically possible within economic constraints.

In the last twenty-five years, an additional revolution has occurred with the advent of auto-focus (AF) technology in still photographic and video cameras. Invented by Minolta in the early 1980s, AF technology was a photographic application of technology developed for the U.S. military. The AF system used an infrared light sensor to reflect light onto an object that allowed a camera's lens to focus on the object by employing a motor in the camera. Canon eventually developed improved methods of auto focus by using electronic means (viz., micro ultrasonic motors) to increase speed and accuracy. This AF technology was integrated with automatic exposure (AE) technology that developed complex algorithms in a "program" mode to combine shutter and aperture data to match each lens with particular subject matter, as well as an aperture-priority exposure mode and a shutter-priority exposure mode. Of course, the photographer could use manual focus and manual exposure at any time, but these improvements increased the creative process and the competitive advantages of camera makers and photographers that employed them. Ultimately, the combination of these developments allowed ordinary photographers to achieve high quality standards.

AE was improved by Nikon, particularly with the use of a "3D color matrix" system, which included a library of pre-programmed image types. The combination of the improved AF and AE subsystems allowed a dramatic simplification of photographic imaging because the photographer no longer labored over the time-consuming focus and the exposure variables. Automated film advance, in the form of built in motor drives, increased the working speeds of

camera operation as well. Nearly all consumer and professional cameras became automated to some degree by the mid-1990s, including formats beyond the 35mm film standard.

In the last decade, a new technology of image stabilization (IS) has emerged to help correct the problem of vibrations caused camera shake that lead to image blur. This technology is implemented in lenses by the use of gyros to reorient the light plane to compensate for camera shake; when combined with the earlier automated camera technologies such as AF and AE, IS further improves the photographic experience, particularly for larger lenses.

In addition to these advances in camera automation, technologies improved in the category of artificial flash as well. With microprocessors and sensors employed to measure minute variances, the development of photographic flash systems allowed the photographer to control the lighting in an environment to some degree. Nikon's use of distance information in its flash system advanced the state of the art in flash photography. The combination of AF and AE with automated flash mechanisms provided increased efficiency and simplicity in image capture processes.

The last several years have witnessed a revolution in digital photography. Because of its simplicity, potential quality improvement, immediate feedback and cost savings, digital photography has captured an increasing market share relative to film-based cameras. Kodak holds a number of patents involving the charge coupled device (CCD) for converting and recording light into electronic format. A competing technology for digital capture is complementary metal-oxide semiconductor (CMOS) which, though developed by Fairchild Semiconductor over forty years ago, is predominantly used in photographic cameras by Canon. Although there are trade-offs in the application of CCD and CMOS digital sensors for image capture, they both find wide acceptance in the market.

In order to correct for digital artifacts in image capture mechanisms, anti-aliasing filters are placed in front of digital sensors. Despite this improvement, digital imaging still has some challenges to overcome in competing with the image quality of film.

At the present time, the most recent advances in digital imaging for professional still photography have come from Hasselblad, which offers a Phase One camera back with a 39 MP digital sensor from Kodak. This system uses software that automatically corrects for digital capture limitations to produce a quality image. Their "digital APO correction" (DAC) technology performs an analysis of meta-data to color-correct the digital capture resulting in moiré-free images.

At the limits of current technology, a Canadian company, Dalsa, has produced a 111MP (10,560 by 10,560 pixels) CCD digital sensor that measures four inches square. This technology must be mated with large format-type lenses with large image area, and may be used for satellite surveillance applications and for other astronomical applications.

With both the larger sensor surface area of a medium format camera system and the high-quality fixed focal-length lenses of Zeiss, Schneider and Rodenstock, the quality of even the top optics will be a limiting barrier to advanced digital sensors' ability to perceive maximum resolution. Without new improvements in optical and digital technologies, further progression of photographic camera systems will be limited.

Photographic Problems

Though every major advance in photography has solved an important problem, there are still remaining photographic problems to be solved in order to meet the goals of optimizing optical imaging quality while increasing simplicity and efficiency and lowering cost. Despite the

advent and evolution of digital imaging, a number of problems have emerged in the digital realm in addition to earlier problems involving optics. Nevertheless, an opportunity exists to solve some of these problems via digital approaches. These problems are generally categorized as optical or digital.

Optical Problems

In the case of optics, lens aberrations are characterized according to lens type, with wide-angle lens problems differentiated from telephoto lens problems. Some of the problems affecting wide-angle lenses arose from the creation of the single lens reflex (SLR) camera. Before the SLR, the rear element of a lens could be placed in a rangefinder to protrude to a point immediately in front of the film plane in order to correct for aberrations. While the advantages of the mirror mechanism include ability to see exactly what one is photographing, because the mirror of the SLR flips up during exposure, the rear element of the lens must be placed in front of the mirror's plane of movement. This mechanical fact limits lens designs in most 35mm and medium-format camera systems and particularly affects wide-angle lens configurations.

It is very difficult to control the five aberrations of Seidel – spherical aberration, distortion (barrel distortion and pin cushion distortion), comatic aberration, astigmatism and curvature of field. In wide-angle SLR lenses as they are currently designed, these aberrations are particularly prominent.

For wide-angle lenses, optical vignetting affects peripheral illumination. Though optical vignetting will affect even retrofocus wide-angle lenses in rangefinders, it is particularly prominent in SLR cameras. According to the Cosine law, light fall-off in peripheral areas of an image increases as the angle-of-view increases. While optical vignetting can be reduced by

stopping down the lens, the aberrations in rectilinear wide-angle lenses generally exhibit more distortion the wider the lens.

In the case of wide-angle lenses, the depth of field range is much broader, with close focusing causing aberrations without stopping down the aperture. To solve this problem, close-distance focusing is improved by the creation of floating groups of lens elements. The rear lens group elements float to correct close-distance aberrations. With wide-angle lenses that have wide apertures, floating lens elements improve lens aberrations in focusing on distance points also.

Modulation transfer function (MTF) curves represent a quantitative methodology used to assess the resolution and contrast of lens performance at specific apertures. Each lens type has a specific lens element composition, formula and behavior as measured by MTF. In general, MTF measures lens sharpness to 30 lines/mm and contrast to 10 lines/mm.

Because different colors of the visible light spectrum behave uniquely, the goal of lens design is to have all colors accurately hit a film plane or digital sensor plane. The particular challenge for telephoto lenses is that the red and green light colors strike the film plane at different times than blue light colors; thus a compensation must be made in the lens configuration to adjust for chromatic aberrations. Camera lens manufacturers have used extra low dispersion glass and fluorite glass elements in telephoto lenses primarily to adjust the red color light spectra to the film plane. In addition, telephoto lenses use carefully designed lens coatings to limit light diffraction-based aberrations.

Due to their construction, super-telephoto lenses are very large and heavy. While modifying the materials used in the lens barrels could reduce size and weight problems, a technological improvement in telephoto lens design was developed by Canon with the addition

of diffractive optical (DO) elements, which behave as a sort of highly-refined fresnel lens magnifier. Though the MTF analyses of wide-angle lenses show dramatic latitude in performance of even high quality SLR lenses, with particular loss in resolution and contrast toward the edges of the image, high quality telephoto lenses show control of aberrations. However, the price of these lenses is prohibitively high.

In the case of zoom lenses, as many as four distinct groups of lens elements correct various optical aberrations. These lens element groups include (a) a focusing group, (b) a magnification variation group, (c) a correction group and (d) an image formation group. Modulating the focal length range of a zoom lens enables the lens to perform within the scope of operation, yet the zoom lens architecture has limits. In particular, the zoom lens configuration sacrifices resolution and wide potential aperture. Generally, the degree of resolution and contrast at the smaller angle of view is traded away in favor of competence at a wider angle of view, or vice-versa. This explains why MTF analyses of zoom lenses generally show a dramatic lowering in resolution and contrast relative to excellent fixed focal length lenses.

Digital Problems

Digital photography has built on the edifice of *film* camera systems. For instance, the size of the sensor is generally limited to the size of the optical circumference of a lens system. In the case of 35mm lenses that are designed for a specific angle of view, the largest that a digital sensor in a 35mm lens system could be, is 24mm by 36mm, with a corresponding maximum image circle of 43mm. In the case of medium format lenses, the largest digital sensors would duplicate the corresponding film plane size, whether 6x4.5 cm, 6x6 cm, 6x7 cm, 6x8 cm, 6x9 cm, 6x12 cm or 6x17 cm (which results in an effective image circle as large as 7 inches).

Digital sensors that are smaller than the limits of a corresponding lens system have been introduced. For example, Nikon digital sensors are smaller than 24mm x 36mm, or advanced photo system (APS) size. Efficient stacking of pixels allows a smaller sensor to eventually match the performance of a corresponding film system, while using the smaller circumference of the same lenses. Since the outside edges of the lens typically degrade resolution and contrast, this model using the smaller digital sensor can have an advantage of using primarily the centralized "sweet spot" of the image area. However, this smaller sensor size sacrifices the peripheral effects of a wide-angle lens, so a 14mm becomes a 21mm in a 1.5x conversion-sized sensor in a 35mm lens system. On the other hand, with telephoto lenses, the angle of view is limited to the center 65% of the image. This gives the appearance of upconverting a telephoto lens by 1.5x and thus provides an impression of increased magnification; a 400mm f/2.8 lens appears as a 600mm f/2.8 lens on a camera with a cropped digital sensor. Ultra-wide-angle lenses have been introduced with smaller image areas than 35mm to compensate for smaller sensor size.

Though invented over thirty years ago by Dr. Bayer, the charge coupled device (CCD) that is used in many digital cameras generally emulates the behavior of film. Specifically, since most photographic film has three layers of green, red and blue, with green representing fifty percent of the emulsion and red and blue twenty-five percent each, the CCD architecture also configured pixels to capture fifty percent of the green photonic visible light spectrum and twenty-five percent each for pixels recording red and blue light. Human eyes see more green than red and blue, so both film and digital sensors seek to emulate the way that we see. Each light color is captured by a different pixel in the CCD, just as there are three emulsion layers of film. In recent years, Foveon has developed a digital sensor for image capture that further seeks

to emulate film by structuring the pixels into three *layers*, again with fifty percent capturing green light and twenty-five percent each capturing red and blue light.

Unfortunately, unwanted artifacts are also captured by the digital image capture process. These include banding and moiré effects that present false patterns and colors. Moiré patterns are created because the dot pattern of a sensor will intermittently overlap with the pattern of a subject to create a third pattern; these effects are optically-generated digital distortions that represent the effect of light hitting a pixel without correction. In order to compensate for these effects, digital sensors have employed low pass filters consisting of liquid crystal structures; however, these filters tend to have the effect of softening image resolution. Additionally, RGB or CMYG color filters are placed in front of digital sensors to ensure the accurate capture of colors.

CMOS digital sensors present an alternative to CCDs. By employing alternating positive and negative transistor networks, the CMOS sensors use less power. While they do not have the low noise ratio of the CCD, they do have greater light exposure latitude, in both range of ISO and dynamic range of detail in highlight and shadow. More importantly, CMOS sensors contain the circuitry, including analog to digital converter (ADC) and digital to analog converter (DAC), for post-processing digital images on the chip itself and enabling increased micro-miniaturization of the digital imaging process. An increase in the bit rate of the CMOS chip up to 32-bit makes possible a much richer color palate and level of detail than with earlier generation CCDs.

CMOS sensors can be full-frame, matching the lens specifications for the camera systems for which they are designed. A relatively bigger sensor has a wider depth of field capability, so the background can appear as a blur to set apart the main subject. Given these capabilities, one problem that emerges is that a digital sensor's enhanced capabilities to capture details may

exceed the maximum optical resolution capabilities of many lenses. Nevertheless, CMOS sensors still require an anti-aliasing filter to be used in front of the sensor, which marginally degrades resolution.

Over the years, cameras have gotten smaller. While in the 19th century cameras were 11x14 or 8x10, literally capturing images on large emulsion plates, cameras of today are smaller and more automated. Yet the larger the film size, the bigger the enlargement potential and the increase in relative detail in the overall image. Similarly in digital photography, the larger the sensor, the more detail available and the bigger the output print can be enlarged. Because of this correspondence of digital sensor to film, the evolution of digital photography has been restricted to respective film camera systems, with 35mm and medium format systems dominating the field because well-developed lens systems have already been organized for these camera formats. The potential exists, however, to develop 35mm camera system digital sensors that rival film-based medium format or large format camera system quality or to surpass the limits of 35mm camera systems with medium format camera system digital sensors. The relative size, cost and automation advantages of 35mm camera systems generally show that these systems not only are competitive, but that these markets are increasingly accelerated relative to larger format systems. For example, the development of large aperture lenses, super-telephotos, rapid auto-focus, refined automated exposure and image stabilization systems in 35mm systems has solved various problems that have emerged in the last century and has improved image quality and camera system efficiency.

However, in the digital imaging realm additional problems have emerged, including the need to improve color (hue and saturation) quality, exposure highlight range, contrast range and other tonal adjustments. In addition, digital image capture brings its own set of aberrations,

including moiré and banding effects and noise and ISO range limits. Additional aberrations are linked to the unique design of each type of digital sensor, with trade-offs presented between types of CCDs or CMOS chips. Moreover, there are still optical problems in the digital realm, namely, a range of optical aberrations created particularly by wide-angle and zoom lenses as well as the limits of very large, costly and heavy super-telephoto lenses.

