

# United States Patent

Credelle et al.

COLOR FLAT PANEL DISPLAY SUB-PIXEL  
ARRANGEMENTS AND LAYOUTS FOR  
SUB-PIXEL RENDERING WITH INCREASED  
MODULATION TRANSFER FUNCTION  
RESPONSE

Patent ~~Application~~

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~~COLOR FLAT PANEL DISPLAY SUB-PIXEL  
ARRANGEMENTS AND LAYOUTS FOR  
SUB-PIXEL RENDERING WITH SPLIT BLUE  
SUB-PIXELS~~

## Related U.S. Application Data

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## ABSTRACT

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Various embodiments of a sub-pixel octal grouping are dis-  
closed. The octal grouping may comprise three-color sub-  
pixels with one colored sub-pixel comprising twice the num-  
ber of positions within the octal sub-pixel grouping as the  
other two colored sub-pixels. Various embodiments for per-

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disclosed.  
**ABSTRACT**

~~Various embodiments of a sub-pixel octal grouping are disclosed. The octal grouping may comprise three color (red, green and blue) sub-pixels with blue colored subpixel comprising twice the number of positions within the octal sub-pixel grouping as the red and green colored sub-pixels. Various embodiments for performing sub-pixel rendering on the sub-pixel groupings are disclosed.~~

[37 Claims, 26 Drawing  
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**COLOR FLAT PANEL DISPLAY SUB-PIXEL  
ARRANGEMENTS AND LAYOUTS FOR  
SUB-PIXEL RENDERING ~~WITH SPLIT-BLUE-  
SUB-PIXELS WITH INCREASED MODULATION  
TRANSFER FUNCTION RESPONSE~~**

**RELATED APPLICATIONS**

~~{0001}~~—This application claims priority to U.S. Provisional ~~Patent Application~~ Appli- cation No. 60/~~346,738~~336,738 (“the ’738 provisional application”), entitled “ARRANGEMENT OF ~~SUBPIXELS WITH~~ SUB-PIXELS WITH DOUBLE BLUE STRIPES,” filed on Jan. 7, 2002, which is hereby incorporated herein by reference. This application is also a continuation-in-part of U.S. patent application Ser. No. 10/243,094, entitled “IMPROVED FOUR COLOR ARRANGEMENTS OF EMITTERS FOR SUB-PIXEL RENDERING,” filed on Sep. 13, 2002, now abandoned and published as United States Patent Publication No. 2004/ 0051724 (“the ’724 application”). which is hereby incorpo- rated herein by reference and is commonly owned by the same assignee of this application.

~~{0002}~~—This application is also related to United States Patent Publication No. 2003/0117J23 (“the ’J23 application”) [U.S. patent application Ser. No. 10/278,328,] entitled “IMPROVEMENTS TO COLOR FLAT PANEL DISPLAY SUB-PI- XEL- ARRANGEMENTS AND LAYOUTS WITH SUB-PIXEL ARR.4NGEMENTS AND L.4YOUTS WITH REDUCED BLUE LUMINANCE LUMIN.4NCE WELL VISIBILITY,” filed on VISIBILITY.”

U.S. patent application Ser. No. 10/278,393, entitled “COLOR DISPLAY HAVING HORIZONTAL SUB-PI- XEL ARRANGEMENTS AND LAYOUTS,” filed on Oct. 22, 2002; United States Patent Publication No. 2003/0090581 (“the ’581 application”) [U.S. patent applica- tioiser. No. 10/278,393,] entitled “COLOR DISPLAY HAV- ING HORIZONTAL SUB-PIXEL ARRANGEMENTS AND L.4YOUTS,” filed on Oct. 22, 2002; and United States Patent Publication No. 2003/0128179 (“the ’179 applica- tion”) [U.S. patent application Ser. No. 10/278,352,] entitled “IMPROVEMENTS TO COLOR FLAT PANEL DISPLAY SUB-PI- XEL- CDLOR FL.4T P.ANEL DISPL.4Y SUB-PIXEL ARRANGEMENTS AND LAYOUTS FOR SUB-PI- XEL SUB-PIXEL RENDERING WITH INCREASED MODU- LATION TRANSFER FUNCTION RESPONSE,” filed on SPLIT BLUE SUBPIX- ELS,” filed on Oct. 22, 2002. which are all hereby incorporated incorpo- rated herein by refer- ence reference and commonly owned by the same assignee of this application.

**BACKGROUND**

~~{0003}~~—The present application relates to improvements improveiients to display layouts, and, moreiioire particularly, to improvedirriproved color

pixel arrangements, meansrriicans of addressing used in displays, and to data format conversion methods for these displays.

~~{0004}~~—Full color perception is produced in the eye by three-color receptor nerve cell types called cones. The three types are sensitive to different wavelengths of light: long, medium, and short (“red”, “green”, and “blue”, ~~respee- tively~~ respectively). The relative density of the three differs significantly ~~from front~~ one another. There are slightly ~~moreiioire~~ red receptors than green receptors. There are very few blue receptors compared to red or green receptors.

~~{0005}~~—The human vision system processes the ~~informa- tion~~ information detected by the eye in several perceptual channels: ~~luminance, chromanance~~ lumi- nance, cliroiianance, and motion. Motion is only important for ~~flicker~~ flicker threshold to the imaging ~~system~~ systems designer. The ~~luminance~~ liiniinace channel takes the input ~~from front~~ only the red and green receptors. In other ~~works~~ words, the ~~luminance~~ luniinace channel is “color blind.” It processes the information in such a manner that the contrast of edges is enhanced. The ~~chromanance~~ clironianance channel does not have edge contrast ~~enhance- ment~~ enhancement. Since the ~~luminance~~ ltuninace channel uses and enhances every red and green receptor, the resolution of the ~~luminance~~ liiiiinace channel is several times higher than the ~~chromanance chan- nels~~ cliroinainance channels. Consequently, the blue

receptor contribution to ~~lumi—nance~~luminance perception is negligible. The ~~luminance~~luminance channel thus acts as a ~~resolution~~spatial frequency signal band pass filter. Its peak response is at 35 cycles per degree (cycles/°). It limits the response at 0 cycles/° and at ~~0.50~~ cycles/° in the horizontal and vertical axis. This means that the luminance channel can only tell the relative brightness between two areas within the field of view. It cannot tell the absolute brightness. Further, if any detail is finer than 50 cycles/°, it simply blends together. The ~~limit~~limit in the horizontal axis is slightly higher than the vertical axis. The limit in the diagonal axes is ~~significantly~~somewhat lower.

~~{0006}~~—The ~~chromanance~~chrominance channel is ~~further~~subdivided into two sub-channels, to allow us to see ~~full~~full color. These channels are quite different from the luminance channel, acting as low pass filters. One can always tell what color an object is, no matter how big it is in our field of view. The red/green ~~chromanance~~chrominance sub-channel resolution limit is at 8 cycles/°, while the yellow/ blue ~~chromanance~~chrominance sub-channel resolution ~~limit~~limit is at 4 cycles/°. Thus, the error introduced by lowering the red/green ~~resolution~~resolution or the yellow/blue ~~reso-~~resolution by one octave will be barely noticeable by the most perceptive viewer, if at all, as experiments at Xerox and ~~NASA, Ames~~NASA, Ames Research Center (see, e.g., R. Martin, J. Gille, J. Larimer, Detectability of Reduced Blue Pixel Count in Projection Displays, SID Digest 1993) have demonstrated.

~~{0007}~~—The luminance channel determines image details by ~~analyzing~~analyzing the spatial frequency Fourier transform ~~com—ponents. From~~components. Front signal theory, any given signal can be ~~rep-~~represented as the ~~summations~~summation of a series of sine waves of varying amplitude and frequency. The process of teasing out, ~~mathematically~~mathematically, these sine-wave-components of a given signal is called a Fourier Transform. The human vision system responds to these ~~sine-wave components in the two-~~sine-wave-components in the two-dimensional image signal.

