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(54) **SYSTEM AND METHOD FOR DECODING AND ANALYZING BARCODES USING A MOBILE DEVICE**

(75) Inventors: **Olivier Attia**, New York, NY (US); **Prateek Shrivastava**, Newark, NJ (US); **Roman Zastepine**, Brooklyn, NY (US); **Avi Outmezguine**, Brooklyn, NY (US)

(73) Assignee: **Scanbuy, Inc.**, New York, NY (US)

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(51) **Int. Cl.**
G06K 7/10 (2006.01)

(52) **U.S. Cl.** **235/462.46**; 235/462.1; 235/462.08; 382/190

(58) **Field of Classification Search** 235/462.46, 235/462.25, 462.01, 462.07, 462.11, 383, 235/385; 382/289; 349/117; 455/422
See application file for complete search history.

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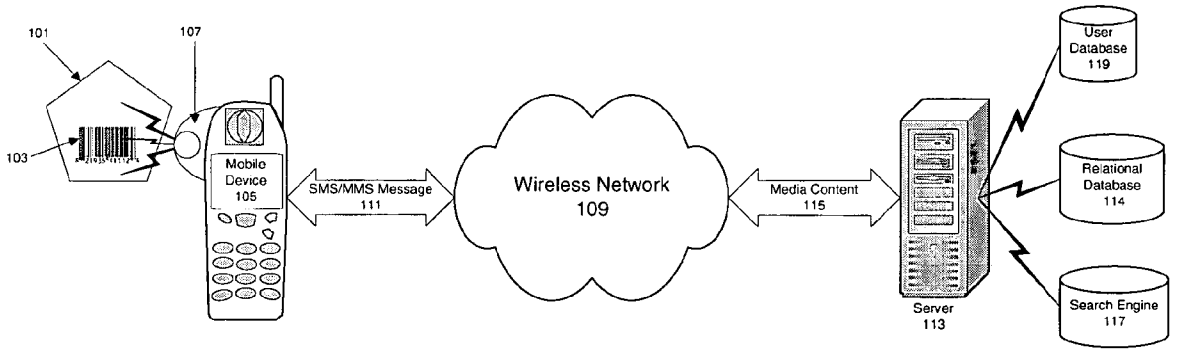
Primary Examiner—Steven S. Paik
(74) *Attorney, Agent, or Firm*—Wilmer Cutler Pickering Hale and Dorr LLP

(57) **ABSTRACT**

The present invention discloses a system and method for decoding barcodes using mobile device. Generally, the barcode image is acquired via a digital camera attached to the mobile device. After the barcode image has been acquired, software located on the mobile device enhances the barcode image and subsequently decodes the barcode information. The barcode information is then transmitted to a server via a wireless network. The server processes the barcode information and transmits media content related to the barcode back to the mobile device.

15 Claims, 11 Drawing Sheets



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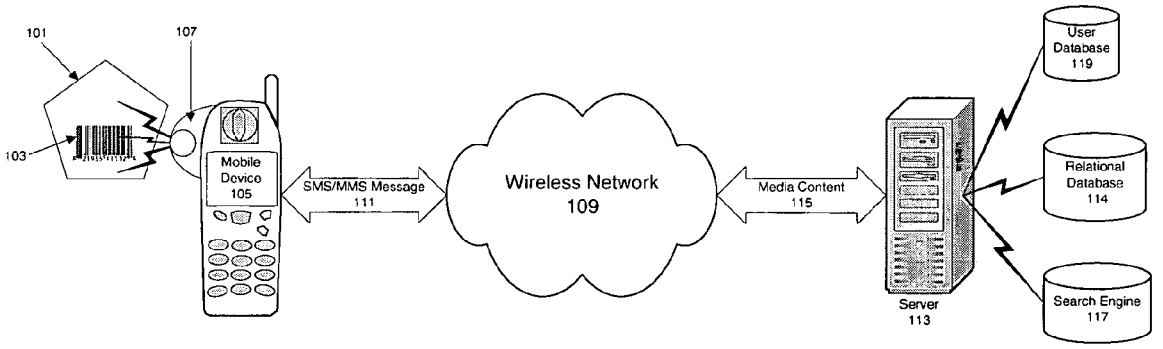
101
107
103
Mobile Device 105
SMS/MMS Message 111
Wireless Network 109
Media Content 115
Server 113
User Database 119
Relational Database 114
Search Engine 117