In order to transcend the optical and digital limits of present camera systems, software systems have been developed that deal with the problems in post-production. While the most notable of these post-production digital editing software programs is Adobe Photoshop, each camera manufacturer has its own proprietary program. In the main, these post-production software programs are limited to color correction and sharpening/softening of images. Additionally, some of these software programs are able to emulate specific artificial filter techniques to produce creative modifications of an original image. Nevertheless, manipulating unfiltered RAW image files in post-production processes is time-consuming and expensive and requires considerable skill.

One unintended effect of using digital sensors to capture images in digital photography is that dust accumulates on the sensor surface and thereby obstructs a clear optical image. The vacuum behavior of increasingly ubiquitous zoom lenses moves dust in lenses that are not internally sealed and the existence of dust is a prevalent feature of digital photography. Dust on the sensor is a non-trivial problem that requires tedious post-production correction for each image. The existence of dust on a digital sensor is an inconvenient impediment to achievement of optical imaging quality.

What is needed to correct these various optical and digital aberrations and unfiltered image files is in-camera modification capability for each specific image problem. The present invention describes a digital imaging system to optimize optical results.

Applications of the Present Invention

The present invention has several practical applications. The digital imaging system applies to consumer and professional still and video camera technologies, to cellular telephones and to personal digital assistants (PDAs). Since video technologies are evolving into digital formats, including HDTV and its successors, the present invention would be applicable to these technologies. The present invention also applies to networks of remote camera sensors for surveillance. The system also applies to native digital cinematography and telecine conversion from analogue to digital media. The system may be applied to image scanning and image copying technologies. Finally, the present system may be applied to any optical digital capture, processing and storage sub-system technologies, including groups of sensors or satellites.

Advantages of the Present Invention

There are several important advantages of the present invention. The present system dramatically improves image quality. This digital imaging system eliminates, or minimizes, post-production processes. In addition, the system presents substantial cost savings as well as time savings relative to existing digital imaging systems because of the automation of integrated in-camera optical and digital corrections of aberrations.

With the present system, in-camera digital filters will largely replace optical filters. With less distortion, cost and weight/size than current optical filters and with far more control and

quality results, the present system demonstrates that in-camera digital filtration out-performs better than external filters. The in-camera filter system is also an improvement over post-production digital filter systems which require substantial time, cost and skill to implement.

By using the present invention, users will be able to use lens apertures that are wider open, because lens aberrations will be corrected. In turn, this increased latitude will allow more efficient (2+ stops) use of available light and will allow slower lenses to achieve quality images that have traditionally been in the domain of expensive fast lenses. The process of photography will be made generally more efficient.

The present system allows camera manufacturers to design different, predominantly smaller, lenses. Moreover, with providing a system for digital corrections, camera lenses may use less expensive optics and still obtain good results. This process will, in turn, accelerate the adoption of low-cost digital photographic systems and, in the aggregate, increase the overall size of the digital photographic market. Similarly, there will be an increase in the effectiveness of zoom lenses, which are already becoming popular. With the present system, 35mm optics may obtain the quality typically recognized by 4x5 film camera systems. The present system will thus facilitate photographic digital imaging to supplant the film era.

Its application to digital scanning and copying will allow the present system to become ubiquitous as a system to improve imaging.

Because the system presents an integration of several critical subsystems that are centered on digital imaging processes, the system has applications to video photography, satellite systems and surveillance systems. The dynamics of the operation of the subsystems of the present digital imaging system reveal the refinement, efficiency and optimization of the digital photographic paradigm.

Importantly, since the present system uses apparatus and methods that are implemented with software processes, in-camera software can be constantly upgraded and remotely downloaded, while image files can be automatically uploaded, organized and published.

If the goal of the evolution of photographic technology is to increase the number and quality of excellent images, the present system will revolutionize photography.

Solutions to Digital Imaging Problems that the Present System Presents

The present system provides in-camera digital corrections to both optical and digital aberrations. In the case of optical aberrations, distinct lens-specific imperfections are caused by wide-angle, telephoto and zoom lens types. In the case of digital aberrations, specific digital artifacts, such as aliasing and dust, must be corrected.

The present invention also designs specific improvements to digital sensor design. These hardware architecture modifications allow digital imaging to maximize both optical resolution and image exposure range.

Post-capture in-camera filtration is only part of the solution. There is also a need to modify the digital sensor, whether CCD or CMOS, with specific filtration in some cases, including a low pass anti-aliasing filter and a polarizing filter. This post-optic pre-sensor filtration works with post-sensor in-camera filtration processes.

In the context of specific complex processes, such as in zoom lens modifications of focal length and in full-motion video processing, additional corrections are performed using the digital imaging system which continuously optimizes performance.

Finally, the present system reveals approaches to improve network coordination and wireless external storage and publication capabilities for digital imaging systems.

SUMMARY

The present invention is divided into several main sub-systems: (1) digital filters to correct optical and digital aberrations; (2) digital sensor improvements and nano-grids; (3) digital system improvements that link multiple digital corrections; (4) dynamic digital imaging system improvements that apply to zoom lenses and video imaging; and (5) digital image network improvements. There are several distinct improvements for each category of sub-system listed.

(I) Digital Filters to Correct Optical and Digital Aberrations

(1) Lens-specific digital correction of fixed focal-length lens for specific optical aberrations in camera.

Each lens has some sort of aberrations because of the trade-offs involved in producing lenses of usable size and practical commercial cost. The challenge of building lenses for SLR camera systems lies in accounting for particular restrictions and compromises, particularly for wide-angle and zoom lenses. In the case of wide-angle fixed focal length lenses, several main kinds of aberrations occur, including spherical aberration, distortion (pin cushion distortion and barrel distortion), astigmatism, curvature of field (manifesting as the reduced corner exposure of vignetting) and comatic aberration (a distortion evident with long exposures). The extremes of each of these aberrations have to be corrected in post-production.

In the case of vignetting, a type of aberration in which the corners of an image are exposed a stop less than the image's center area, software can digitally emulate a center-neutral density filter to compensate for the light fall-off on the edges. This operation identifies the degree of light fall-off for each specific lens and adjusts the brighter areas in the center of the lens by appropriate exposure compensation. A consequence of this digital equivalent of the

traditional optical solution to vignetting is that the image will require exposure metering of the subject at a level consistent with the outside edges of the image rather than the typical inner section. In the present system, the camera will use pre-set calculations compensating (generally one stop) for the specific gradations of the curvature of the field for each lens, with an increasing compensation correlated to an increased angle of view. Similarly, barrel distortion and pin-cushion distortion, which also manifest in image corners, are corrected using processes of employing pre-set calculations, to compensate for optical distortion, particularly in wide-angle and zoom lenses.

In addition to integrating into the camera the traditional process of image correction for exposure gradations of vignetting, the present invention offers two further embodiments. First, instead of darkening the center to match the darker corners, the in-camera digital compensation system will lighten the corners to match the exposure of the center of the image. In the second embodiment, the in-camera digital compensation system will both lighten the corners somewhat and darken the center of the image somewhat, to produce a more pleasing and realistic effect. The in-camera digital corrections of the vignetting problem dramatically improve the traditional optical solution of a center-weighted neutral density filter, which typically degrades image quality as it evenly illuminates the full image.

Since each lens has specific aberrations, depending on manufacturer and even differences in the specimens themselves, the camera software system will have preprogrammed general corrections for each specific lens type. For instance, while a 20mm f2.8 lens varies among manufacturers, the general optical aberrations will be similar. An effective software solution is one which brings the optical image quality to a level consistent with a benchmark as measured by low MTF curves for each lens in its class in terms of both resolution and contrast throughout

the image. To exemplify this benchmark, retrofocus rangefinder lens performance results of wide-angle lenses, which lack a shutter mechanism to design around, can be used for comparison. To accommodate the mirror in the SLR design type, the rear nodal point in SLR lenses are shifted forward, creating distortion. In contrast, the present system suggests applying a digital solution to compensate for this problem.

In a general sense, this process of correction is similar to correcting an ocular astigmatism with reading glasses. However, rather than using an optical solution to an ocular problem, the present system reveals a digital solution to an optical problem.

In the process, the camera identifies a specific lens and refers to a database that matches the lens type with the specific aberrations. The aberrations are consistent throughout all images for each formula of a specific prime lens type and are thus corrected by adjusting for each specific aberration category. Generally, the larger the angle of view of a lens, the greater the distortion and the greater the need for in-camera digital corrections.

In addition to the kinds of distortions created in wide-angle lenses, other types of distortion occur primarily in large aperture telephoto lenses, most notably chromatic aberrations that require apochromatic corrections. Rather than employing large, heavy and expensive extra dispersion glass, such as fluorite elements, the present system allows each lens type to be digitally corrected for these types of aberrations. The in-camera digital process works by identifying a specific lens and comparing the lens pattern to an internal database. Mathematical calculations compensate for the shift in red and green light that apochromatic corrections require for very low MTF curves registering high standards of resolution and contrast by emulating the optical benefits of extra low dispersion glass elements.

Since lenses of the same focal length but with different maximum apertures represent completely different lens designs, modifications of their aberrations will vary relative to each specific lens type. For example, a 24mm f/2.8 lens will have a different optical formula than a 24mm f1.4 lens in a 35mm camera system. Similarly, a 28mm f/2.8 will differ from both a 28mm f/2 lens and a 28mm f1.4 lens and will thus each require different adjustments for vignetting, spherical aberration, pin cushion distortion, barrel distortion and coma. In other words, each lens with a unique optical formula will have specific aberrations, the corrections for which will be accessible in a database.

Another type of optical aberration that affects lenses involves flare, which is a sort of specific reflection of light sources. While improvements in lens coatings have been used to correct for flare, high refractive glass also eliminates flare. The present system uses digital processes to emulate these flare reduction functions on lenses even at maximum apertures.

In addition to the lens-specific types of corrections that are supplied by in-camera software, a function that optimizes contrast provided by limited reflected light is required. In general, lens hoods reduce reflected light. However, in the absence of a lens hood, scattered light will adversely affect contrast in all lenses. Thus, a general digital solution will optimize contrast from reflected light by emulating the effects of a lens hood.

Because the pixels on a digital sensor behave as neutral intermediaries to record light, the aberrations on specific fixed focal length lenses will be prominent. It is therefore necessary to filter out various optical impurities. In all cases, the digital in-camera software program emulates specific filters to effectively correct specific optical aberrations.

By digitally adjusting for optical distortions, the present system advances the state of the art for fixed focal length lens optics, beyond any opportunities available in film cameras. The

following chart illustrates a list of optical distortions that are corrected by in-camera digital solutions.

	Fixed Focal Length Lens Type		Zoom Lens Type		
Specific Aberrations	**Wide-angle**	**Telephoto**	**Wide-angle**	**Wide-to-Tele**	**Telephoto**
Spherical	X		X	X	
Comatic	X	X	X	X	X
Astigmatism	X		X		
Distortion (Pin Cushion and Barrel Distortion	X		X		
Curvature of Field	X		X		
Chromatic		X		X	X
Flare	X	X	X	X	X
Scattered light (Unpolarized)	X	X	X	X	X
Color Accuracy	X	X	X	X	X
No Lens Coatings	X	X	X	X	X

(2) Multivariate digital correction using matrix filter system in camera

Since typically several distinct aberrations exist in a lens, it is necessary to correct each of the aberrations. For this multi-dimensional problem there is a multivariate digital in-camera software correction solution. The problem of correcting multiple aberrations presents the additional challenge of requiring acceleration to complete multiple tasks rapidly. In most cases, the hardware employed in a camera's chip set will include an application specific integrated

circuit (ASIC) which processes a particular program rapidly. It is appropriate to facilitate the combination of corrections to multiple simultaneous aberrations with an ASIC or multiple ASICs.

There is a need to optimize both resolution and contrast across the image area for accurate light reproduction. One way to do this is to stop down the lens to an optimum aperture of about f/8. However, this solution sacrifices the advantages of a fast lens design and capability, namely, limited depth of field and bokeh (smooth out-of-focus area). Though resolution is typically improved by stopping down a lens, digital sensors are generally still restricted in their latitude of contrast. Therefore, regarding both resolution and contrast, it is necessary to provide multiple adjustments of the native image with in-camera digital corrections.

While it is possible to produce mathematical algorithms for automatic correction of optical aberrations, it is also useful to have manually adjustable variables. Therefore, the present system includes a function whereby one may omit a specific correction in an image by using a lens with multiple aberrations in order to induce a particular creative effect. This factor may involve a lack of exposure compensation, a lack of correction for spherical aberration or an improperly or partially corrected apochromatic modification.

In one example of the use of multiple corrections, simultaneous application of multiple digital filters concurrently corrects multiple aberrations. In effect, this is like adding layers of different eye glasses to repair multiple types of astigmatisms for each specific ocular condition. The dynamics of correcting multiple simultaneous aberrations may be complex, but since the number and type of aberrations are constrained to a specific lens type, a centralized database may be accessed with specific corrections for each respective aberration. For example, lenses with multiple complex aberrations, such as in very wide-angle lenses, will require multiple

corrections. These combinations of corrections become complex as focal length modes change in zoom lenses and as aperture changes.