~~{0008}~~—Color perception is influenced by a process called “~~assimilation~~assimilation” or the Von Bezold color blending effect. This is what allows separate color pixels (also known as ~~sub—pixels~~sub-pixels or emitters) of a display to be perceived as a mixed color. This blending ~~effect~~effect happens over a given angular distance in the field of view. Because of the relatively scarce blue receptors, this blending happens over a greater angle for blue than for red or green. This distance is approximately 0.25° for blue, while for red or green it is approximately 0.12°. At a viewing distance of twelve inches, 0.25° ~~sub—tends~~subtends 50 mils (~~1.270~~1.270) on a display. Thus, if the blue pixel pitch is less than half(~~625~~625) of this blending pitch, the colors will blend without loss of picture quality. This ~~blend—ing effect~~blending effect is directly related to the ~~chromanance~~chrominance sub-channel resolution limits described above. Below the resolution limit, one sees separate colors, above the resolution limit, one sees the combined color.

#### BRIEF DESCRIPTION OF THE ~~DRAWINGS~~DRAWINGS

~~{0009}~~—The accompanying drawings, which are ~~incorpo—rated~~incorporated in, and constitute a part of this specification illustrate various implementations and embodiments disclosed herein.

FIG. 1A shows an arrangement of four-color pixel elements in an array, in a single plane, for a display device, having a repeat cell consisting of eight

sub-pixels.

~~{0010}~~ FIG. 1B shows an arrangement of ~~sub-pixel~~  
~~emitters comprising three colors red, green, and~~  
~~blue~~ ~~n group~~ ~~ings that create a larger rectilinearly~~  
~~repeating cell group~~ three-color pixel ele- ments in ari  
array, in a single plane, for a display device, having a  
repeat cell of consisting of eight sub-pixels wherein  
~~the blue~~ gener- ated by selecting and defining four of the  
eight sub-pixels are "split" of FIG. 1A as the same  
color.

FIG. 1C shows an arrangeiient of three-color pixel  
ele- ments in an array, in a single plane, for a display  
device, having a repeat cell of consisting of eight  
sub-pixels gener-

ated by selecting and defining four of the eight sub-pixels of FIG. 1A as the source color and reducing their widths.

FIG. 2 shows a schematic of an electronic drive arrangement for the arrangement of sub-pixels shown in FIGS. 1A, 1B, and 1C.

FIGS. 3A and 3B illustrate the relative polarities of active matrix dot inversion drive methods for a Liquid Crystal Display using the arrangement of color sub-pixels of FIG. 1C and the drive arrangement of FIG. 2.

~~{0011}—FIGS. 2A, 2B, 2C, and 2D illustrate one embodiment of red, a set of green, and blue resample area arrays for the red, green and blue color planes respectively to match the sub-pixel, and red resample areas separately and overlaid, respectively, for the arrangement of sub-pixels of FIG. 1C.~~

~~{0012}—FIGS. 3 and 4 illustrate the red and green resample area arrays of FIGS. 2 and 3 overlaid on the sub-pixel arrangement of FIG. 1 respectively.~~

FIGS. 5A, 5B, 5C, and 5D illustrate the set of green, blue, and red resample areas of FIGS. 4A, 4B, 4C, and 4D respectively, overlaid on the arrangement of sub-pixels of FIG. 1C to show their relative positions.

~~{0013}—FIG. 5E illustrates one particular inter-color plane phase relationship between the red and green color resample areas overlaid on the sub-pixel two logical pixels displayed on the arrangement of FIG. 1C, resulting from the sub-pixel rendering operation of the resample areas of FIG. 4D.~~

FIG. 6A illustrates two logical pixels displayed on the arrangement of FIG. 1C, resulting from the sub-pixel rendering operation of the resample areas of FIG. 6D.

FIGS. 6B, 6C, and 6D illustrate a set of blue and red resample areas separately, and overlaid along with the green resample areas illustrated in FIG. 4A on arrangement of sub-pixels of FIG. 1C, respectively.

~~{0014}—FIGS. 8A and 8B illustrate two possible schematics for a driver arrangement for the arrangement of color emitter sub-pixels in FIG. 1.~~

FIG. 7A illustrates the set of green, blue, and red resample areas of FIGS. 4A, 4B, and 4C respectively, overlaid show their relative positions.

~~{0015} FIGS. 9 and 10 show two “dot inversion” schemes—commonly known as “2x1” and “1x1”, respectively matching FIG. 8A’s schematic.~~

~~{0016} FIGS. 11 and 13 depict alternative blue color-plane resample area arrays to replace the one shown in FIG. 4.~~

~~{0017} FIGS. 12 and 14 show how the respective blue color-plane resample areas of FIGS. 11 and 13 would map onto the sub-pixel layout as shown in FIG. 1.~~

~~poorly FIGS. 15 and 16 show two “dot inversion” schemes—commonly known as “2x1” and “1x1”, respectively matching FIG. 8B’s schematic.~~

~~{0019} FIG. 17B illustrates the results of turning on two full color incoming data pixels arrangement of resample areas of FIG. 7A overlaid on the arrangement of sub-pixels of FIG. 1C to show their relative positions.~~

~~{0020} FIGS. 8A and 8B show other embodiments of the octal subpixel arrangement with various vertical displacements of the subpixels.~~

~~{0021} FIGS. 9A and 9B show yet other embodiments of the octal subpixel arrangement of various displacements of the split majority subpixel within the subpixel grouping.~~

~~{0022} FIG. 10 depicts a system incorporating sub-pixel rendering techniques suitable to drive a panel made in accordance with the various embodiments described herein.~~

~~FIGS. 11A and 11B depict two particular embodiments of flowcharts to perform software and hardware sub-pixel rendering on a suitable display.~~

~~FIG. 12 is one particular embodiment of an arrangement of a display made in accordance with several embodiments herein disclosed.~~

#### DETAILED DESCRIPTION

~~{0023} Reference will now be made in detail to various implementations and embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.~~

#### Sub-Pixel Arrangements

FIG. 1A shows an arrangement of sub-pixel emitters 100 having four color emitters in groupings 110 that is shifted down every other column group by one sub-pixel. This creates a larger rectilinearly repeating cell group 120 of eight sub-pixels. This layout was introduced in the '724 application Also disclosed in the '724 application is the practice of setting a plurality of the sub-pixels within the repeat cell to the same color point, an example of which is illustrated in FIG. 1B, wherein four of the emitters 106 in the eight emitter repeat cell group 120 are set to the same color. For example, these

four emitters 106 may be set to be luminance adjusted (i.e. balanced) green in color. For example, the other sub-pixel emitters may be set to be red 104 and blue 102. The luminance balanced green 106 sub-pixels have twice the area, i.e., “real-estate,” per color as the red 104 and blue 102 sub-pixels, but being balanced to have the same luminance as the red 104 sub-pixels, the total green energy is balanced to produce a pleasing white point when all sub-pixels are illuminated fully. The manner of balancing the luminance of the green color sub-pixel was previously disclosed in the '724 application.

In FIG. 1C, the four sub-pixel emitters 106 are reduced in size and aspect ratio compared to the other two sub-pixel emitters 104 and 102. The minority sub-pixels 104 and 102 may also be adjusted in aspect ratio. In this example, the relative size of sub-pixel 106 is adjusted to be one half of that of sub-pixels 104 or 102. As before, the colors may be assigned as desired. It should also be noted that although the repeat octal grouping is shown such that the majority color sub-pixels occupy the second and fourth columns, it also suffices that the majority sub-pixels could occupy the first and the third columns as well.

In another embodiment, the colors are assigned as red 104, blue 102, and non-luminance balanced green 106. Since there are twice as many green 106 as there are of the other two colors, red 104 and blue 102, the result is a pleasing white point when all sub-pixels are illuminated fully.