FIG. 1

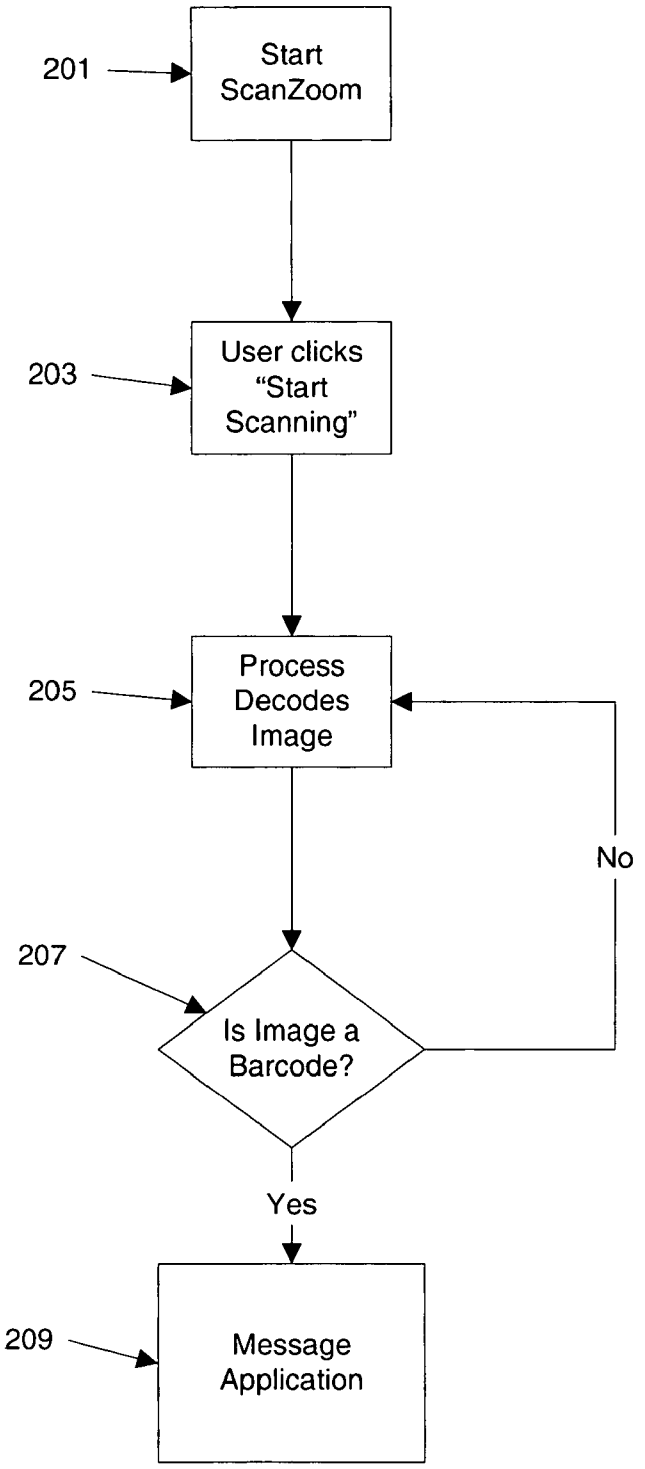
201
Start ScanZoom
203
User clicks "Start Scanning"
205
Process Decodes Image
No
207
Is Image a Barcode?
Yes
209
Message Application