The following is a list of filter types that provide digital methods of correcting image problems or creating specific effects. This list is not intended to be comprehensive or systematic.

Filter Type in Digital App.	**Most Common Uses**	**Other Filter Types**
UV (and Sky)	General Use	Polarizer
Color-enhancing (and warming)	17mm-200mm (in 35mm)	Close-up
Contrast	17mm-200mm (in 35mm)	Special effects filters
Black and White (Red, Orange, Yellow, Green)	17mm-200mm (in 35mm)	
Infrared	17mm-200mm (in 35mm)	
Color Graduated (Neutral Density)	17mm-200mm (in 35mm)	
Diffusion (Soft, mist/fog, star, streak)	24mm-135mm (in 35mm)	
Combinations (Neutral density and enhancing, Polarizer and UV)	17mm-200mm (in 35mm)	

In the past, these optical filtration processes were added after the production process via editing software such as Photoshop. However, in the present system, these combinations of processes are performed in-camera by user-adjusted settings. In the case of artificial color changes to an image, digital processes emulate specific optical filters by adding a specific color or a combination of colors. On the other hand, in the case of diffusion filtration, the in-camera digital process creates an emulation of optical filters. The classic example of this diffusion approach is the soft filter, which is used for portraiture. In this case, various user-adjustable settings in the camera digitally manipulates soft filtration.

(3) Depth-of-field optimization using digital correction in camera

In addition to correcting optically-generated aberrations with in-camera digital processes, the present system allows in-camera depth-of-field (DOF) optimization by affecting the aperture of the lens that is used.

DOF in an image is dependent on the aperture setting in a lens, in which a moderate DOF range – allowing a subject to be isolated in an image – can be manipulated, that is, extended or narrowed, by the camera's digital processing capability. In the film paradigm, one obtains a specific aperture, and thus the corresponding DOF, that is preset by the photographer. However, in the digital paradigm, by contrast, one can *narrow* an image's surplus DOF range in-camera by manipulating the aperture. This process can only be done in the camera, because once the digital file is sent to post-production editing, the aperture and DOF is already set and incapable of being changed. The aperture is narrowed in camera by isolating the subject and shifting the field of view (forward from the rear range of DOF and backward from the front range of the DOF). Distance information is used to recalculate an optimal DOF. In another embodiment, the camera provides feedback from an internal computational analysis that results in a specification of less DOF and takes another image (or images) with a larger aperture to accomplish reduced DOF at a specific focus point.

The camera will effectively identify a type of subject and provide an optimal aperture for this subject. For instance, for a portrait, the camera will select a shallow DOF around the subject. In the case of a distant landscape, the camera will focus on a distance at infinity and provide a nominal aperture to correspond to shutter speed that will fit the available light as matched to a specific lens. A near landscape photographed with a wide-angle lens will, on the other hand, have a near focus and a maximum DOF; specific subjects will be highlighted with

ample DOF. The camera will also have the capability to bracket exposures in several successive images based on DOF variations.

The DOF manipulation thus depends on a combination of data sets including the particular lens used (wide-angle lenses have greater DOF at moderate distances than telephoto lenses), the distance information and the unique combinations of aperture and shutter speed. DOF will narrow with less distance, with use of a telephoto lens and a fast aperture; contrarily, DOF will expand with a further distance, with use of a wide-angle lens and a slower aperture.

In another embodiment of this process, test images are taken and analyzed, then later images taken with new settings optimize DOF for each image type.

(4) Exposure optimization using digital correction in camera

One phenomenon that film currently records better than digital photo technology is exposure latitude. Film is capable of greater exposure latitude than either CCD or CMOS digital sensors, though each digital sensor type has strengths and weaknesses. For the crucial detail recorded in a scene, film provides far more depth of tonal range. Yet some of this problem – caused by the limits of digital sensors themselves and the way that photons are recorded by electrically charged pixels – can be digitally corrected and optimized in-camera.

The problem derives equally from the method of measuring exposure as well as the method of image capture by a digital sensor. In general, since there is less exposure latitude in digital sensors, as compared to film, the maximum scope is two or three stops in the image tonal range. Consequently, the camera must meter the image within constraints of the tonal range of the digital sensor, with the sacrifice of either shadow detail or highlight detail. In an image with broad exposure range, then, the image will generally be either too light or too dark because metering for one area sacrifices the other tonal category.

One way to solve this problem is to manipulate the lens aperture, because increased aperture within an optimal limit generally increases detail. An optimal aperture of f/8 provides more detail and clarity than at f/2 or at f/32. The in-camera processor may thus seek out more detail in the image by manipulating the aperture to the optimal range of f/5.6 to f/11, depending on the type of subject and the availability of light. With more detail in the original image, it is possible to interpolate the digital data in the image file by increasing both shadow and highlight detail and to gain an additional stop or two of tonal range.

In another embodiment, the tonal range of an image data set is enhanced in-camera by using meta-data to sample the range of shadow and highlight detail. The data sets are interpolated to add requested shadow detail and/or highlight detail. Obviously, some subjects require more or less shadow or highlight (or both), which the camera can correspondingly adjust. These tonal range corrections are user-adjustable.

In an additional embodiment of in-camera tonal range corrections, exposure data are bracketed by manipulating the aperture and shutter speed to lower or raise the overall exposure in one-third to one-half stop increments. This bracketing method may be correspondingly limited to a specific image type. For instance, in a portrait, the extraneous background, which ought to be out of focus, is not emphasized in the exposure data, while the main subject is carefully nuanced for balancing an optimum of both highlight and shadow, or for an exclusive emphasis on either highlight or shadow.

The overall problem of limited tonal range in digital photography stems from mismatched exposure-metering mechanisms of digital sensors with substantially restricted tonal range capabilities. One interesting example of this problem occurs in scenes with two or more stops of difference, such as a landscape with sky on top and earth on bottom. A filtration process will

operate on the key parts of such an image, as described above regarding the vignetting phenomenon; the overexposed top half of the scene will be gradually underexposed while the lower half of the scene will be gradually overexposed. This scene-specific adjustment of exposure greatly increases the tonal range of digital images and is made possible via analysis of the scene and comparison to a database of typical scenes categorized by the in-camera digital processor which effects correction using the methods described herein. In this example, the corrective process emulates the use of neutral-density optical filters.

(5) Special effects digital filtration of specific objects

Though there are several main categories of special effects optical filters, including color enhancing, infrared and diffusion, the use of diffusion filters appears to elicit the most dramatic effect. Diffusion filters are categorized as soft effect, mist/fog, black mist, gold diffusion, and star and streak, with various degrees of diffusion producing lesser or greater distortions. In effect, rather than removing optically-generated distortions, we are deliberately creating photographically desirable distortions. It is possible to reproduce these special effects by using the digital post-capture production processes in the camera. In this case, the camera digitally emulates the special effect by applying user-adjustable filter settings.

Portraits have traditionally used some sort of soft effect filtration approach which is producible in the camera using the methods described here. After the image is captured, the camera analyzes the image's meta-data and applies a correction by interpolating the data with specific filter emulation. In the past, specific camera lenses, such as the 135mm soft effects (also called "defocus control") lenses performed this function optically with an included adjustable lens element. This defocus control lens type will focus on the main subject and a lens element setting of the telephoto lens to produce a soft filter effect. In addition, because this lens type uses

a nine blade aperture, the background that is out of focus has a pleasing bokeh in which the gradations of tone are evenly smooth. Nevertheless, a sophisticated digital camera is able to produce the same results with more information provided by a normal telephoto lens, using the method of emulating special effects in-camera.

Another novel special effect that is a further embodiment of the system is the ability of the in-camera digital corrective system to use complex data sets contained and analyzed in an image to create a three dimensional (3-D) representation of the image. The camera creates a 3-D image by arranging the DOF in a way that optimizes the aperture by using distance information and autofocus data to isolate a subject. By removing the foreground and background of the image as a center of subject focus, the DOF will emphasize the subject only as 3-D. The key to this effect is the application of specific exposure data as indicated above, because it is in the increased extension of the range of highlight and shadow that the subject in the image will attain a 3-D quality in contrast to its out of focus foreground and background.

An additional embodiment of the present system would extend the still photography in-camera special effects to video with full-motion ranges of filtration actions.

Finally, it is possible to *combine* different user-programmable special effects in-camera by adding the various types of diffusion methods for a specific image.

(6) Selective in-camera filtration of specific objects

The combination of sophisticated auto-focus technologies and in-camera auto-exposure systems provides the opportunity to isolate a subject by focusing on the subject and narrowing the DOF range by manipulating the aperture. In a further extension of the subject-isolating capabilities of these technologies, it is possible to digitally filter out specific objects in a scene in-camera while focusing on other selected objects that are in a specific range of DOF. In other

words, one may apply filtration to correct aspects of a single object or only the background of a scene to the exclusion of an isolated object, rather than correcting a whole scene. Selective filtering of specific objects in an image by in-camera digital processing affords greater creative flexibility.

Because the camera uses distance information to isolate a specific object by focusing on the object within a range of DOF, it is possible to isolate a particular object for the purposes of applying a specific filtration preference, such as manipulating the color, correcting the optical aberration (say, if the object is in a corner of the image of a wide-angle lens), providing a special effect (such as a soft effect only on a specific object rather than the scene as a whole) or using some combination of these corrections. Once the camera isolates the selected object (using auto-focus mechanisms and distance information), the user selects programmable correction features to perform a corrective function only on the specific object (or only on the parts of the scene that are exclusive of the object). In a further embodiment, contrastively, once the object is isolated, only the background may be selectively manipulated with filtration, achieving pleasing effects. This in-camera corrective feature provides a powerful tool to rapidly manipulate an image without using post-production editing software tools.

These object-specific in-camera selective filtration capabilities are particularly dramatic with fast-moving action photography in which split-second timing produces the preferred complex effects. Selectively identifying a particular object for intensive combinations of filtration is a highlight of the present system.

(7) Digital correction in-camera of intermittent aberrations caused by dust on digital sensor

Dust on a digital sensor is a major concern for photographers. The use of zoom lenses compounds this condition, because as the zoom lens changes focal-length positions, air is

transmitted, which results in the proliferation and diffusion of sensor dust. Unless photography is isolated to a clean room, the problem of dust on a digital sensor will remain prevalent. The present system provides a method to correct for this phenomenon.

In the case of dust on a sensor, a specific consistent pattern emerges on each image captured by the digital sensor. Consequently, information from various images is analyzed, and the pixels affected by dust are identified. Information from the consistent fixed pixel positions that are affected by the dust are then isolated. The specific positions with the dust are then analyzed by comparing the immediate areas surrounding the dust that are not affected by it. These unaffected areas are analyzed, and the affected areas are interpolated to provide a continuous tone. In effect, the images identify the locations with dust by using caching technology. The continuity of the location of the dust between multiple images provides information to the in-camera image processor to detect the specific pixel locations. The camera will then apply a corrective process to the isolated dust locations with adjoining exposures by interpolating these distinct locations for each specific image configuration.

In another embodiment of the present system, "hot" (too bright) or "dead" (too dark) pixels are interpolated out of the scene using the method described above. Unlike hot or dead pixels, dust is a similar but temporary version of the same problem of an artifact that requires in-camera modification. In effect, a map is built to discover, isolate and interpolate bad pixels, which are a permanent problem revealing a key limit in digital sensor technology. Separate maps are constructed for permanent pixel dysfunctions and temporary pixel aberrations (viz., dust). In both cases, the camera works from these maps to correct the aberrations on a pixel-level.

In a further embodiment of the present system, Monte Carlo analysis is applied to the problem of identifying the location of dust on specific pixels (or partial pixels) by randomly creating an initial map from information of at least two contaminated images.

In still another embodiment of the present system, the process of modifying pixel aberrations (either permanent or temporary) uses a sequence of operation which begins by correcting the major aberrations first, then repairing the minor aberrations, thereby maximizing efficiency. This is done by starting the corrective process in a specific location of the image and moving to other positions in an efficient pattern.

(8) Sequence of corrections for multiple (optical and digital) types of aberrations in camera

Since it is evident that multiple digital filtration approaches may be used for specific types of problems or aberrations or to achieve specific effects, it is clear that a combination of the techniques may be employed simultaneously on specific images. The present invention allows the various optical and digital corrections to be performed in camera in a sequence of actions. The user selects the various combinations of functions required to be performed, inspects the effects, and chooses the most effective combination of effects. Thus the invention offers a combinatorial optimization of the totality of corrective filtration approaches.

After the images have been taken, it is possible to inspect them in the camera using the camera's image read-out. This makes it possible to create new files, or to adapt a RAW file, in real time, by manipulating the various corrections in sequence. This post-image-capture in-camera editing process allows multiple corrections to be applied to a range of optical and digital aberrations by combining various specific corrective techniques.

In some cases, the user can pre-set specific corrections. For instance, to correct for optical aberrations, a user may leave this function on permanently. In other cases, such as

selective filtration of a specific object or optimization for DOF or exposure, there may be discriminating use of specific corrective functions. In the case of selective user choice, it is possible, by using the present invention, to select a priority sequence of corrections in layers. While specific select layers may be permanently activated, for example to automatically adjust specific optical aberrations, additional sets of layers may be manually selected in order to modify the specific aspects of each image, particularly to adjust or correct digital aberrations. This process can be performed with a single microprocessor, multiple microprocessors, multiple ASICs or a combination of microprocessors and ASICs.