In this or another color assignment embodiment, the sub-pixel aspect ratios may be adjusted so that the display array 100 consists of square repeat cell groups 120. This will put the majority color sub-pixel emitter 106 on a square grid. It will also put the minority color sub-pixel emitters 102 and 104 on, or nearly on, an idealized “checkerboard”. For an example of another color assignment embodiment, sub-pixels 106 could be assigned the color red and sub-pixels 104 could be assigned the color green in FIGS. 1B and 1C. Under this color assignment, the algorithms for sub-pixel rendering discussed below would work similarly.

Not only may the green or the red sub-pixels occupy the majority colored sub-pixels in octal grouping 120, but the blue sub-pixels may also occupy the majority sub-pixels. Such an arrangement was previously disclosed in '738 provisional application. Thus, all three colors—red, green, and blue—may occupy the majority sub-pixel position in this grouping. Additionally, while the colors—red, green and blue—have been used for the purposes of illustrating the present embodiments, it should be appreciated that another suitable choice of three colors—representing a suitable color gamut for a display—may also suffice for the purposes of the present invention.

~~{0024} In FIG. 1, in the arrangement of sub-pixel emitters 100, there are three color emitters in groupings 120 that create a larger rectilinearly repeating cell group of eight sub-pixels. This layout was introduced in the~~

the '738 provisional application and included herein by reference. Grouping 120 comprises red sub-pixels 104, green sub-pixels 106 and blue sub-pixels 102. As may be seen, blue sub-pixels 102 are "split" i.e. having a smaller width along the horizontal axis than either red or green sub-pixels but doubled in number per grouping or repeat cell. Such a "split" sub-pixel can refer to a sub-pixel having a smaller area than a non-split sub-pixel. Splitting the blue sub-pixels helps in breaking up the noticeable effect of visible vertical blue stripes down the display, as further discussed in U.S. patent application Ser. No. \_\_\_\_\_ ("the \_\_\_\_\_ application"), entitled "IMPROVEMENTS TO COLOR FLAT PANEL DISPLAY SUBPIXEL ARRANGEMENTS AND LAYOUTS WITH REDUCED BLUE LUMINANCE WELL VISIBILITY," filed on \_\_\_\_\_, incorporated by reference.

{0025} As may additionally be seen in FIG. 1, the red and the green sub-pixels are placed upon a "checkerboard" pattern with the repeat cell itself. As discussed further in the

\_\_\_\_\_ application, it may be desirable to alter the repeat cell grouping 120 color assignments to have a split green sub-pixel in position of sub-pixels 102 and have the remaining red and blue sub-pixels form the checkerboard pattern. Likewise, it might be desirable to have the red sub-pixels split and the green and blue sub-pixels on a checkerboard pattern. The alternating "checkerboard" of emitters is similar to the red and green "checkerboard" that was disclosed in co-pending and commonly assigned U.S. patent application Ser. No. 09/916,232, entitled "ARRANGEMENT OF

COLOR PIXELS FOR FULL COLOR IMAGING DEVICES WITH SIMPLIFIED ADDRESSING," filed on

Jul. 28, 2000, which is hereby incorporated herein by reference.

{0026} It should be appreciated that while FIG. 1 depicts the "split" blue subpixel as narrower than either the red or the green subpixels, another embodiment of the present invention employs blue subpixels of equal area dimensions to the red and green subpixels. To achieve a pleasing white point with all subpixels on in a logical pixel, the relative intensities of the red, green and blue emitters can be changed appropriately as discussed in co-pending and commonly assigned U.S. patent application Ser. No. 10/243,094, entitled "IMPROVED FOUR COLOR ARRANGEMENTS OF EMITTERS FOR SUBPIXEL RENDERING," filed Sep. 13, 2002, which is hereby incorporated herein by reference.

{0027} As shown in FIGS. 4A, 4B and 4C, the subpixels appear to have a substantially rectangular appearance. It should be appreciated that other shapes to the subpixels are also possible and are contemplated within the scope of the present invention. For example, a multitude of other regular or irregular shapes for the subpixels are possible and are desirable if manufacturable. It suffices only that there is an octal grouping of colored subpixels in the fashion herein described that may be addressable for the purposes of subpixel rendering (SPR).

{0028} As subpixel shapes may vary under the scope of the present invention, so too may the exact positions of the subpixels be varied under the scope of the present invention. For example, FIGS. 4A, 4B and 4C depict a similar octal subpixel grouping wherein one or both of the majority stripes 102, 106 are offset (relatively or otherwise) from the other subpixels 104 and 106. Other vertical offsets are also possible.

{0029} Other embodiments of the octal groupings are also possible. FIGS. 4A and 4B depict octal groupings wherein the majority

majority subpixels ~~102~~106 are interspersed within the ~~checkerboard~~checker-board of subpixels 102 and ~~104~~ and ~~106~~. Other ~~arrange-ments-of-majority-~~subpixel~~arrangements of rriajority silbpixel~~ placement within such a ~~cheek-erboard~~checkerboard are also possible and are contemplated within the scope of the present invention.

~~{0030}~~ FIGS. ~~19A~~9A and ~~19B~~9B may have column electrodes that zig-zag across the display. ~~Column~~Collinin driver savings should be one third when compared to the RGB stripe system with the ~~same~~sauce resolution and the ~~number~~innumber of subpixels are about two thirds of the number of subpixels when compared to the RGB stripe system.

~~{0031}~~ Yet other embodiments of the present invention are ~~possible~~pos- sible. For example, ~~the~~entire~~licentire~~ octal subpixel groupings may be rotated 90 degrees to reverse the roles of row and column driver ~~connections~~coiunctions to the grouping. Such a ~~horizon- tal arrangement for subpixels is further disclosed in the co-pending and commonly assigned application~~horizontal arrangerient for siibpixels is fiirtlierdisclosed in the co-pend- ing application United States Patent Publication No. 2003/ 0090581 ("the '581 application") entitled "COLOR DISPLAYDIS- PLAY HAVING HORIZONTAL SUB-PIXEL SUB-PIXEL ARRANGEMENTS AND LAYOUTS;" and is incorporated by reference.

~~{0032}~~ The alternating "~~checkerboard~~clieckerboard" of emitters is ~~simi- lar~~similar to the red and green "~~checkerboard~~clieckerboard" that was disclosed in ~~co-pending-co-pend- ing and conunonly assigned United States Patent Ptblication No. 2002/0015110 ("the '110 application")~~ [U.S. patent application Ser. No. 09/~~916,232 ("the '232 application")~~;916J32] entitled "ARRANGEMENTARRANGE- MENT OF COLOR PIXELS FOR FULL COLOR IMAGINGIMAG- ING DEVICES WITH SIMPLIFIED ADDRESSING," filed ~~on Jul. 25, 2001 and hereby incorporated herein by reference.~~

~~{0033} With the display comprised substantially of repeat cell 120 having the blue sub-pixel split as sub-pixel 102, it is possible to perform on Jul. 25, 2001, using sub-pixel rendering upon this display using the area resampling techniques as such as that described in cop-ending United States Patent Publication No. 2003/0103058 ("the '058 application") [U.S. patent Application application Ser. No. 10/150,355 ("the '355 application"),] entitled "METHODS AND SYSTEMS SYS- TEMS FOR SUB-PIXEL RENDERING WITH GAMMA ADJUSTMENT," filed on May 17, 2002. These co-pending applications are hereby incorporated herein by reference. The methods described in the above co-pending applications may be modified for the embodiments disclosed herein. May 17, 2002, which is hereby incorporated herein by reference and is commonly owned by the same assignee of this application. One such embodiment of area resampling is shown in FIGS. 2 through 7.~~

FIG. 2 illustrates a schematic for a driver arrangement 200 for the arrangement of color emitter sub-pixels in FIGS. 1A, 1B, and 1C. For convenience, the example given has the same number of sub-pixels illustrated as FIG. 1C. This drive arrangement may be used for a number of display technologies, as the blocks 210 may represent one or several electrical components, which are not shown so as not to obscure the embodiments. In particular, they may represent the capacitive display cell element for passively addressed Liquid Crystal Display (LCD), or ElectroLuminescent (EL) Display. They may represent the gaseous discharge element in a Plasma Display Panel (PDP). They may represent the semiconductor diode element of a passively addressed Inorganic Light Emitting Diode or an Organic Light Emitting Diode Display. They may also represent the transistor, storage capacitor, and capacitive cell element of an Active Matrix Liquid Crystal Display (AMLCD). They may further represent the multi-transistor, storage capacitor, and light emitting element of an Active Matrix Organic Light Emitting Diode Display (AMOLED). They may also represent, in general, the color sub-pixel and its associated electronic elements found in other known or yet to be developed display technologies.

The drive timing and method may be any of those known in the art for NxM drive matrices as those shown. However, there may be modifications needed due to the specific color assignments, particularly any checkerboard across the panel or color alternations within a single column. For example, the technique known in the art as "Multi-Row Addressing" or "Multi-Line Addressing" for passive LCD may be modified such that groupings of rows are restricted to odd and even row

combinations. This will reduce potential color crosstalk since, within a column with two alternating color sub-pixels, only one color will be addressed at a time.

Inversion schemes, switching the electrical field polarity across the display cell to provide a time averaged zero net field and ion current across the cell, can be applied to the embodiments disclosed herein. FIGS. 3A and 3B show two "dot inversion" schemes 300 and 310, referred to as "1x1" and "2x1", respectively, on Active Matrix Liquid Crystal Displays, both of which will perform satisfactorily. The scheme shown on FIG. 3B may perform better when slight imbalances of light transmission occur between positive and negative polarities, especially when the eye is tracking the motion of displayed images moving across the screen. Each of the Figures shows the polarities during half of the display addressing fields. The polarities are reversed for the other half, alternating every field, resulting in a net zero current (zero DC bias), as is well known in the art.

#### Data Format Conversion

~~{0034} FIGS. 2, 3 and 4 illustrate red 200, green 300, and blue 400. For one embodiment of data format conversion using area resampling techniques, FIGS. 4A, 4B, and 4C illustrate green 406, blue 402, and red 404 resample area arrays for the red, green and, blue, and red color planes, respectively. It should be noted that each color resample area array 200, 300, and 400 comprises of resample areas 206, 306 and 404 406, 402, and 404 consists of resample areas 426, 422, and 424 and that each resample area has an associated resample point 202 416, 302 412, and 402 414, respectively, associated with it. The resample points 202 416, 302 412, and 402 414 match the relative positions of the red 104, green 106 and, blue 102, and red 104 sub-pixel locations, respectively, within each color plane; but not necessarily their exact inter-color-plane-phase relationships. It should be appreciated that any number of phase relationships are also possible, a number of which have useful properties in given data format conversion cases.~~

~~{0035} FIGS. 5 and 6 illustrate the red and green resample area arrays of FIGS. 2 and 3 overlaid on the sub-pixel arrangement 100 of FIG. 1, respectively. FIG. 7 FIG. 4D illustrates one particular inter-color-plane-phase relationship between the red and green color resample areas overlaid on the sub-pixel arrangement 100. This particular intercolor-plane-phase 400. This relationship depicts converting might be employed to convert the conventional fully fully converged square grid red-green-blue-RGB format which is to be displayed "one-to-one" with the square blue 102 green 106 sub-pixel grid of FIG. 1C. In this inter-color-plane-phase inter-color-plane-phase relationship 400, the green 300 406, blue 400 402, and red 200 404 resample area arrays are substantially positioned such that the red 202 416 and green 302 412 resample points overlap the blue 402 green 416 sample points. This treats the blue green sub-pixels 102 106 as though they lay on top of, or intimately~~

associated with, the red 104 and ~~green-106~~blue 102 sub-pixel ~~checkerboard~~checkerboard.

~~{0036}—FIGS. 11 and 13 depict alternative blue color plane 5A, 5B, and 5C illustrate the green 406, blue 402, and red 404 resample area arrays to replace the one shown in FIG.~~

~~of FIGS. 4A, 4B, and 4C overlaid on the sub-pixel arrangement 100 of FIG. 1C, respectively, with the inter-color-plane-phase relationship 400 of FIG. 4D. FIG. 5D illustrates the inter-color-plane-phase relationship 400 of FIG. 4D overlaid on the sub-pixel arrangement 100 of FIG. 1C. 4. FIGS. 12 and 14 show how these respective blue color plane resample area would map onto the sub-pixel layout as shown in FIG. 1. FIGS. 11 and 13 depict two different embodiments of resample areas 406 for blue with the phase shift shown. It should be appreciated that other phase shifts suffice for the purposes of the present invention. Additionally, other resample areas for the blue pixel data could be employed without departing from the scope of the present invention.~~

~~{0037}—These Figures are merely illustrativeillus-~~  
~~trative~~ and only serve to provide an understanding of the relationship between the ~~resample~~resarriple points, ~~reconstruction~~reconstniction points, ~~resa-mples~~resample areas, and sub-pixel locations for this embodiment.

~~{0038}—The sub-pixel rendering techniques as described in the '355above referenced '058 patent application can-  
bedescribes the iiietliod used to convert the incoming data formatfonnat to that suitable for the display. In such a case, the method-proceedsiiiietliodproceeds as follows: (1) determining implied sample areas for each data point of incomingincorriing three-color pixel data; (2) determining thea resample area for each color sub-pixel in the display; (3) forming a set of eoedleientscoefficients for each said-resample area, the eoefffieientscoef- ficients comprising fractions whose denominators are a function-  
of~~

~~ftnc-~~  
~~tioiof~~

the resample area and ~~the numerators~~whose nlienerators are a function of an area of each ~~said~~-implied sample ~~areas~~area that may partially overlap the resample ~~areas~~area; (4) multiplying the incoming pixel data for each implied ~~samples~~sarriple area by the coefficient resulting

in a product; and (5) adding each product to obtain luminance values for each resample area.

Examining a "one-to-one" format conversion case for the resample operation illustrated in FIG. 4D and 5D, the green plane conversion is a unity filter. The red and blue color planes use a 3x3 filter coefficient matrix, derived as explained in detail in the '058 application:

[0039] Other sub-pixel rendering techniques are possible to employ with the various sub-pixel arrangements as disclosed herein. For example, the techniques known as "adaptive filtering" may be employed in the same fashion as described in U.S. patent application Ser. No. 10/215,843, entitled "METHODS AND SYSTEMS FOR SUB-PIXEL RENDERING WITH ADAPTIVE FILTERING," filed on Aug. 8, 2002, which is hereby incorporated herein by reference and commonly owned by the same assignee of this application. Adaptive filtering can be adopted so as not to require a 3x3 sample of input data, which uses a minimum of two lines of memory. The test may be based on a smaller sample of input data, for example 1x3 or 1x2 matrices. The input data is sampled to test for vertical or diagonal lines, dots and edges, or other high contrast features and then actions are taken, depending on the outcome of the tests.

[0040] Test masks may be used and compared to the image data

G>iiiix, then a register value is set to 1, otherwise the register value is set to 0; compare the register values for three successive green data points to test masks to see if an edge is detected; if detected then take an appropriate action to the red and/or blue data--e.g. apply gamma or apply a new value or different filter coefficient. Otherwise, if no feature is detected, then no action may be taken.

The following table is illustrative of this embodiment:

|       |       |       |      |      |      |
|-------|-------|-------|------|------|------|
|       | 0.125 |       | 0.98 | 0.05 | 0.0  |
| 0.125 |       | 0.125 | 0    | 1    | 1    |
|       | 0.125 |       | 1    | 0    | 0    |
|       |       |       | True | True | True |

FIG. 5E illustrates the results of turning on two full color incoming data pixels. The two pixels are converted to two clusters of output sub-pixels, called "logical pixels" 500 and 501, turned on at varying amplitudes. One of the logical pixels 500 is centered on or near a red sub-pixel 104. The green sub-pixel 106 is set at 100% illumination. The red sub-pixel 104 is set to 50% illumination, while the four surrounding blue sub-pixels 102 are set to 12.5% each. The result is a white dot visible to the human eye, centered between the red 104 and the green 106 sub-pixels. The other logical pixel 501, centered on or near blue sub-pixel 102, similarly has the green sub-pixel 106 set to 100% and the near by blue sub-pixel 102 set to 50% with the four surrounding red sub-pixels 104 set at 12.5% each.