An additional embodiment of the system provides multiple combinations of corrections and effects via multiple independent ASICs, which only perform specific functions, working in parallel. The various tasks are divided into specific-function ASICs for rapid processing. The advantage of this approach is accelerated processing speed in performing multiple simultaneous functions.

(II) Digital Sensor Improvement and Nano-grids

(9) Interchangeable digital sensor system using both CCD and CMOS to optimize best results

Because the main digital sensor types of CCD and CMOS, like film types, each have benefits and detriments, it is sometimes advantageous to provide the utility of both sensor types in a camera system. With the exception of a video camera, which employs three CCDs, the use of multiple sensors has not been adopted. Two generations ago, however, the idea of using a twin reflex camera for medium format photography was implemented. In this case, though focus was coupled between the lenses, one lens was used to see the subject, while the other lens took

the picture. This method was used to obtain the benefits of a rangefinder camera with a single lens reflex camera.

The use of two types of sensors in a camera is compelling, because the user benefits from the strengths of both. In the present invention, one sensor is selected from among at least two different types of sensors that are rotated to an active position by the user. One advantage of this approach is that if one sensor experiences a problem, there is a reserve sensor available at the push of a button.

This capability usefully exploits the strengths of each particular sensor. For instance, in situations in which high resolution is required, a CCD may be preferable, while in cases in which increased tonal range or low noise is preferable, a CMOS sensor may be preferable. With this approach, a customer does not need to choose between different types of sensors.

The process of interchanging the two chips is performed by placing the two chips on either façade of a plane that "flips" over (i.e., rotates 180 degrees) upon demand to obtain the requirements of the chosen chip type. This mechanism would fit behind an SLR's mirror and could easily be performed as long as the mirror is in the "up" position. In another embodiment, the chip exchange process can occur by sliding alternating chips into a sleeve from a single location and replacing the non-utilized chip(s) into the reserve compartment. In either event, the camera will detect the chip exchange and will automatically reprogram software functions and settings for the usable chip.

(10) Nano-grids for selected pixels on CCD or CMOS integrated circuits to optimize selective modifications of exposure, ISO and aberrations in digital photography

Digital sensors consist of arrays of pixels, arranged in rows, which behave as tiny buckets for converting photons to electrons. As the pixels fill up with light, they are able to discern slight differences in color and exposure and transfer the energy, in the form of electrons, to storage.

Charge coupled devices (CCDs) have been the predominant form of digital sensor because they use a form of electronic charge which creates the behavior of a bucket brigade of transferring data, once the buckets in a row are filled up, to successive rows for digital data storage of the electronic charge sets. CMOS digital sensors may be structured with larger bucket pixels, which can increase the depth of the light captured and thus the latitude of light exposure that is stored. However, for the relatively larger buckets to provide increased photon capture capacity, it is necessary to control the width of the opening in the top and the width of the buckets so that the amount of light captured may be modulated.

The present invention introduces a key advance in the ability of digital sensors, particularly CMOS sensors, to modulate the size of the openings of the pixels. Specifically, the present system provides for a nano-grid, or a very small matrix of filaments, which fits over the sensor. The nano-grid is carefully calibrated to match the rows of pixels on the sensor so as to limit the amount of light that each of the buckets may receive. Use of the nano-grid allows a selective closing of the large buckets in order for photons to be restricted. Selective modification of specific pixels on the neutral grid makes it possible to identify specific sets of pixels to correct for various exposure or lens aberrations.

In this embodiment of the present system, data about a specific lens are provided to the camera in order to correct specific lens aberrations, while exposure data is used to modify image capture using nano-grids for optimum image performance.

Nano-grids may be selectively switched at different pixel sites, akin to continuously programmable field programmable gate array (CP-FPGA) semiconductors, which modify architecture in order to optimize effective operation by constantly manipulating the chip's gates.

Nano-grids may be used for specific image modes, for example, nocturnal imaging, which requires more time to read a sufficient amount of light. In this case, a specific software module may provide lens and exposure data to the camera, which then determine the precise composition of nano-grid correction to provide to specific sets of pixels on the digital sensor. In effect, nano-filaments move to positions to effectively block out the full capacity of the pixel buckets and thus change the pixel effects. With use of preset nano-grid positions for particular applications, the identification of specific vectors of nano-filaments is performed, and exposure adjustments are made on specific images in hardware.

The nano-grid is overlaid over the surface of the pixel architecture. The nano-grid is used not only in specific pre-set positions, but it also provides feedback to the post-capture system for analysis and repositioning to achieve the desired effects. One effect of the nano-grid is to manually expand or narrow the range of a set of pixel buckets; this process in turn effectively modifies not only the exposure range but also sharpness at high ISO, thereby dramatically reducing noise. Consequently, it becomes possible, by modifying the pixel bucket width and height, to obtain extremely sharp images with excellent contrast and tonal range even in poor lighting, a feat heretofore impossible.

The nano-grid performs these mechanical functions by moving the nano-filaments in an arc, like expandable windshield wipers. Though nano-grids are particularly useful in CMOS chips, they are also useful with CCDs. In fact, with the advent of nano-grids, CCD pixel size (and density in pixel-rows which will affect the overall sensor size) may be expanded and thus made substantially more versatile.

In a further embodiment of the present invention, multiple screens, or grids, would be placed over the digital sensor. The use of multiple nano-grids provides increased capacity to

perform the function of closing off the pixel buckets and, in fact, to completely close off selected pixels to make the image effect completely dark. The combinations of nano-grids behave as multiple screens that move left and right to achieve the desired effect. Although there is a need to periodically calibrate the screens to effect their precise positions, this system will employ an electric charge to push the nano-filaments to the desired locations.

Nano-filaments move to block the space allowing photons to hit the pixel in order to limit the amount of light capacity available to the pixel. The complete darkening of the pixel will result in a total black color in the resulting image.

Exposure data feedback is provided to the digital sensor to effect the precise positioning of the nano-grid(s). In a further aspect of the present system, the camera's computer will anticipate the exposure data by statistically extrapolating from the pattern created by at least three data sets. A microprocessor (or ASIC) controlled nano-grid mechanism will use the feedback to anticipate specific nano-grid positions in order to optimize the exposure and corrective functions.

In one application of the nano-grid, the problem of vignetting in wide-angle lenses may be solved by activating nano-filaments in nano-grid(s) primarily in the corners to correct for the darkening from the limits of the optical aberrations, while still maintaining very low noise in a high ISO (low light) photographic situation. The use of the nano-grid would thus contribute to solving multiple problems.

Nano-grids will also be useful in accurately correcting for both color and exposure detail. In fact, with nano-grids, the capacity of digital sensors' range should be substantially increased, because the chips' pixel bucket sizes can be modulated. Therefore, not only will the lighting and

color be accurate, but sharpness and optical aberrations will also be optimized, in ways not possible before.

(11) Integrated nano-grids in digital sensor

In a further embodiment of the system, nano-grids may be integrated into the digital sensor. In this form of the nano-grid, the nano-filaments are constructed *within* the pixel buckets in order to increase their accuracy and responsiveness. The nano-filaments mechanically move in various directions to perform the main operation of modulating light into their respective pixels. This method of organizing nano-grids and nano-filaments increases the rapidity of response to feedback. In effect, each pixel has a mask, or flexible lid, contained in it, which may open and close, to allow more or less light into the pixel bucket.

The integrated nano-filaments are activated by oscillation between positive and negative charges. In the context of a CMOS sensor, the transistor networks oscillate between positive and negative charges. This architecture allows a "push-pull" design of nano-filaments in which the negative charge "pulls" and the positive charge "pushes" the activation of the nano-filaments. This charge-enabled nano-grid (CENG) advantageously allows modulating gates (i.e., filaments) integrated into the pixel to reduce spaces between pixels, thereby allowing more pixels to be packed on the same surface area. The net benefit of the use of integrated CENG filaments is that specific sets of nano-filaments will produce specific effects on-demand and allow far more tonal detail than has been possible before.

In a further embodiment of the present system, sophisticated digital sensors may contain combinations of nano-grids that appear on top of the sensor as well as nano-grids that are integrated into the digital sensor. This combination will provide maximum latitude for processing the greatest effect available.

(12) Combinations of nano-grids and digital corrections applied to digital imaging system

Whereas it is possible to exclusively implement nano-grids to control the amount of light penetrating specific pixels, and it is possible to exclusively provide digital corrections as specified above regarding correcting optical or digital aberrations, a further embodiment of the present invention combines the two processes in order to optimize imaging.

Combining these two complex processes makes it possible to modify pixel capacity to maximize exposure latitude, to expand exposure modification and to apply digital correctives for optical and digital aberrations. Hence selective exposure far beyond the limits of present film or digital photography is made possible. The restrictions of film can thus be transcended by using the present system, whereas use of a static and limited digital system would not be sufficient to facilitate these complex corrections.

The unique combinations of these processes also illustrate a complex system that provides feedback from both the environment and the photographer. The photographer may select preset exposure settings that will activate a range of options in both the nano-grids and the digital corrective system, while the lens aberration corrective system is automatically implemented. Once the camera detects specific conditions, such as a broad range of exposure latitude, from very bright to very dark, in the scene, it computes the precise number and location of nano-grids needed to modulate the pixels for optimum exposure with highlight and shadow detail and extreme sharpness, even in relatively low light. The dynamics of these multiple processes present trade-offs in selecting the best available set of selected modifications.

(13) Tri-well pixels

As indicated above, one of the key problems with current digital sensors involves dynamic range. There is a need to limit the scope of the space in the pixel well, into which light

is captured, then converted into electrons. The challenge with current technologies is to balance details in shadow and highlight areas, particularly to acheive low noise at relatively high ISO speeds.

In addition to the concept of nano-grids, both in surface screen and integrated embodiments, as specified in (10) to (11) above, the present system introduces the notion of three side-by-side differentially-sized buckets within each pixel intended to optimize dynamic range for increased sensitivity. In the most common configuration, the three different-sized buckets are arranged with the largest bucket (in both width and height) in the center, with the second and third largest buckets on either side. The buckets are elliptical and concave in architecture to increase efficiency of fitting together in a round pixel structure. Their structures are semi-circular and elongated. The largest and tallest bucket will be tasked with maintaining the details in highlights, and the smallest will be tasked with maximizing the details in shadows, while the mid-sized bucket will be tasked with maintaining the middle range of exposure details. The pixel will have data from all three buckets available, but will select the data from one or more buckets depending on the exposure details.

The system is analogous to the high fidelity sound technology in speakers with crossovers, whose several frequencies are used by the tweeters, mid-range(s) and woofers; the crossover point at which the frequency changes from one component to another can be modified based on the specific mechanics of each component.

In the case of the multiple buckets in a single pixel, the buckets are connected by filaments to a central grid which captures and stores the electrons. When the photographic scene displays increased light, image data from the larger buckets are selected to be recorded by the processor, while in cases of darkness and increased need for sensitivity, the smaller buckets are

selected to be recorded; the mid-sized bucket is used in normal light situations of most cases. Further, this multi-aspect architecture can use pixels in varying positions on the sensor differently, particularly to facilitate processing far more dynamic range and to produce uniform tonal range in scenes that vary more than two or three stops. This novel multi-aspect model solves a number of key problems involving exposure dynamics in digital photography.

In another embodiment of the system, there may be more than three buckets in a pixel, so as to divide out the functions further and create even finer tonal continuity. In a further embodiment of the system, several pixels in a super-pixel allow red, green and blue colors to be segregated by each sub-pixel. This approach will be useful particularly in CCD semiconductors because of limits of this architecture, which require coupling circuitry between pixels to pass a charge between rows of pixels. In this case, outputs will vary between the micro-pixels to facilitate the differential processing required.

While cases of two side-by-side pixels might solve these exposure latitude problems, they represent an inadequate solution, much as a speaker with only two components limits the dynamic range output dramatically in contrast with a speaker with five components. This is similar to comparing a diode and a transistor.

(III) Digital System Improvements that Link Multiple Digital Corrections

(14) Auto pre-programmed modules for specific functions in digital imaging system

To process the functions specified in this integrated digital imaging system, it is necessary for automated pre-programmed modules to detect the specific lens type and the specific digital sensor(s) used to assess the appropriate corrections or alterations. The purpose of the pre-programmed modules is to access a preset library of (a) typical corrections of lenses, (b)

typical scene types with appropriate exposure modes, (c) specific effects that may be selected and (d) specific sensor functions. It is important to match a particular lens to a particular sensor type so that adjustments are calibrated to this pairing. The processing software is stored in either a microprocessor or an ASIC in order to process the images after they are captured by the sensor but before they are transferred to storage on a memory device.

In another embodiment, the system processes image corrections after the digital data is stored and constantly accesses the original stored data file in the production of a corrected file. This process allows for immediate data processing and storage which affords more time to accomplish specific corrective functions. There are thus cases when real-time correctives are neither necessary nor possible. Such increased processing capability may also facilitate a more complete corrective task.