FIGS. 6B and 6C show an alternative blue color plane resample area array 602 and an alternative red color plane resample area array 604, respectively, shown herein as box filters ([0.5 0.5]) to replace the blue and red resample area arrays 402 and 404 of FIGS. 4B and 4C, respectively. FIG. 6D illustrates an inter-color-plane-phase relationship 610 using the green resample area array 406 of FIG. 4A, and blue and red resample area arrays 602 and 604. FIG. 6A shows the logical pixels 600 and 601 that result from turning on two input data format pixels using the resample operation of the inter-color-plane-phase relationship 610 (FIG. 6D) from input data with a "one-to-one" pixel to green sub-pixel 106 mapping. These logical pixels 600 and 601 may be in the

For the example above, an edge has been detected and there is an array of options and/or actions to take at this point. For example, the gamma correction could be applied to the output of the box filter for red and/or blue; or a new fixed value representing the output required to balance color could be used; or use a new SPR filter.

The test for black lines, dots, edges and diagonal lines are similar in this case, since only three values are examined:

| Register Value |   |   |   | Binary no. |
|----------------|---|---|---|------------|
| 1              | 1 | 1 | 1 | 5          |
| 2              | 1 | 1 | 1 | 6          |
| 1              | 1 | 1 | 1 | 7          |

In the above table, the first row could represent a black pixel with white pixels on either side. The second row could represent an edge of a black line or dot. The third row could represent an edge of a black line in a different location. The binary numbers are used as an encoding for the test.

The test for white lines, dots, edges, and diagonal lines might be as follows:

same relative positions as the two logical pixels 500 and 501 in FIG. 5E. Also,

| Register value |   |   |   | Binary no. |
|----------------|---|---|---|------------|
| 1              | 1 | 1 | 1 | 4          |
| 1              | 1 | 1 | 1 | 5          |
| 1              | 1 | 1 | 1 | 6          |

If the tests are true and the high and low tests are, for example, 240 and 16 (out of 255) respectively, the output value for these edges using the box filter might be  $128 \pm 4$  or some other suitable value. The pattern matching is to the binary numbers shown adjacent to the register values. A simple replacement of 128 raised to an appropriate gamma power could be output to the display. For example, for gamma=2.2, the output value is approximately 186. Even though the input may vary, this is just an edge correction term so a fixed value can be used without noticeable error. Of course, for more precision, a gamma lookup table could likewise be used. It should be appreciated that a different value, but possibly similar, of correction could be used for white and black edges. It should likewise be appreciated that as a result of detecting an edge, the red and/or blue data could be acted on by a different set of filter coefficients---e.g. apply a [1 0] filter (i.e. unity filter) which would effectively turn off sub pixel rendering for that pixel value.

The above tests were primarily for a greentest, followed by action on red and blue. Alternatively, the red and blue can be tested separately and actions taken as needed. If one desired

to only apply the correction for black and white edges, than all three color data sets can be tested and the result ANDed together.

A further simplification could be made as follows. If only two pixels in a row are tested for edges, then the test above is further simplified. High and low thresholding may still be accomplished. If [0 1] or [1 0] is detected, then a new value could be applied—otherwise the original value could be used. Yet another simplification could be accomplished as follows (illustrated for the red): subtract the red data value,  $R_{n-1}$ , from the red value immediately to the left,  $R_n$ ; if the delta is greater than a predetermined number—say for example 240—then an edge is detected. If an edge is detected, one could substitute a new value, or apply gamma, output the value  $R_n$  to the display, or apply new SPR filter coefficients; otherwise, if no edge is detected, output the results of the box filter to the display. As either  $R_n$  or  $R_{n-1}$  may be larger, the absolute value of the delta could be tested. The same simplification could occur for the blue; but the green does not need to be tested or adjusted, if green is the split pixel in the grouping. Alternatively, a different action could be taken for falling edges (i.e.  $R_n - R_{n-1} < 0$ ) and rising edges (i.e.

$R_n - R_{n-1} > 0$ ).

The results are logical pixels 600 and 601 that have only three sub-pixels each. For a white dot and using a box filter for red and blue data, the green sub-pixels 106 are set to 100% as before. The nearby red 104, as well as the nearby blue 102, could be all set to 50%. The resample operation of inter-color-plane-phase relationship 610 of FIG. 6D is very simple and inexpensive to implement, while still providing good image quality.

Both of the above data format conversion methods match the human eye by placing the center of logical pixels at the numerically superior green sub-pixels. The green sub-pixels are each seen as the same brightness as the red sub-pixel, even though half as wide. Each green sub-pixel 106 acts as though it were half the brightness of the associated logical pixel at every location, while the rest of the brightness is associated with the nearby red sub-pixel illuminated. Thus, the green serves to provide the bulk of the high resolution luminance modulation, while the red and blue provide lower resolution color modulation, matching the human eye.

[0041] FIG. 17A illustrates the results of turning on two full color incoming data pixels. The two pixels are converted to two clusters of sub-pixels, called “logical pixels”, turned on at varying amplitudes. The logical pixel on the left is centered on or near a green sub-pixel 106. The logical pixel on the right is centered on or near a red sub-pixel 104. In both logical pixels, the various sub-pixels are turned on to the appropriate illumination such that a pleasing white color is formed and centered on the green and red sub-pixels, respectively, an alternative inter-color-plane-phase relationship 700 using the green, blue, and red resample area arrays 406, 402 and 404 of FIGS. 4A, 4B, and 4C. Note that inter-color-plane-phase relationship 700 has the same relative phase as color sub-pixel arrangement 100 of FIG. 1C as illustrated in FIG. 7B. Note that the relative phases of the resample points of inter-color-plane-phase relationship 700 is the same as that for inter-color-plane-phase relationship 610 of

FIG. 6D. If this inter-color-plane-phase relationship 700 were used for the “one-to-one” data format conversion, the green would again be a unitary filter, while the red and blue would use 3x2 coefficient filter kernel:

[0042] Figs. 8A and 8B illustrate two possible schematics for a driver arrangement 800 for the arrangement of color-emitter sub-pixels in FIG. 1. FIG. 8A shows a one-to-one correspondence of column drivers to columns in the display; however, with the split blue sub-pixels, it may be desirable to tie adjacent columns of split blue sub-pixels via connections 820. As may be seen in FIG. 8B, this scheme has the advantage of saving on the number of column drivers.

[0043] For convenience, these examples given have the same number of sub-pixels illustrated as FIG. 1. These drive arrangements may be used for a number of display technologies, as the blocks 810 may represent one or several electrical components. They may represent the capacitive display cell element for passively addressed Liquid Crystal Display (LCD), or ElectroLuminescent (EL) Display. It may represent the gaseous discharge element in a Plasma Display Panel (PDP). It may represent the semiconductor diode element of a passively Inorganic Light Emitting Diode or an Organic Light Emitting Diode Display. It may represent the transistor, storage capacitor, and capacitive cell element of an Active Matrix Liquid Crystal Display (AMLCD). It may represent the multi-transistor, storage capacitor, and light emitting element of an Active Matrix Organic Light Emitting Diode Display (AMOLED). It may represent, in general, the color sub-pixel and its associated electronic elements found in other known or yet to be invented display technologies.