In an additional embodiment, because similar correctives and effects may be provided to images that share the specific combination of lens and sensor, in order to accelerate the process of optimizing the images, batches of similar images may be processed together. This batch processing method may include the creation of duplicate images for each image captured, including a RAW image that contains no changes to the native image capture and a simultaneous auto-corrected image. The optimized image may be simultaneously compressed, to maximize storage capabilities, while the RAW image may be left uncompressed so as to maintain original detail.

(15) Apparatus and process for affecting pre-sensor optical and digital corrections in digital imaging system

Given the nature of light transmission, not all optical corrections are optimized by modification after the image is captured by the sensor. Though a range of important corrections and effects may be made after image capture, such as correction for optical or digital aberrations,

there are several types of corrections that are required to be made before the light reaches the sensor. One example of this pre-sensor digital correction involves the use of a low-pass or anti-aliasing filter that resides in front of the digital sensor to minimize moiré and aliasing digital problems (although the use of this filter adversely affects image sharpness).

In the case of optical corrections, one class of filter that requires use before the digital sensor is the polarizing filter, because once light is captured on the digital sensor, the polarizing effect will not be available. Another type of correction that involves use of a filter or lens before the digital sensor is the close-up filter. This latter solution allows a lens's closest focusing plane to be closer to the front of a lens and has the effect of diminishing the rear plane of the depth of field. The close-up filter may be optimized for use with floating rear-element group lenses which allow increasingly close focusing. In one embodiment of the system, specific pre-sensor optical filters may be used to provide polarization and close up corrections. The use of in-camera optical (circular) polarization would help standardize this valuable process and eliminate the need to maintain several external polarizer filters for each lens mount.

Since the present system entails an embodiment which uses nano-grids to perform specific exposure modifications before the light hits the digital sensor, it is possible to use these nano-grids for the applications of polarization and close-up filter. These filtration capabilities occur between the lens and the digital sensor.

In order to optimize the use of pre-sensor filtration, an image is initially tested and analyzed before the optimized corrections are activated and the pre-sensor changes are made. This process is analogous to the use of automated flash photography in which a feedback mechanism is provided; a scene is evaluated, and the initial flash data analyzed and modified to correspond to the correct exposure before a final flash is produced.

Because the camera system processes post-capture data, in order to optimize images for optical and digital problems, as well as continuously makes changes to pre-sensor filtration, multiple ASICs work in parallel to make the conversion of the image after capture. The use of parallel ASICs to perform specific correction processes solves the problem of capturing images and making post-capture corrections while simultaneously adapting the pre-sensor filtration system.

As an alternative embodiment of the system, a microprocessor (and software) may perform specific pre-sensor adjustments while the ASIC(s) performs specific corrective functions. In another embodiment, the ASIC(s) may perform the specific pre-sensor adjustments while a microprocessor (and software) will perform the specific corrective functions.

(16) Integrated digital imaging system for optical and digital corrections with feedback dynamics

Because the present system consists of, and uses, complex sub-systems, including an auto-focus mechanism, an auto-exposure mechanism, a shutter mechanism, an automatic flash mechanism, a digital sensor mechanism, a digital processing mechanism and a digital storage mechanism, it is possible to realize interaction dynamics that contain feedback. The interactive process of operating these sub-systems involves a learning progression. The image is analyzed, solutions are tested and an optimal solution is selected and implemented, all in real time. By choosing a specific logic vector in a decision tree involving an initial variable, the process begins again with another key variable in real-time until the final image is captured and optimized.

In order to accomplish these complex processes, specific variables, such as aperture data, shutter speed data, lens data, digital sensor data and subject type are registered and analyzed by the camera. As environmental data changes, the camera mechanisms adapt to the environmental and the photographer's situation.

In order to accelerate these processes, the camera learns to anticipate the user's behaviors, the user's preferences and the subject's behaviors. By providing user-adjusted setting modifications for optical and digital corrections, the camera establishes a reference point for processing rapid image changes. In particular, the camera's software will analyze trends in the user's pattern of behaviors and preferences as well as pattern changes in the subject's behaviors. Anticipation processes are programmed into the autofocus and automated flash systems because of the extremely rapid reaction-time requirements of these specific mechanisms.

In one embodiment of the system, a method of processing a chain of rapid image captures is to employ computer-caching techniques in which a first image is processed in a normal way while later images are processed in an accelerated way. This is possible because the first image provides data to the system to analyze; these data then allow the system to anticipate further similar images and to use similar auto-focus and auto-exposure data. The optical and digital corrections are performed in a batch fashion by applying similar changes to near-identical image problems in order to dramatically accelerate the processing speed of a chain of images. This caching and anticipation approach is very useful in fast-paced action photography.

Another embodiment of the process of rapidly capturing a chain of images in sequence employs multi-threading techniques. Dividing the functions between specific subsystem ASICs allows multiple corrections to be performed in a parallel cascade for efficient task completion. One advantage of breaking down functions to specific processors is the acquired ability to start on one function and, while the system is in the process of completing a task, to begin other tasks. This process eliminates the lag between the specific subsystems.

(17) Adaptive user pattern learning with user-programmable functions in digital imaging system

In order to optimize its functions, the camera needs to learn about the user's preferences. When the user uses the camera, the camera evaluates the use patterns. Since the camera is programmed with a database of common user patterns, it can identify common uses and anticipate common uses of similar users by employing a "collaborative filtering" mechanism (i.e., if you like this camera setting, you should like this other setting because similar users who have liked the first setting have also liked the second setting). By anticipating common uses of each camera user, the camera optimizes its functions for each use and for each user. In effect, the camera's learning of user preferences is a sort of guided process of experimentation. Evolving algorithms learn about the user from actual use patterns.

One positive effect of this learning process of the camera about the user's patterns of behavior is that the filtration process becomes adaptive. The camera builds an initial map of the user's preferences from the user's actual selections. From the starting point of common types of personal selections, the camera uses standard templates of main types of uses that are fulfilled for each user's applications. For instance, if a photographer typically takes portraits with a traditional portrait lens, the camera will be aware of this and will activate filtration processes that are optimal for this type of portraiture photography, such as instilling limited depth of field on a subject and out-of-focus foreground and background. Contrarily, if landscape images are selected, depth of field will be increased substantially and the lens focused on either infinity or a medium point depending on the specific type of subject matter. The camera builds a model for each user based on the accumulation of experience.

In order for the camera to learn about the preferences of a specific user, the camera must adjust to each particular user, much as each individual identity must log onto a computer network privately.

Since the dynamics of the combined subsystems are complex, and adaptive, it is necessary that automated adjustments be interactive. Once detection of the lens type, the sensor type, the exposure settings, the user and the subject is made, optical and digital distortions are identified and specific combinations of corrections are applied both before and after the digital sensor in order to optimize the image. All of this is accomplished in less time than the blink of an eye.

(18) Software privacy function in digital imaging system

Because digital camera systems are able to use software and wireless mechanisms for their operation, it is possible to activate aspects of the camera remotely. Conversely, it is possible to disable operations of the camera remotely.

The present invention embodies a capability to externally disable the camera remotely in specific locations that require privacy, such as secret government areas (courthouses), private homes or businesses that are image-free zones. In these cases, a signal from an external source is provided to disable the shutter from firing. This black-out capability will allow external control of access to specific sites. As a condition of access, only a camera with this feature may be admitted to public buildings, so that even if the camera is permitted to operate, permission is only conditional. For instance, the owner of the building may allow the camera to function only in a specific set of rooms but not in others. Cameras without this feature may not be allowed in private spaces where control must be externally restricted.

This blocking feature will require the addition of specific blocking software, which may be automatically downloaded as one enters specific buildings. Similarly, in order to be granted permission to access the camera, or specific functions of the camera, the downloading of a "key" may be required.

Moreover, a further embodiment of the system may make it necessary to download software keys to get access to filtration capabilities in the camera in order to obtain optimum images. For example, the user may be required to pay a fee to download software in real time that will permit her to access a particular function in the camera to obtain a critical image. A spectrum of quality and complexity in filtration capabilities may be made obtainable for a range of fees on-demand. Therefore, the external downloading of software for the camera need not be limited to a black out function.

(IV) Dynamic Digital Imaging System Improvements that Apply to Zoom Lenses and Video Imaging

(19) Dynamics of zoom lens corrections in digital imaging system

Whereas the optical aberrations of prime (fixed focal length) lenses were discussed above, the modulation of optical aberrations of zoom lenses is another problem to consider. As a wholly different species of lens, zoom lenses have become extremely complex optical mechanisms consisting of multiple groups of lens elements. The general problem with zoom lenses is the trade-off that must be made: To minimize the distortions of the widest possible focal length, distortions become maximized at the longest possible focal length, and vice-versa. Consequently, zoom lens architecture is inherently compromised on image quality. Over the years, lens designers have developed lens formulas that have dramatically improved image quality and that compete with typical prime lenses. As an example of this evolution in quality,

the class of 70-200 f/2.8 35mm zoom lenses, now in their sixth generation, has supplied substantial improvements over earlier telephoto zooms. However, in general, zoom lenses have more aberrations than primes and thus require increased optical corrections. The need to solve the problem of zoom lens aberration correction is accentuated by their increased use in photography because of their simplicity and versatility.

The dynamics of the zooming process present specific difficulties for the purposes of correcting optical aberrations in digital imaging systems. With fixed-focal length lenses, the camera can detect the lens and provide an immediate consistent modification for a varying range of apertures. In the case of zooms, however, where the focal-length is not fixed, the adjustments must correlate to the changes in the focal length. In effect, this condition presents a continuous resampling process. When combined with changing scenes, the zooming process requires far faster responses to changing inputs by the camera system. This process resembles the tracking of a kaleidoscope's changing image structures as the wheel on the device is constantly turned.

In order to solve the problem of distortion at the wide-angle part of select zoom lenses, manufacturers have been using aspherical elements which are complex shapes that require special production techniques. On the other hand, in order to solve the problem of chromatic aberration in select telephoto lenses, manufacturers have used extra low dispersion glass elements, particularly at the front of the zoom lens. Since there are generally three main classes of zoom lenses – wide-angle to wide-angle, wide-angle to telephoto and telephoto to telephoto – aspherical elements have been used in wide-angle zoom lenses, while extra low dispersion glass has been used in the telephoto zoom lenses and both kinds of lens elements have been included in the wide-angle to telephoto zoom lenses.

The changing focal lengths of zoom lenses add a variable to the complex set of variables of the interacting sub-systems in the digital imaging system. The digital camera system must therefore track the movement of the changes in the focal lengths in zoom lenses and continuously make modifications to the varied optical aberrations in these types of lenses. Unlike in fixed focal length lenses, the aberrations change at different focal lengths in zoom lenses, and the camera must track these changes.

The present system is designed to make the corrections to these changing aberrations in zoom lenses by noting the changed focal length at specific times of each lens. For a fixed focal length lens, the camera refers to a database of information to provide information to correct specific types of aberrations; for a zoom lens, the camera's database contains multiplex information for each focal length in each respective zoom lens type. This is as if each zoom lens contains a combination of multiple lenses of specific focal lengths. When the zoom is moved to a new focal position, the camera reads the lens as a specific focal length and makes corrections to aberrations based on this specific setting. Although the camera reads the zoom lens at a specific moment in time and adjusts the necessary modifications to correct for aberrations at that specific focal length at that time, overall the zoom lens requires the camera to rapidly make these adjustments.

Since zoom lenses employ dynamic processes of change, it is possible to track a moving subject in real-time by changing focal length from a stationary vantage. These changed focal length positions are tracked by the auto-focus system, but also by the auto-exposure system in the camera. The present system thus allows for zoom tracking in order to anticipate the direction of zoom lens changes, much as the focus on the moving subject involves focus tracking mechanisms. These systems use fuzzy logic and evolutionary algorithms to anticipate the

movement of the subject and thus of the focal length change of zoom lens. In this way it is possible to accelerate the lens aberration correction process using zoom lenses.

Because the zoom lenses typically increase aberrations precisely because of the lens design compromises, these types of lenses are ideally suited to the present digital imaging system. The present system allows the zoom lens to be used at high quality without needing to stop down the aperture, thereby resulting in superior photographic opportunities.

(20) Dynamic changes in video corrections of digital imaging system

While the zoom lens presents the need to provide a dynamic solution to the process of making corrections to optical aberrations, video photography provides another case of a process that requires dynamic solutions. The same principles that apply to still photography apply to video; auto-focus variability, aperture and depth-of-field variability aspects, shutter speed variability aspects, differences in lens focal length and artificial lighting variability suggest that video be viewed as merely a very rapid (30 to 60 frames per second) application of still photography. Nonetheless, video presents new classes of dynamic problems, most notably regarding the matter of tracking changing subjects in real time.

The process of shifting subject positions, even if the camera is stationary, presents a change of multiple variables that require the automated subsystems (auto-focus, auto-exposure, auto-flash, etc.) to be integrated. Feedback is presented by subjects in the external environment with changing focus and exposure variables. In these cases, even with a modulating shutter speed, the three main variables of change are a zoom lens to continuously change the focal length, auto-focus to track a subject and aperture modifications to continuously change depth-of-field.

The unique dynamics of these complex sub-systems presents particular challenges for a digital imaging system to produce rapid results with the use of advanced ASICs and microprocessors. By incorporating techniques that track objects with advanced auto-focus mechanisms, anticipate zoom lens changes and predict optimal exposures as well as make automatic corrections to both optical and digital aberrations in real time, the present system continuously optimizes the video imaging process.

(21) "Stationary-scene object-motion" caching process, with application to video, in digital imaging system

Because video imaging processes employ full motion activity, particularly of subjects in the environment, tracking a subject in a video system is problematic. Once a subject is identified and selected, the subject is automatically tracked with auto-focus and auto-exposure mechanisms by a zoom lens apparatus. There is a particular need to identify and track a subject within a broad stationary scene.

The present system accomplishes this task by using anticipatory object-trajectory tracking. The parts of the stationary scene that are not being tracked are cached. In other words, precisely because the background of the scene is stationary, this part of the scene is not tracked for focus or exposure. On the other hand, the object in motion is identified and tracked by subtracting the extraneous data of the stationary scene. Multiple objects are tracked by comparing data about these combinations of objects and their relations and determining the appropriate exposure and focus settings.

While Monte Carlo processes use random settings to self-organize an initial map, which are useful as a baseline for the purpose of anticipating tracking data sets, the present system subtracts the known information about the specific object(s) being tracked from the stationary background in the environment. In other words, the background data is "blanked out" in a

caching process while the main subject(s) are tracked. By so using these techniques, the camera system can efficiently calculate the modifications needed to optimize the video scene.

In a further embodiment of the system, a chip-set is enabled in video display devices (i.e., video monitors) to implement select corrections for optical and digital distortions. The user may modify settings for automating the process of achieving optimum video images.

(V) Digital Image Network Aspects

(22) Network coordination of fixed sensor grid to track multiple objects in digital video imaging system

While the previous discussion has focused on employing a single camera to capture images, the present system is also useful for networking sensors in a sensor grid in order to track multiple objects. Specifically, the present system may be used in surveillance and reconnaissance situations to track objects over time. Using a grid of image sensors with overlapping range parameters makes it possible to organize a complex network of sensors for surveillance activities.

After selecting specific objects to track, the system follows the objects as they move from location to location, appropriately modulating the focus, the lens focal length, the ISO and the exposure settings. As the subject moves from one section of a grid to another, the sensors are coordinated to "hand off" the object to other sensors on the grid, much like a cellular phone network hands off calls between cells.

In another embodiment of the present system, the cameras in the network may be mobile instead of stationary in a fixed sensor grid. In this case, self-organizing aspects of the mobile sensor grid track mobile objects in real time. One application of this complex system, which draws on earlier work in collective robotics, is in cinematography, which requires multiple

transportable perspectives of mobile subjects. The complex dynamics of a mobile sensor network provides complex feedback in this manifestation of the present system.

(23) Automatic wireless off-porting of back-up images to external data bank

Because the present system uses digital files, it is possible to move these files to an external site for storage. The present system has capabilities to off-port images to an external data bank automatically. This feature is valuable in order to preserve on-board storage capability.

Whether implemented in a local area network (LAN) or a wide area network (WAN), by using a built-in wireless router, the present digital imaging system may be set to send data files directly and automatically to hard-drive storage either in a device in the same room or uploaded to the Internet for storage around the world. This capability is critical for managing massive files of large sensor data sets and preserving valuable in-camera storage space. When automatically sending data files to a nearby computer, the computer may act as a data-port relay to automatically resend the images to an Internet site for storage. The system will maintain the option of keeping some images in the camera and sending duplicate copies of digital files of images to another site for storage as a backup. This automatic back-up process provides insurance for the photographer.

In another embodiment of the system, just as image files are off-loaded to external storage, software files are periodically downloaded to the camera in order to update the camera settings and the database system. For example, as the camera manufacturer provides new lenses for the camera, it becomes necessary to load new updated settings to accommodate corrections for the new lenses. Similarly, as the camera requires new software updates with improved algorithms to further optimize the corrective functions of both the optical and digital

mechanisms, the camera will automatically accept these. This feature is particularly important to both manufacturer and user because the ability to update software capability periodically will protect a user from needing to upgrade major hardware such as with a lens replacement.

(24) Image organization system

The present digital imaging system does not merely allow for the storage of image data files on external storage. Because of the problems of protecting storage and the need to make multiple back-ups in the digital sphere, it is also necessary to store digital image files in multiple database locations. The images are organized in a main database by various criteria, such as time, location, subject-type, etc., and then rerouted to various locations around the world for safe storage. While specific sets of images may be stored together, the need to identify the locations is less important than the need to have control of the main database list which identifies the locations.

In order to maintain security, the digital imaging files may periodically be rotated randomly between locations. Only the main database list, which is constantly updated, maintains information on their location. In fact, specific digital bits of a single image may be maintained at different locations in order to maintain further security. Thus, on many computers around the world bits of each image may be stored, and continuously rotated, with constantly updated registries maintaining their complex hybrid whereabouts. These rotation storage functions are performed by a randomizer logic engine.

In a further embodiment of the present system, once the digital files are off-loaded from the camera system to external storage, specific images may be automatically identified and further specific corrections automatically provided.

In yet another embodiment of the system, the images that are off-loaded from the camera to the external storage system are organized according to various criteria, such as accuracy of focus or exposure or quality of image type, in order to be automatically prioritized. The camera, with the assistance of an initial setting of user priorities, will automatically order new images with a higher or lower priority relative to other images and camera settings. Thus, at the end of a day, the images may be displayed in an order preferred by the user. Lesser images will be automatically routed to a lower position as they do not meet specific criteria, and better images will be routed to a relatively higher position in the organization of files. This feature of automatically assisting in the organization of the digital image files is a very useful one which will save photographers time.

(25) Wireless digital image system automatically generating prints from image capture

The present digital imaging system not only automatically off-loads digital image files to remote locations for storage; the system also will allow one to photograph an image (or sequence of images) in one location (i.e., Paris) and instantly print it in another location (i.e., Los Angeles) for publication in real time. In addition, an image may be captured by the camera and instantly uploaded to a pre-programmed Web site for publication by using wireless technologies. In addition, it is possible to automatically print the digital image file anywhere in the world virtually the moment the image is taken. This system makes this instantaneity particularly possible precisely because the image corrections are automated in-camera. Since there is no need in most cases to further edit the image files, they are thus generally ready for immediate release.

Reference to the remaining portions of the specification, including the drawings and claims, will realize other features and advantages of the present invention. Further features and

advantages of the present invention, as well as the structure and operation of various embodiments of the present invention, are described in detail below with respect to accompanying drawings.

It is understood that the examples and embodiments described herein are for illustrative purposes only and that various modifications or changes in light thereof will be suggested to persons skilled in the art and are to be included within the spirit and purview of this application and scope of the appended claims. All publications, patents, and patent applications cited herein are hereby incorporated by reference for all purposes in their entirety.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	25130-11823
	Application Number	
Title of Invention	Digital Imaging System	

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Application Information:

Title of the Invention	Digital Imaging System		
Attorney Docket Number	25130-11823	Small Entity Status Claimed	☑
Application Type	Provisional		
Subject Matter	Utility		
Suggested Class (if any)		Sub Class (if any)	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)		Suggested Figure for Publication (if any)	

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	25130-11823
	Application Number	
Title of Invention	Digital Imaging System	

Publication Information:	
☐	Request Early Publication (Fee required at time of Request 37 CFR 1.219)
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Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	25130-11823
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Signature	/Daniel R. Brownstone 46,581/			Date (YYYY-MM-DD)	2006-07-11
First Name	Daniel	Last Name	Brownstone	Registration Number	46581

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Application Number:	60807065
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First Named Inventor:	Neal E. Solomon
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1	Specification	25130_11832_Specification__Provisional_.pdf	219173	no	55
Warnings:					
Information:					
2	Application Data Sheet	25130_11823_US_ADS_Form_SB_14.pdf	2222971	no	4
Warnings:					
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3	Fee Worksheet (PTO-875)	fee-info.pdf	8079	no	2
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		Total Files Size (in bytes):	2450223		

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

ABSTRACT

A system is disclosed for the automated correction of optical and digital aberrations in a digital imaging system. The system includes several main parts, including (a) digital filters, (b) hardware modifications, (c) digital system corrections, (d) digital system dynamics and (e) network aspects. The system solves numerous problems in still and video photography that are presented in the digital imaging environment.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY
(Chapter I of the Patent Cooperation Treaty)

(PCT Rule 44*bis*)

Applicant's or agent's file reference 13241 PCT	**FOR FURTHER ACTION**	See item 4 below
International application No. PCT/US2007/015544	International filing date *(day/month/year)* 07 July 2007 (07.07.2007)	Priority date *(day/month/year)* 11 July 2006 (11.07.2006)
International Patent Classification (8th edition unless older edition indicated) See relevant information in Form PCT/ISA/237		
Applicant SOLOMON, Neal		

1. This international preliminary report on patentability (Chapter I) is issued by the International Bureau on behalf of the International Searching Authority under Rule 44 *bis*.1(a).

2. This REPORT consists of a total of 8 sheets, including this cover sheet.

   In the attached sheets, any reference to the written opinion of the International Searching Authority should be read as a reference to the international preliminary report on patentability (Chapter I) instead.

3. This report contains indications relating to the following items:

☒	Box No. I	Basis of the report
☐	Box No. II	Priority
☐	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
☐	Box No. IV	Lack of unity of invention
☒	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
☐	Box No. VI	Certain documents cited
☐	Box No. VII	Certain defects in the international application
☐	Box No. VIII	Certain observations on the international application

4. The International Bureau will communicate this report to designated Offices in accordance with Rules 44*bis*.3(c) and 93*bis*.1 but not, except where the applicant makes an express request under Article 23(2), before the expiration of 30 months from the priority date (Rule 44*bis* .2).

	Date of issuance of this report 13 January 2009 (13.01.2009)
The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No. +41 22 338 82 70	Authorized officer Athina Nickitas-Etienne e-mail: pt04.pct@wipo.int

Form PCT/IB/373 (January 2004)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
NEAL SOLOMON
P.O. BOX 21297
OAK LAND, CA 94620

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Applicant's or agent's file reference	Date of mailing (*day/month/year*) 26 AUG 2008 **FOR FURTHER ACTION** See paragraph 2 below

International application No.	International filing date (*day/month/year*)	Priority date (*day/month/year*)
PCT/US07/15544	07 July 2007 (07.07.2007)	06 July 2007 (06.07.2007)

International Patent Classification (IPC) or both national classification and IPC

IPC: **H04N 5/76**(2006.01) H04N 5/225(2006.01)
USPC: 348/231.99,340

Applicant

SOLOMON, NEAL

1. This opinion contains indications relating to the following items:

- ☒ Box No. I — Basis of the opinion
- ☐ Box No. II — Priority
- ☐ Box No. III — Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV — Lack of unity of invention
- ☒ Box No. V — Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI — Certain documents cited
- ☐ Box No. VII — Certain defects in the international application
- ☐ Box No. VIII — Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(*b*) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA/ US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450	04 August 2008 (04.08.2008)	David Ometz
Facsimile No. (571) 273-3201		Telephone No. (571) 270-1131

Form PCT/ISA/237 (cover sheet) (April 2007)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US07/15544

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:

☒ the international application in the language in which it was filed

☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a))

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of:

a. type of material

☐ a sequence listing

☐ table(s) related to the sequence listing

b. format of material

☐ on paper

☐ in electronic form

c. time of filing/furnishing

☐ contained in the international application as filed.

☐ filed together with the international application in electronic form.

☐ furnished subsequently to this Authority for the purposes of search.

4. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table(s) relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US07/15544

Box No. V Reasoned statement under Rule 43 *bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims 1-4,6-10	YES
	Claims 5	NO
Inventive step (IS)	Claims 3,4,6-10	YES
	Claims 1,2,5	NO
Industrial applicability (IA)	Claims 1-10	YES
	Claims NONE	NO

2. Citations and explanations:

Please See Continuation Sheet

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US07/15544

Supplemental Box
In case the space in any of the preceding boxes is not sufficient.

V. 2. Citations and Explanations:
Claim 5 lack novelty under PCT Article 33(2) as being unpatentable over USPN Alon et al. (US PgPub 2007/0236574).

Regarding **claim 5,** Alon et al. teaches a digital imaging system (paragraph 0007 and 0025 *et seq.*) comprising: a digital camera mechanism (paragraph 0007 *et seq.* and 0025 *et seq.*), an optical lens mechanism (paragraphs 0008, 0039, and 0051 *et seq.*), a digital sensor (paragraphs 0011 and 0020 *et seq.*), a microprocessor (paragraph 0047), a nano-grid mechanism (paragraphs 0008 *et seq.* filter), a digital signal processor (paragraphs 0048 and 0092), system software (paragraphs 0020 and 0054) and a memory storage sub-system (paragraphs 0089, 0092, and 0095 - 0096); wherein the nano-grid mechanism is between the optical lens mechanism and the digital sensor (paragraphs 0008 *et seq.* filter); wherein the nano-grid mechanism is comprised of an array of nano-filaments (paragraphs 0008 *et seq.* filter); wherein the nano-grid mechanism receives an electrical signal from the microprocessor and modifies its filament structure by modulating the filaments (paragraphs 0008 *et seq.* filter); wherein the nano-grid mechanism performs a function to provide filtration to the image before the digital sensor captures the image (paragraphs 0008 *et seq.* filter); wherein the image is captured by the digital sensor (paragraphs 0011 and 0020 *et seq.*) and the digital image file forwarded to the digital signal processor (paragraphs 0048 and 0092)and; wherein the digital file is stored in memory (paragraphs 0089, 0092, and 0095 - 0096).