~~{0044} Known drive timing and methods may be used for NxM drive matrices as those shown. However, there may be modifications needed due to the specific color assignments, particularly any checkerboard across the panel or color alternations within a single column. For example, the technique known in the art as Multi-Line Addressing for passive LCD may be modified such that groupings of rows are restricted to odd and even row combinations. This will reduce potential color cross-talk since, within a column with two alternating color sub-pixels, only one color will be addressed at a time.~~

~~{0045} Inversion schemes, switching the electrical field polarity across the display cell to provide a time-averaged zero net field and ion current across the cell can be used to the above unique sub-pixel arrangements. FIGS. 9 and 10 (matching FIG. 8A's schematic) and FIGS. 15 and 16 (matching FIG. 8B's schematic) show two "dot inversion" schemes referred to as "2x1" and "1x1", respectively on Active Matrix Liquid Crystal Displays, both of which will perform satisfactorily. The scheme shown on FIGS. 9 and 15 may perform better when slight imbalances of light transmission occur between positive and negative polarities, especially when the eye is tracking the motion of displayed images moving across the screen. Each of the Figures shows the polarities during half of the display addressing fields. The polarities are reversed for the other half, alternating every field, resulting in a net zero current (zero DC bias), as is well known in the art.~~

|                   |                   |
|-------------------|-------------------|
| <del>0.0625</del> | <del>0.0625</del> |
| <del>0.575</del>  | <del>0.375</del>  |
| <del>0.0625</del> | <del>0.0625</del> |

Note that the two columns add up to 0.5 each, similar to the coefficients for the red and blue resample filter operation for the inter-color-plane-phase relationship 610 of FIG. 6D.

This inter-color-plane-phase relationship 700 shown in FIG. 7A is useful for scaling, both up and down, of conventional format data sets. The area resample method of calcu-

lation of the filter coefficients and keeping track of the input and output data buffers was described in the referenced '058 application. However, according to another embodiment, while the red and blue color planes may be area resampled, it may be advantageous to calculate the filter coefficients for the square grid of green sub-pixels 106 using a novel implementation of a bi-cubic interpolation algorithm for scaling up data sets while converting them to be displayed on the arrangement of color sub-pixels 100 of FIG. 1C.

~~{0046} FIG. 10 depicts a system 2000 in which a display as constructed in accordance with the various embodiments disclosed herein is driven by a sub-pixel rendering technique 1004 which may be resident on a physical device 1002. An input image data stream 1008 may be input into the sub-pixel rendering technique 1004 and converted in the manner herein disclosed. An output image data stream 1010 is sent to the display device 1006 in order to drive the various sub-pixels to form an image thereupon. As discussed in several references incorporated herein, the sub-pixel rendering (SPR) technique 1004 may be implemented in either hardware and/or software or a combination thereof. For example, SPR techniques 1004 could be resident as logic (either hardware or software) on the display itself or it could reside on a graphics controller chip or board.~~

FIGS. 11A and 11B depict two particular flowchart embodiments disclosing sub-pixel rendering in software and hardware respectively. In FIG. 11A, SPR may be accomplished in advance on a PC or other processing system and/or means. Front there, the pre-rendered images could be downloaded to a controller/interface and sent along to a drive running the display. In FIG. 11B, image data may be input from many different sources—for example, a notebook PC with DVI output or a desktop with DVI output—to a hardware module doing SPR. Front there, the sub-pixel rendered data could be sent ultimately to the display via a controller/interface and a drive. Of course, other hardware and software implementations are possible and that FIGS. 11A and 11B merely describe two possible such implementations.

FIG. 12 shows one particular display embodiment for a 320x320 STN display using the sub-pixel repeat cell as disclosed herein. Although various sub-pixel dimensions are also disclosed in FIG. 12, it should be appreciated that other dimensions would also suffice and that FIG. 12 is merely offered for illustrative purposes for a single embodiment.

~~{0047} While the invention has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings without departing from the essential~~

scope thereof. For example, ~~some~~sort of the ~~embodiments~~embodiments above may be implemented in other display technologies such as Organic Light Emitting Diode (OLED), ~~Electroluminescent~~Electroluminescent (EL), Electrophoretic, Active Matrix Liquid ~~Crys~~tal Crystal Display (AMLCD), Passive Matrix Liquid Crystal ~~display~~display (AMLCD), Incandescent, solid state Light Emitting Diode (LED), ~~Plasma~~Plasma Display Panel (PDP), and Iridescent. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode ~~contemplated~~contemplated for carrying out this invention, but that the ~~invention~~invention will include all ~~embodiments~~embodiments falling within the scope of the appended claims.

~~What is~~The invention claimed is:

1. A method of converting incoming three-color pixel data of a first format for rendering onto a display panel; said display panel comprising a plurality of a sub-pixel group; said sub-pixel group further comprising eight ~~sub-pixels;~~sub-pixels; wherein

wherein each said sub-pixel is one of a ~~red color sub-pixel~~, a ~~green first color sub-pixel~~, a ~~second color sub-pixel~~ and a ~~blue third color sub-pixel~~; wherein said sub-pixel group ~~further comprises four sub-pixels of said blue color, two further comprises four sub-pixels of said red first color, two sub-pixels of said second color and two sub-pixels of said green third color~~; wherein ~~further~~ ~~further~~ said sub-pixels of said ~~red second color~~ and said sub-pixels of said ~~green third color~~ form substantially a ~~checkerboard pattern~~; ~~the method comprising: determining a plurality of sample areas for each data point of~~

~~said a plurality of three-color pixel data;~~  
~~determining a resample area for each color sub-pixel on said display panel;~~  
~~forming a set of coefficients for each resample area, said coefficients comprising fractions whose denominators are a function of the resample area and whose numerators are a function of an area of each sample area that may partially overlap said resample area;~~  
~~multiplying the incoming pixel data for each sample area by a coefficient resulting in a product; and adding each product to obtain a cumulative value for said color sub-pixel on said display panel represented by each resample area.~~

2. The ~~display method~~ as recited in claim 1 wherein ~~said sub-pixels of said blue color comprises a smaller area than said sub-pixels of said red color and said green color, a plurality of resample areas for each color sub-pixel in the display forms a resample area array, and wherein the method further comprises:~~

~~determining a phase relationship among the resample area arrays for each color sub-pixel.~~

3. The ~~method~~ as recited in claim 2 wherein ~~determining a phase relationship further comprises:~~  
~~positioning resample points for each said color resample areas such that the resample points for said second color and said third color substantially overlay the resample points for said first color.~~

4. The ~~method~~ as recited in claim 1 wherein said first color is green, and said second and third colors are red and blue respectively;

~~wherein said set of coefficients for said resample areas for the green color comprises a unity filter; and~~

~~wherein said set of coefficients for said resample areas for the red and blue colors are each a 3x3 filter coefficient matrix.~~

5. The ~~method~~ as recited in claim 1 wherein said unity filter is centered to substantially match an input pixel by adjusting said unity filter with respect to a sub-pixel grid.

36. The ~~display method~~ as recited in ~~claim~~ ~~claims~~ 1 ~~wherein~~ wherein said eight sub-pixels of said sub-pixel group ~~further comprises substantially~~ are disposed in two rows ~~and of~~ four columns of sub-pixels; and

wherein ~~further a first set of two non-adjacent columns comprise four sub-pixels of said blue color and a second set of two non-adjacent columns comprise two sub-pixels of said red color and two sub-pixels of said green color~~ first color, one sub-pixel of said second color and one sub-pixel of said third color are disposed in each of said two rows.

4. The ~~display as recited in claim 3 wherein said two non-adjacent columns comprising four sub-pixels of said blue color are offset vertically from said two non-adjacent columns comprise two sub-pixels of said red color and two sub-pixels of said green color.~~

7. The ~~method~~ as recited in claim 1 wherein said eight sub-pixels of said sub-pixel group are disposed in two rows of four sub-pixels, and wherein said checkerboard pattern is formed by one of said sub-pixel of said second color following one of said sub-pixel of said third color in a first row, and one of said sub-pixel of said third color following one of said sub-pixel of said second color in a second row.