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US07/15544

Supplemental Box
In case the space in any of the preceding boxes is not sufficient.

Claims 1 - 2 lack novelty under PCT Article 33(2) as being unpatentable over Alon et al. (US PgPub 007/0236574) in view of over Havens (US PgPub 2007/0080280).

Regarding **claim 1,** Alon et al. teaches a digital imaging system (paragraph 0007 and 0025 *et seq.*) comprising: A digital camera mechanism (paragraph 0007 *et seq.* and 0025 *et seq.*), an optical lens mechanism (paragraphs 0008, 0039, and 0051 *et seq.*), a digital sensor (paragraphs 0011 and 0020 *et seq.*), a microprocessor (paragraph 0047), a digital signal processor (paragraphs 0048 and 0092), system software (paragraphs 0020 and 0054), a database management system (paragraphs 0089, 0092, and 0095 - 0096) and a memory storage sub-system (paragraphs 0089, 0092, and 0095 - 0096); wherein the optical lens mechanism is a fixed focal length (paragraphs 0008, 0039, and 0051 *et seq.*); wherein the aberrations from the optical lens mechanism are corrected by applying digital filtration by using the digital signal processor (paragraphs 0007 0011 – 00209, 0047 and 0097); wherein a microprocessor is used to provide digital and optical data to the digital signal processor (paragraph 0047); wherein the system software is organized to identify specific optical aberrations and to access the database to identify specific corrections to the aberrations (paragraphs 0020 and 0054); wherein the system software forwards the data file from the digital sensor to the digital signal processor (paragraphs 0020 and 0054); wherein the digital signal processor selects a specific procedure to optimize the image and corrects the aberrations (paragraphs 0048 and 0092; Also, paragraphs 0007 0011 – 0020, 0047 and 0097) and; wherein the modified digital file consisting of the digital data optimized from the aberrations that are corrected from the original optical image is stored in memory (paragraphs 0089, 0092, and 0095 - 0096).

However, Alon et al. fails to teach an application specific integrated circuit used for correcting aberrations. Havens, on the other hand teaches an application specific integrated circuit along with a microprocessor can be used for processing data.

More specifically, Havens teaches an application specific integrated circuit along with a microprocessor can be used for processing data (paragraphs 0045 – 0046, 0063).

Therefore, one of ordinary skill in the art at the time the invention was made would have been motivated to incorporate the teachings of Havens with the teachings of Alon et al. since the use of both an ASIC and a microprocessor in a system will increase the system speed.

Regarding **claim 2,** Alon et al. teaches a digital imaging system (paragraph 0007 and 0025 *et seq.*) comprising: A digital camera mechanism (paragraph 0007 *et seq.* and 0025 *et seq.*), an optical lens mechanism (paragraphs 0008, 0039, and 0051 *et seq.*), a digital sensor (paragraphs 0011 and 0020 *et seq.*), a microprocessor (paragraph 0047), a digital signal processor (paragraphs 0048 and 0092), system software (paragraphs 0020 and 0054), a database management system (paragraphs 0089, 0092, and 0095 - 0096) and a memory storage sub-system (paragraphs 0089, 0092, and 0095 - 0096); wherein the optical lens mechanism is a fixed focal length (paragraphs 0008, 0039, and 0051 *et seq.*); wherein image depth-

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US07/15544

Supplemental Box
In case the space in any of the preceding boxes is not sufficient.

of-field is optimized by forwarding the digital file from the digital sensor to the microprocessor (paragraphs 0047, 0049, 0056 - 0057, and 0071); wherein system software accesses a database to determine the optimal aperture by comparing the distance data to similar images in the database (paragraphs 0020 and 0054; also, 0089, 0092, and 0095 - 0096); wherein a microprocessor is used to provide digital image data to the digital signal processor (paragraph 0047); wherein the digital signal processor optimizes the digital file aperture setting by comparing it to the database data (paragraphs 0089, 0092, and 0095 - 0096); wherein the microprocessor adjusts the camera's aperture setting (paragraphs 0047, 0049, 0056 - 0057, and 0071); wherein the digital sensor captures the image and forwards the image data file to the digital signal processor to make modifications to the digital file (paragraphs 0048 and 0092; Also, paragraphs 0007 0011 – 0020, 0047 and 0097) and; wherein the digital file is stored in memory (paragraphs 0089, 0092, and 0095 - 0096).

However, Alon et al. fails to teach an application specific integrated circuit used for correcting aberrations. Havens, on the other hand teaches an application specific integrated circuit along with a microprocessor can be used for processing data.

More specifically, Havens teaches an application specific integrated circuit along with a microprocessor can be used for processing data (paragraphs 0045 – 0046, 0063).

Therefore, one of ordinary skill in the art at the time the invention was made would have been motivated to incorporate the teachings of Havens with the teachings of Alon et al. since the use of both an ASIC and a microprocessor in a system will increase the system speed.

Claims 3 - 4 and 6 - 10 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest the.

In claim 3: A system as claimed in claim 1 in which the type of filtration applied by the digital signal processor are special effects; wherein the digital signal processor applies a fast Fourier transform to the digital file in order to satisfy a user specified special effects function.

In claim 4: A system as claimed in claim 1 in which the type of filtration applied by the digital signal processor are applied only to specific objects; wherein the digital file is analyzed by the microprocessor to separate specific objects in the image using the differentiation of the depth-of-field; wherein the digital signal processor applies filtration only to specific objects in the image and.

In claim 6: The system of claim 1; wherein the digital sensor contains a tri-pixel configuration; wherein three differentiated sub-pixels in each pixel in which one of the sub-pixels is in the center of the pixel and is the largest and deepest of the sub-pixels; wherein the other two sub-pixels are smaller than the center sub-pixel and are on the sides of the center sub-pixel; wherein the sub-pixels forward image data to the filament on each row and; wherein each row forwards the

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US07/15544

Supplemental Box
In case the space in any of the preceding boxes is not sufficient.

image data to the digital signal processor.

In claim 7: The system of claim 1 comprising: wherein the lens focal length alternates from specific fixed focal length lens settings in a succession of steps and; wherein optical aberrations are corrected with digital filtration to modify multiple images from different focal lengths in a succession of data files.

In claim 8: The system of claim 1: wherein the imaging system is integrated into a video camera.

In claim 9: The system of claim 1; wherein the type of filtration applied by the digital signal processor is applied to specific moving objects; wherein the digital image that is captured is forwarded from the digital sensor to the microprocessor and to the digital signal processor; wherein the digital file is analyzed by the microprocessor to separate specific objects in the image using the temporal differentiation of caching in which successive images share geometric elements; wherein the digital signal processor applies filtration only to a specific continuous object that is isolated and is in motion and; wherein the digital signal processor forwards the modified digital file to be stored in memory.

In claim 10: The system of claim 1; wherein a network of digital imaging sensors is linked together in a fixed structure; wherein the network is coordinated to track specific objects that are within its collective field of vision; wherein the network captures images of objects using the digital imaging sensors; wherein the individual digital imaging sensors forward the imaging data to a central digital signal processor.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 January 2008 (17.01.2008)

PCT

(10) International Publication Number
WO 2008/008280 A3

(51) International Patent Classification:
H04N 5/76 (2006.01)

(21) International Application Number:
PCT/US2007/015544

(22) International Filing Date: 7 July 2007 (07.07.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

60/807,065	11 July 2006 (11.07.2006)	US
Not furnished	6 July 2007 (06.07.2007)	US

(71) Applicant and
(72) Inventor: **SOLOMON, Neal** [US/US]; P.O. Box 21297, Oakland, CA 94620 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*
— *of inventorship (Rule 4.17(iv))*

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

(88) Date of publication of the international search report:
23 October 2008

(54) Title: DIGITAL IMAGING SYSTEM

(57) Abstract: A system is disclosed for the automated correction of optical and digital aberrations in a digital imaging system. The system includes several main parts, including (a) digital filters, (b) hardware modifications, (c) digital system corrections, (d) digital system dynamics and (e) network aspects. The system solves numerous problems in still and video photography that are presented in the digital imaging environment.

WO 2008/008280 A3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US07/15544

A. CLASSIFICATION OF SUBJECT MATTER
IPC: **H04N 5/76**
H04N 5/225(2006.01)

USPC: 348/231.99,340
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 348/231.99,340

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2007/0236574 A1 (Alon et al.) 11 October 2007 (11.10.2007), 0007 0011 – 0020, and 0047 - 0097.	5 --- 1,2
Y	US 2007/0080280 A1 (Havens) 12 April 2007 (12.04.2007) Paragraphs 0045- 0063.	1,2

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 July 2008 (24.07.2008)	26 AUG 2008
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	Authorized officer David Ometz Telephone No. (571) 270-1131

Form PCT/ISA/210 (second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US07/15544

Continuation of Item 4 of the first sheet:
DIGITAL IMAGING SYSTEM FOR CORRECTING ABERRATIONS USING DIGITAL FILTRATION BY USING APPLICATION SPECIFIC INTEGRATED CIRCUIT

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92*bis*.1 and Administrative Instructions, Section 422)

To:

SACHS, Robert, R.
Fenwick & West LLP
Silicon Valley Center
801 California Street
Mountain View, CA 94041
ETATS-UNIS D'AMERIQUE

Date of mailing *(day/month/year)*
21 November 2008 (21.11.2008)

Applicant's or agent's file reference
13241 PCT

IMPORTANT NOTIFICATION

International application No.
PCT/US2007/015544

International filing date *(day/month/year)*
07 July 2007 (07.07.2007)

1. The following indications appeared on record concerning:

☐ the applicant ☐ the inventor ☒ the agent ☐ the common representative

Name and Address

State of Nationality | State of Residence

Telephone No.

Facsimile No.

E-mail address

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☒ the person ☐ the name ☐ the address ☐ the nationality ☐ the residence

Name and Address
SACHS, Robert, R.
Fenwick & West LLP
Silicon Valley Center
801 California Street
Mountain View, CA 94041
United States of America

State of Nationality | State of Residence

Telephone No.
(415) 875 2410

Facsimile No.
(650) 938 5200

E-mail address
☐ Notifications by e-mail authorized

3. Further observations, if necessary:
The request for recording of the above change was received by the International Bureau between 20 and 30 months from the priority date. A new agent has been appointed, as indicated in Box 2. The new agent's file reference is : 13241 PCT

4. A copy of this notification has been sent to:

☒ the receiving Office
☐ the International Searching Authority
☐ the International Preliminary Examining Authority
☒ the designated Offices concerned
☐ the elected Offices concerned
☒ other: SOLOMON, Neal

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. +41 22 338 89 95

Authorized officer
Laniel David
e-mail pt04.pct@wipo.int
Telephone No. +41 22 338 74 04

REQUEST FOR CONTINUED EXAMINATION (RCE) TRANSMITTAL		
	Application Number	13/691,805
	Filing Date	December 2, 2012
	First Named Inventor	Neal Solomon
	Confirmation Number	6244
	Group Art Unit	2699
	Examiner Name	Marly Camargo
	Attorney Docket Number	5311.001US3
	Customer No.	21186

This is a Request for Continued Examination (RCE) under 37 C.F.R § 1.114 of the above-identified application entitled
DIGITAL IMAGING SYSTEM FOR CORRECTING VIDEO IMAGE ABERRATIONS

1. Submission required under 37 C.F.R. § 1.114:

   X Information Disclosure Statement (6 pages), Form 1449 (0 page), and copies of cited documents (13).

2. Fees

   X Authorization to charge deposit account 19-0743 in the amount of $650.00 to pay the RCE filing fee required under 37 C.F.R. § 1.17(e).

The Commissioner is hereby authorized to charge any additional fees or credit overpayment to Deposit Account No. 19-0743.

SCHWEGMAN LUNDBERG & WOESSNER, P.A.

By: /Timothy E. Bianchi/
Timothy E. Bianchi
Reg. No. 39,610

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 13/691,805	Filing Date 12/02/2012	☐ To be Mailed

ENTITY: ☐ LARGE ☑ SMALL ☐ MICRO

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A		N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A		N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*		x $31 =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*		x $125 =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).				
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))					
* If the difference in column 1 is less than zero, enter "0" in column 2.				TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT	05/15/2020	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 29	Minus	** 30	= 0		x $50 =	0
	Independent (37 CFR 1.16(h))	* 3	Minus	*** 3	= 0		x $230 =	0
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	0

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=		x $0 =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=		x $0 =	
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.	LIE
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".	/TRINA RIDDICK/
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".	
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.	