58. The ~~display method~~ as recited in claim 1 wherein ~~said sub-pixels of said blue color are interspersed said substantially formed checkerboard pattern of a combined area of said two sub-pixels of said red first color is substantially equal to the area of one of said sub-pixel of said second color and said green sub-pixel of said third color.~~

6. The ~~display as recited in claim 1 wherein said display is an active matrix liquid crystal display.~~

9. The ~~method~~ as recited in claim 1 wherein said eight sub-pixels of said sub-pixel group are disposed in two rows of four sub-pixels, and wherein said sub-pixels of said first color are disposed in columns in said sub-pixel group.

10. The ~~display method~~ as recited in claim 69 wherein ~~a first one of said display applies a dot inversion scheme for driving the columns of said sub-pixels in each sub-pixel group of said first color is offset~~

8. The ~~display as recited in claim 7 wherein said dot inversion scheme is 1x1 dot inversion.~~

9. The ~~display as recited in claim 7 wherein said dot inversion scheme is 2x1 dot inversion.~~

from a second one of said columns of said sub-pixels of said first color in said sub-pixel group.

11. The method of claim 1 wherein said display panel is an element of a display system utilizing one of a group of display technologies, said group of technologies comprising passively addressed Liquid Crystal Display (LCD), ElectroLuminescent (EL) Display, Plasma Display, passively addressed Inorganic Light Emitting Diode, Organic Light Emitting Diode Display, Active Matrix Liquid Crystal Display (AM-LCD), and Active Matrix Organic Light Emitting Diode Display (AMOLED).

12. A system comprising:

10. In a display panel, said display panel comprising a plurality of a sub-pixel group; said sub-pixel group further comprising eight sub-pixels; wherein each said sub-pixel is one of a blue color sub-pixel, a red color sub-pixel and a green color sub-pixel; wherein said sub-pixel group further comprises specifying an output data format; said sub-pixel group further comprising four sub-pixels of said blue first color, two sub-pixels of said red second color and two sub-pixels of said green color; wherein further sub-pixels of a third color; said sub-pixels of said red second color and said sub-pixels of said green third color form substantially a checkerboard forming a checkerboard pattern;

a method of converting a source pixel data of a first format for rendering onto said display comprising:

means for receiving input image data specified in an input data format different from said output data format; and means for subpixel rendering said input image data specified in said input data format to said output data format of said plurality of sub-pixel groups on said display panel.

13. The system as recited in claim 12 wherein said means for subpixel rendering input image data further comprises:

determining means for determining implied sample areas for each data point of incoming three-color pixel said input image data;

means for determining the resample area for each color sub-pixel in the display;

means for forming a set of coefficients for each the resample area, said coefficients comprising fractions whose denominators are a function of the resample area and the numerators are a function whose numerators are a function of an area of each the implied sample area that may partially overlap said resample area; resample area;

~~means for multiplying the incoming pixel~~input image data for each implied sample area by ~~the~~a coefficient resulting in a ~~product~~prod-uct; and ~~means for adding each the product to obtain luminance values~~a luminance value for each ~~resample~~resample area.

~~11. The method as recited in claim 10 wherein determining the resample area further comprises:~~

~~14. The systems as recited in claims 13 wherein a plurality of resample areas for each color sub-pixel in the display forms a resample area array, and wherein the system further comprises:~~

~~means for determining a phase relationship between~~among the resample area ~~arms~~arms for each color ~~subpixel~~sub-pixel.

~~12. The method systems as recited in claim 11~~claims 14 wherein ~~deter-mining~~means for determining a phase relationship ~~further~~flirtlier comprises:

~~means for positioning resample~~resample points for each said color ~~resample~~resample areas such that the resample points for said ~~red~~second color and said ~~green~~third color substantially overlay the resample points for said ~~blue~~first color.

~~13. In a display, said display comprising a plurality of a sub-pixel group; said sub-pixel group further comprising eight sub-pixels; wherein each said sub-pixel is one of a blue color sub-pixel, a red color sub-pixel and a green color sub-pixel; wherein said sub-pixel group further comprises four sub-pixels of said blue color, two sub-pixels of said red color and two sub-pixels of said green color; wherein further said sub-pixels of said red color and said sub-pixels of said green color form substantially a checkerboard pattern;~~

~~a method of converting a source pixel data of a first format for rendering onto said display comprising:~~

~~inputting a set of color image data;~~

~~testing the input data for a plurality of conditions;~~

~~and taking appropriate actions in response to the outcome of said testing of the input data;~~

~~14. The method as recited in claim 13 wherein said set of color image input data comprises a sample of a 1x3 matrix of input data.~~

~~15. The method as recited in claim 13 wherein said set of color image input data comprises a sample of a 1x2 matrix of input data.~~

~~16. The method system as recited in claim 13 wherein testing the input data for a plurality of conditions further comprises: said first color is green, and said second and third colors are red and blue respectively;~~

~~wherein said set of coefficients for said resample areas for the green color comprises a unity filter; and~~

~~wherein said set of coefficients for said resample areas for the red and blue colors are each a 3x3 filter coefficient matrix.~~

~~testing for the detection of a high contrast feature in the~~

~~input data.~~

~~17. The method systems as recited in claim 16 wherein said high contrast feature comprises one of a group, said group comprising an edge, a line, and a dot; unity filter is centered to substantially intersect an input pixel by adjusting said filter with respect to a sub-pixel grid.~~

~~18. The method as recited in claim 13 wherein taking appropriate actions in response to the outcome of said testing of the input data further comprises:~~

~~substituting a new color data value for the current color~~

~~data value.~~

~~19. The method as recited in claim 13 wherein taking appropriate actions in response to the outcome of said testing of the input data further comprises:~~

~~applying gamma correction to the current color data value.~~

~~20. The method as recited in claim 13 wherein taking appropriate actions in response to the outcome of said testing of the input data further comprises:~~

~~apply new sub-pixel rendering filter coefficients to the input data.~~

~~21. A system comprising:~~

18. The system as recited in claim 12 wherein said eight sub-pixels of said sub-pixel group are disposed in two rows of four sub-pixels, and wherein two sub-pixels of said first color, one sub-pixel of said second color and one sub-pixel of said third color are disposed in each of said two rows.

19. The system as recited in claim 12 wherein said eight sub-pixels of said sub-pixel group are disposed in two rows of four sub-pixels, and wherein said checkerboard pattern is formed by one of said sub-pixel of said second color following one of said sub-pixel of said third color in a first row, and one of said sub-pixel of said third color following one of said sub-pixel of said second color in a second row.

20. The system as recited in claim 12 wherein a combined area of said two sub-pixels of said first color is substantially equal to the area of one of said sub-pixel of said second color and said sub-pixel of said third color.

21. The system as recited in claim 12 wherein said eight sub-pixels of said sub-pixel group are disposed in two rows of four sub-pixels, and wherein said sub-pixels of said first color are disposed in columns in said sub-pixel group.

22. The system as recited in claim 21 wherein a first one of said columns of said sub-pixels of said first color is offset from a second one of said columns of said sub-pixels of said first color in said sub-pixel group.

23. The system as recited in claim 12 wherein said system utilizes one of a group of display technologies, said group of technologies comprising passively addressed Liquid Crystal Display (LCD), ElectroLuminescent (EL) Display, Plasma Display, passively addressed Inorganic Light Emitting Diode, Organic Light Emitting Diode Display, Active Matrix Liquid Crystal Display (AMLCD), and Active Matrix Organic Light Emitting Diode Display (AMOLED).

24. A method of rendering input image data specified in a format comprising first, second and third color data values onto a display panel substantially comprising a sub-pixel repeating group comprising eight sub-pixels of first, second and third colors disposed in two rows; said sub-pixel repeating group further comprising two sub-pixels of said first color, one sub-pixel of said second color and one sub-pixel of said third color disposed in each of said two rows; the method comprising:

determining a plurality of input sample areas for said input image data; each said input sample area representing one input image pixel indicating first, second and third color data values in said input image data;

determining a first color resample area array for said first color sub-pixels on the display panel; said first color resample area array comprising a plurality of first color resample areas each comprising a first color resample point such that one first color resample point represents one first color sub-pixel on the display panel;

for each first color resample point in said first color resample area array, assigning said first color data value of said one input image pixel represented by a corresponding implied sample area to a first

luminance value for said first color sub-pixel represented by said first color resample point;

determining a second color resample area array and a third color resample area array for said respective second color and third color sub-pixels on the display panel; each of said second color and third color resample area arrays comprising a plurality of respective second color and third color resample areas each comprising respective second color and third color resample points such that one second color resample point represents one

second color sub-pixel on the display panel and one third color resample point represents one third color sub-pixel on the display panel;

computing a set of coefficients for each of said second color resample areas and said third color resample areas, said coefficients comprising fractions whose denominators are a function of the respective resample area and whose numerators are a function of any partial area of each input sample area that may overlap said respective resample area when said respective resample area array overlays said input sample areas; and

producing a second luminance value and a third luminance value for each respective second color sub-pixel and third color sub-pixel on the display panel by multiplying respective ones of said coefficients of a corresponding resample area by respective second color and third color data values of the input image data for each input sample area overlaid by said resample area, and adding the resulting products.

a display, said display comprising a plurality of a sub-pixel group<sup>25</sup>. The method as recited in claim 24 wherein said first color is green, said second color is red and said third color is blue; said sub-pixel repeating group ~~further comprising eight~~ two green sub-pixels; ~~wherein each said sub-pixel is one of one blue sub-pixel and one red sub-pixel disposed in each of said two rows.~~

26. The method as recited in claim 25 wherein a combined area of said two green sub-pixels disposed in each row is substantially equal to the area of one of said blue sub-pixel and said red sub-pixel.

~~a blue color sub-pixel, a red color sub-pixel and a green color sub-pixel;~~<sup>27</sup>. The method as recited in claims 24 wherein said first color is green, and wherein said sub-pixel repeating group ~~further comprises~~ comprises four green sub-pixels ~~of said blue color, two sub-~~ disposed in columns in said sub-pixel repeating group.

28. The method as recited in claim 24 wherein said sub-pixels of said red second color and two sub-pixels of said green color; wherein further said sub-pixels of said red color and said sub-pixels of said green third color form substantially a checkerboard pattern; and substantially a checkerboard pattern in said two rows such that a sub-pixel of said second color is followed by a sub-pixel of said third color in said first row, and a sub-pixel of said third color is followed by a sub-pixel of said second color in said second row.

29. The method as recited in claim 24 wherein each of said respective second color and third color resample areas overlaps at least two partial rows of input sample areas representing input image pixels in said input image data.

30. The method as recited in claims 24 wherein each of said respective second color and third color resample areas overlaps at most one partial row of input sample areas representing input image pixels in said input image data.

31. The method as recited in claim 24 wherein a plurality of said respective second color and third color resample areas has a diamond shape.

32. The method as recited in claims 24 further comprising determining a phase relationship among said first, second and third resample area arrays.

33. The method as recited in claim 32 wherein determining a phase relationship among said first, second and third resample area arrays comprises positioning said first, second and third color resample points for each respective first, second and third color resample area such that said first, second and third color resample points are substantially coincident.

34. The method as recited in claim 32 wherein determining a phase relationship among said first, second and third resample area arrays comprises positioning said first, second and third color resample points for each respective first, second and third color resample area such that none of said first, second and third color resample points are substantially coincident.

35. The method as recited in claim 24 wherein the step of corrupting a set of coefficients for each of said second color resample areas and said third color resample areas comprises computing a 3x3 filter coefficient matrix having the values

|        |               |
|--------|---------------|
| (Add   | <u>0.0625</u> |
| 0.0625 | <u>0.373</u>  |
|        | <u>0.062</u>  |

means for subpixel rendering input image data:

~~22. The system as recited in claim 21 wherein said means for subpixel rendering input data further comprises:~~

~~means for inputting a set of color image data;~~

~~means for testing the input data for a plurality of conditions; and~~

~~means for taking appropriate actions in response to the outcome of said testing of the input data.~~

~~23. The system as recited in claim 22 wherein said set of color image input data comprises a sample of a 1x3 matrix of input data.~~

~~24. The system as recited in claim 22 wherein said set of color image input data comprises a sample of a 1x2 matrix of input data.~~

~~25. The system as recited in claim 22 wherein said means for testing the input data for a plurality of conditions further comprises:~~

~~means for testing for the detection of a high contrast feature in the input data.~~

~~26. The system as recited in claim 25 wherein said high contrast feature comprises one of a group, said group comprising an edge, a line, and a dot.~~

~~27. The system as recited in claim 22 wherein means for taking appropriate actions in response to the outcome of said testing of the input data further comprises:~~

~~means for substituting a new color data value for the current color data value.~~

~~28. The system as recited in claim 22 wherein means for taking appropriate actions in response to the outcome of said testing of the input data further comprises:~~

~~means for applying gamma correction to the current color data value.~~

~~29. The system as recited in claim 22 wherein means for taking appropriate actions in response to the outcome of said testing of the input data further comprises:~~

~~means for applying new sub pixel rendering filter coefficients to the input data.~~

~~30. The system as recited in claim 21 wherein said means for subpixel rendering input data further comprises:~~

~~means for determining implied sample areas for each data point of incoming three color pixel data;~~

~~means for determining the resample area for each color sub pixel in the display;~~

~~means for forming a set of coefficients for each the resample area, said coefficients comprising fractions whose denominators are a function of the resample area and the numerators are a function of an area of each the implied sample areas that may partially overlap said resample areas;~~

~~means for multiplying the incoming pixel data for each implied sample area by the coefficient resulting in a product; and~~

~~means for adding each the product to obtain luminance values for each resample area.~~

0.125

0.12

0

0.125

0.

37.  
The  
method of  
claim 24  
wherein  
said  
display  
panel is  
an  
element  
of a  
display  
system  
utilizing  
one of a  
group of  
display  
technolo  
gies, said  
group of

technolo  
gies  
comprisi  
ng pas-  
sively  
addresse

d Liquid  
Crystal  
Display  
(LCD),  
ElectroLt  
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t(EL)  
Display,  
Plasma  
Display,  
passively

addresse  
d  
Inorganic  
Light  
Emitting  
Diode,  
Organic  
Light  
Emitting

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36. The method as recited in claim 24 wherein the step  
of computing a set of coefficients for each of said second  
color resample areas and said third color resainple areas  
coiiiprises computing a 3x2 filter coefficient matrix  
having the values

Diode Display, Active Matrix Liquid Crystal Display  
(AM- LCD), and Active Matrix Organic Light Emitting  
Diode Dis- play (AMOLED).

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| <b>Summary report:</b><br><b>Litera Compare for Word 11.10.1.2 Document comparison done on 7/9/2025</b><br><b>12:49:57 PM</b> |      |
| <b>Style name:</b> No formatting                                                                                              |      |
| <b>Intelligent Table Comparison:</b> Active                                                                                   |      |
| <b>Original filename:</b> US 20030128179 Credelle-179 Redacted.pdf                                                            |      |
| <b>Modified filename:</b> US 7492379 Credelle-379 Redacted.pdf                                                                |      |
| <b>Changes:</b>                                                                                                               |      |
| <u>Add</u>                                                                                                                    | 740  |
| <del>Delete</del>                                                                                                             | 512  |
| <del>Move From</del>                                                                                                          | 51   |
| <u>Move To</u>                                                                                                                | 51   |
| <u>Table Insert</u>                                                                                                           | 6    |
| <del>Table Delete</del>                                                                                                       | 0    |
| <u>Table moves to</u>                                                                                                         | 0    |
| <del>Table moves from</del>                                                                                                   | 0    |
| Embedded Graphics (Visio, ChemDraw, Images etc.)                                                                              | 12   |
| Embedded Excel                                                                                                                | 0    |
| Format changes                                                                                                                | 0    |
| <b>Total Changes:</b>                                                                                                         | 1372 |