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	0	"124" and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 13:49
L2	0	"S124" and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 13:52
L3	0	"S125" and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 13:52
L4	7	348/241,231.99,222.1,335,240.99,240.1,240.3,333.08,340,342,208.11,345,346-350,355,349.ccls. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3	US-PGPUB; USPAT; USOCR;	OR	ON	2020/05/25 13:53

		with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	FPRS; EPO; JPO; DERWENT; IBM_TDB			
L5	0	359/16,637,666,665,207.2,354,676.ccls. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 13:54
L6	5	(H04N5/357 | H04N5/217 | H04N5/2253 | H04N5/2254 | H04N5/228 | H04N5/238 | H04N5/76 | H04N5/225 | H04N5/374 | G06K9/36 | G06K9/40 | G01J1/20 | g01j1/0411 | g01j3/028).CPC. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 13:54
L7	1	(US-10210602-$ | US-10674047-$ | US-13691805-$ | US-20020012054-$ | US-20020041383-$ | US-20030039402-$ | US-20040150726-$ | US-20050030394-$ | US-20060120599-$ | US-20070252074-$ | US-20080175514-$ | US-20120229654-$ | US-7327390-$ | US-9077842-$).DID. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 13:55
L8	39	("20040150732" | "20040218813" | "20050179788" | "20080007630" | "20080240709" | "20080291447" | "20090009633" | "20090052769" | "20090167925" | "20090202171" | "20090262231" | "20120300112" | "5227832" | "6646760" | "6747757" | "7321685" |	US-PGPUB; USPAT; USOCR; FPRS;	OR	ON	2020/05/25 13:56

		"7425988").PN. OR ("9077842").URPN. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	EPO; JPO; DERWENT; IBM_TDB			
L9	6	348/241,231.99,222.1,335,240.99,240.1,240.3,333.08,340,342,208.11,345,346-350,355,349.ccls. and ((digital with camera$1 or video$1) and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (fixed focus lens) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3))))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 13:57
L10	0	382/167,254,255,264,263,266,275.ccls. and ((digital with camera$1 or video$1) and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (fixed focus lens) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3))))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 13:58
L11	1	(US-10210602-$ | US-10674047-$ | US-13691805-$ | US-20020012054-$ | US-20020041383-$ | US-20030039402-$ | US-20040150726-$ | US-20050030394-$ | US-20060120599-$ | US-20070252074-$ | US-20080175514-$ | US-20120229654-$ | US-7327390-$ | US-9077842-$).DID. and ((digital with camera$1 or video$1) and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (fixed focus lens) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3))))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 13:59
L12	4	(H04N5/357 | H04N5/217 | H04N5/2253 | H04N5/2254 | H04N5/228 | H04N5/238 | H04N5/76 | H04N5/225 | H04N5/374 | G06K9/36 | G06K9/40 | G01J1/20 | g01j1/0411 | g01j3/028).CPC. and ((digital with camera$1 or video$1) and ((aberration$1 with digital with database)	US-PGPUB; USPAT; USOCR; FPRS;	OR	ON	2020/05/25 14:00

		and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (fixed focus lens) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3))))	EPO; JPO; DERWENT; IBM_TDB			
L13	0	382/167,254,255,264,263,266,275.ccls. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 14:01
L14	10	((aberration$1 with digital with database)).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 14:02
L15	0	(camera and (aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1))) and (algorithm or procedure)).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 14:03
L16	0	((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1)))).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO;	OR	ON	2020/05/25 14:07

			JPO; DERWENT; IBM_TDB			
L17	0	((digital with camera$1 or video$1) and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (chang$3 with focus with position$1) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3)))).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 14:07
L18	1	((digital with camera$1 or video$1) and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (fixed focus lens) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3)))).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 14:08
L19	5	((camera with lens) with (aberration$1 with digital with database))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 14:09
L20	3	((camera with lens) with (aberration$1 with digital with database)).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	ON	2020/05/25 14:09

			DERWENT; IBM_TDB			
L21	10	(camera and (aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1))) and (algorithm or procedure))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 14:10
L22	14	(camera and (aberration$1 distortion$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1))) and (algorithm or procedure))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 14:11
L23	0	(camera and (aberration$1 distortion$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1))) and (algorithm or procedure)).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 14:14
L24	14	((aberration$1 distortion$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1))))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWE	OR	ON	2020/05/25 14:15

			NT; IBM_TDB			
L25	0	((aberration$1 distortion$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1)))).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 14:15
L26	6	((digital with camera$1 or video$1) and ((aberration$1 distortion$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (chang$3 with focus with position$1) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3))))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 14:15
L27	0	((digital with camera$1 or video$1) and ((aberration$1 distortion$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (chang$3 with focus with position$1) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3)))).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 14:16
L28	13	((digital with camera$1 or video$1) and ((aberration$1 distortion$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (fixed focus lens) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3))))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT;	OR	ON	2020/05/25 14:17

			IBM_TDB			
L29	1	((digital with camera$1 or video$1) and ((aberration$1 distortion$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (fixed focus lens) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3)))).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/05/25 14:18
S1	0	13/691805	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 12:06
S2	2	12/586221	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 12:06
S3	4	11/825521	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT;	OR	ON	2019/05/10 12:08

			IBM_TDB			
S4	139	(neal with solomon).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 12:09
S5	17	(neal with solomon).in. and (correct$4 with aberration$1)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 12:10
S6	11	(neal with solomon).as.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 12:11
S7	6	("20070080280" | "20070236574").PN. OR ("8451339").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 12:19
S8	0	(11/278268).APP.	USPAT; USOCR	OR	ON	2019/05/10 12:25

S9	1	(11/546531).APP.	USPAT; USOCR	OR	ON	2019/05/10 12:26
S10	116	("1269422" | "20030098952" | "20040008853" | "20040218283" | "20040227063" | "20040228003" | "20050002113" | "20050014306" | "20050100270" | "20050212952" | "20050218231" | "20060072915" | "20060076540" | "20060086596" | "20070063048" | "20070080280" | "20070116858" | "20080144185" | "20080144186" | "20080245872" | "20090072037" | "2062468" | "2300251" | "3161718" | "3305294" | "3583790" | "3761157" | "3778170" | "4134393" | "4191594" | "4210121" | "4249516" | "4261655" | "4286839" | "4289379" | "4312709" | "4407567" | "4487659" | "4514048" | "4783153" | "4783155" | "4784479" | "4802746" | "5091801" | "5150234" | "5305356" | "5389222" | "5396144" | "5684637" | "5892625" | "5917657" | "5973852" | "6081388" | "6109852" | "6188526" | "6212015" | "6368954" | "6369954" | "6376971" | "6399954" | "6437925" | "6449081" | "6475639" | "6529620" | "6538823" | "6542309" | "6545815" | "6545816" | "6586859" | "6628040" | "6702483" | "6715876" | "6734903" | "6747806" | "6762210" | "6806621" | "6806988" | "6809462" | "6812624" | "6882086" | "6891317" | "6934090" | "6936809" | "7169822" | "7224106" | "7301708" | "7416125" | "RE39874").PN. OR ("8027095").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 12:27
S11	28	("20020176148" | "20040228003" | "5071229" | "5150234").PN. OR ("6934090").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 12:32
S12	480	(marly with camargo).xa,xp.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 12:36

S13	18	(marly with camargo).xa,xp. and (correct$4 with aberration$1)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 12:36
S14	5	("20060228097" | "8395677" | "9077842" | "9392176" | "9998652").PN. OR ("10237485").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 12:38
S15	9	("20080309771" | "20090256952" | "20100013947" | "20100194966" | "20120274837" | "20140036134" | "20140340567" | "6363220").PN. OR ("9998652").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 12:39
S16	12	(aberration$1 with digital with database)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 12:42
S17	10	(aberration$1 with digital with database) and vignet$5	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 12:43
S18	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 12:44
S19	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 12:46
S20	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 12:46

S21	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1)))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 12:49
S22	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1))) and (algorithm or procedure)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 12:49
S23	33470	348/241,231.99,222.1,335,240.99,240.1,240.3,333.08,340,342,208.11,345,346-350,355,349.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 17:32
S24	15928	382/254,255,264,263,266,275.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 17:32
S25	5250	359/16,637,666,665,207.2,354,676.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 17:33

S26	119424	(H04N5/357 | H04N5/217 | H04N5/2253 | H04N5/2254 | H04N5/228 | H04N5/238 | H04N5/76 | H04N5/225 | H04N5/374 | G06K9/36 | G06K9/40 | G01J1/20).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 18:20
S27	17	(aberration$1 with digital with database)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 18:21
S28	9	S23 and S27	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 18:21
S29	0	S24 and S27	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 18:21

S30	0	S25 and S27	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 18:21
S31	5	S26 and S27	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 18:22
S32	0	canon.as. and (aberration$1 with digital with database)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/05/10 18:22
S34	0	canon.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 18:23
S35	0	fuji.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 18:23

S36	0	microsoft.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 18:23
S37	0	panasoninc.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 18:24
S38	0	nikon.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 18:24
S39	0	omnivision.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 18:26
S40	0	olympus.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 18:29
S41	0	olympus.as. and ((aberration$1 with digital with database) and vignet$5)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 18:29
S42	0	pelican.as. and ((aberration$1 with digital with database) and vignet$5)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 18:29
S43	0	fotonation.as. and ((aberration$1 with digital with database) and vignet$5)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 18:30
S44	0	(carl with zeiss).as. and ((aberration$1 with digital with database) and vignet$5)	US-PGPUB; USPAT; USOCR	OR	ON	2019/05/10 18:30
S45	139	(neal with solomon).in.	US-PGPUB; USPAT; USOCR;	OR	ON	2020/01/13 09:56

			FPRS; EPO; JPO; DERWENT; IBM_TDB			
S46	11	(neal with solomon).as.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 09:57
S47	104	((("SOLOMON") near3 ("Neal"))).INV.	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT	OR	ON	2020/01/13 09:59
S48	17	(neal with solomon).in. and (correct$4 with aberration$1)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:01
S49	522	(marly with camargo).xa,xp.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWE	OR	ON	2020/01/13 10:03

			NT; IBM_TDB			
S50	18	(marly with camargo).xa,xp. and (correct$4 with aberration$1)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:03
S51	7	("20070080280" | "20070236574").PN. OR ("8451339").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2020/01/13 10:06
S52	12	(aberration$1 with digital with database)	US-PGPUB; USPAT; USOCR	OR	ON	2020/01/13 10:26
S53	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:31
S54	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT;	OR	ON	2020/01/13 10:31

			IBM_TDB			
S55	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:32
S56	10	(aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and video and (modif$5 or chang$3 or alter$4) and (stor$4 with (original with (video$1 or image$1))) and (algorithm or procedure)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:33
S57	0	canon.as. and (aberration$1 with digital with database)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:34
S58	0	canon.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT;	OR	ON	2020/01/13 10:34

			IBM_TDB			
S59	0	fuji.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:34
S60	0	sony.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:34
S61	0	microsoft.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:35
S62	0	apple.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT;	OR	ON	2020/01/13 10:35

			IBM_TDB			
S63	0	aptina.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:35
S64	0	oplympus.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:36
S65	0	panasonic.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:36
S66	0	omnivision.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT;	OR	ON	2020/01/13 10:36

			IBM_TDB			
S67	0	fotonation.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:37
S68	0	pelican.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:37
S69	0	nikon.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:38
S70	0	(eastman with kodak).as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT;	OR	ON	2020/01/13 10:39

			IBM_TDB			
S71	0	(blur with technologies).as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:45
S72	0	(d$blur with technologies).as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:46
S73	0	casio.as. and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 10:48
S74	8	(digital with camera$1 or video$1) and ((aberration$1 with digital with database) and vignet$5 and (integrat$3 with circuit) and (lens with mechanism) and identif$5 and (imag$3 with file$1) and zoom$4 and (fixed focus lens) and (identify$3 with aberration$1) and (memory or storage or buffer) and (DSP or (digital signal process$3)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT;	OR	ON	2020/01/13 10:55

			IBM_TDB			
S75	8	("20050261849" | "20070030357" | "20070236574" | "20080174678").PN. OR ("8384785").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2020/01/13 11:03
S76	6	("20070236574" | "20080174678").PN. OR ("8395668").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2020/01/13 11:09
S77	21	(dudi with vakrat).in.	US-PGPUB; USPAT; USOCR	OR	ON	2020/01/13 11:13
S78	7	(dudi with vakrat).in. and aberration$1	US-PGPUB; USPAT; USOCR	OR	ON	2020/01/13 11:13
S79	19	("20030038957" | "20040150732" | "20040227978" | "20050162532" | "20060061664" | "20060062562" | "20060232681" | "20070103744" | "4466018" | "5713053" | "6788822" | "6807299" | "6822762" | "6862373" | "7088388" | "7158686" | "7973850" | "8089555" | "8194136").PN. OR ("8654240").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2020/01/13 11:20
S80	48	(katsuhiko with nagata).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:33
S81	9	(katsuhiko with nagata).in. and aberration$1	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	ON	2020/01/13 11:34

			DERWENT; IBM_TDB			
S82	1	(12/717769).APP.	USPAT; USOCR	OR	ON	2020/01/13 11:37
S83	174	(jeffrey with stafford).in.	USPAT; USOCR	OR	ON	2020/01/13 11:39
S84	1109	(jeffrey with stafford).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:39
S85	212	(jeffrey with roger with stafford).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:39
S86	8	(jeffrey with roger with stafford).in. and aberration$1	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/13 11:39