FIG. 2A

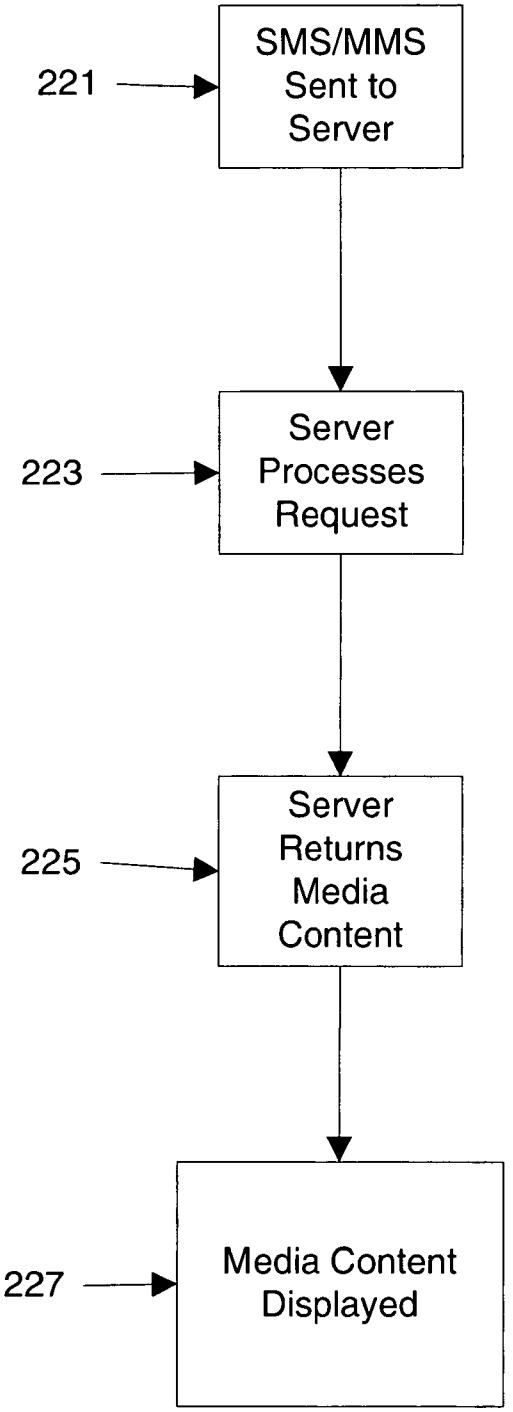
221
SMS/MMS Sent to Server
223
Server Processes Request
225
Server Returns Media Content
227
Media Content Displayed

FIG. 2B

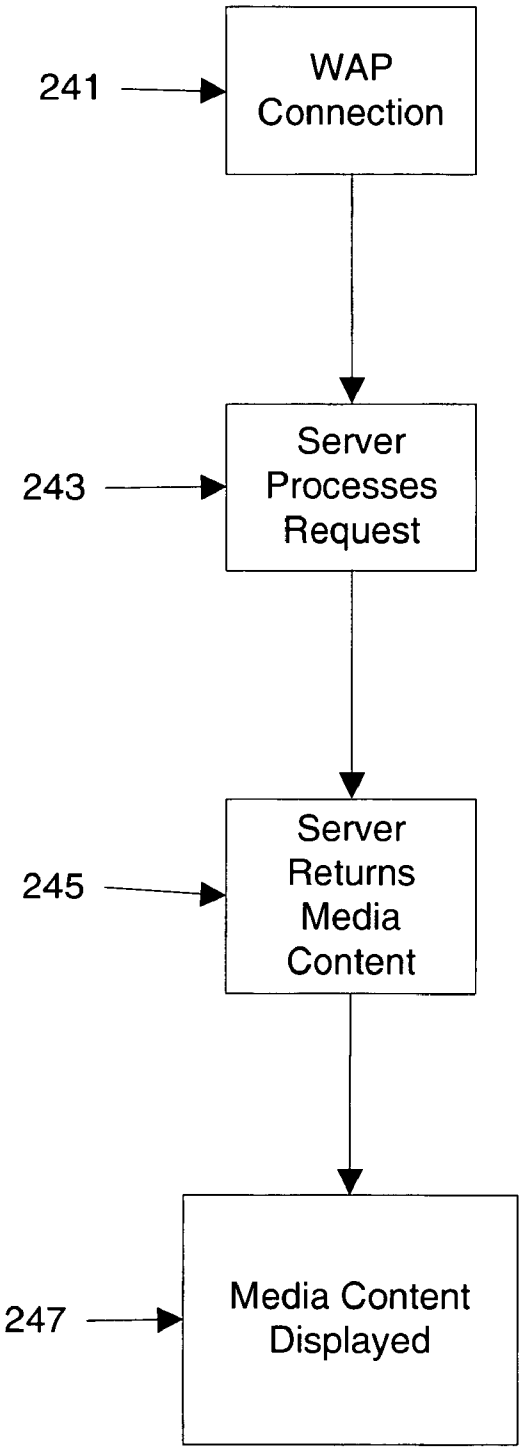
241
WAP Connection
243
Server Processes Request
245
Server Returns Media Content
247
Media Content Displayed

FIG. 2C

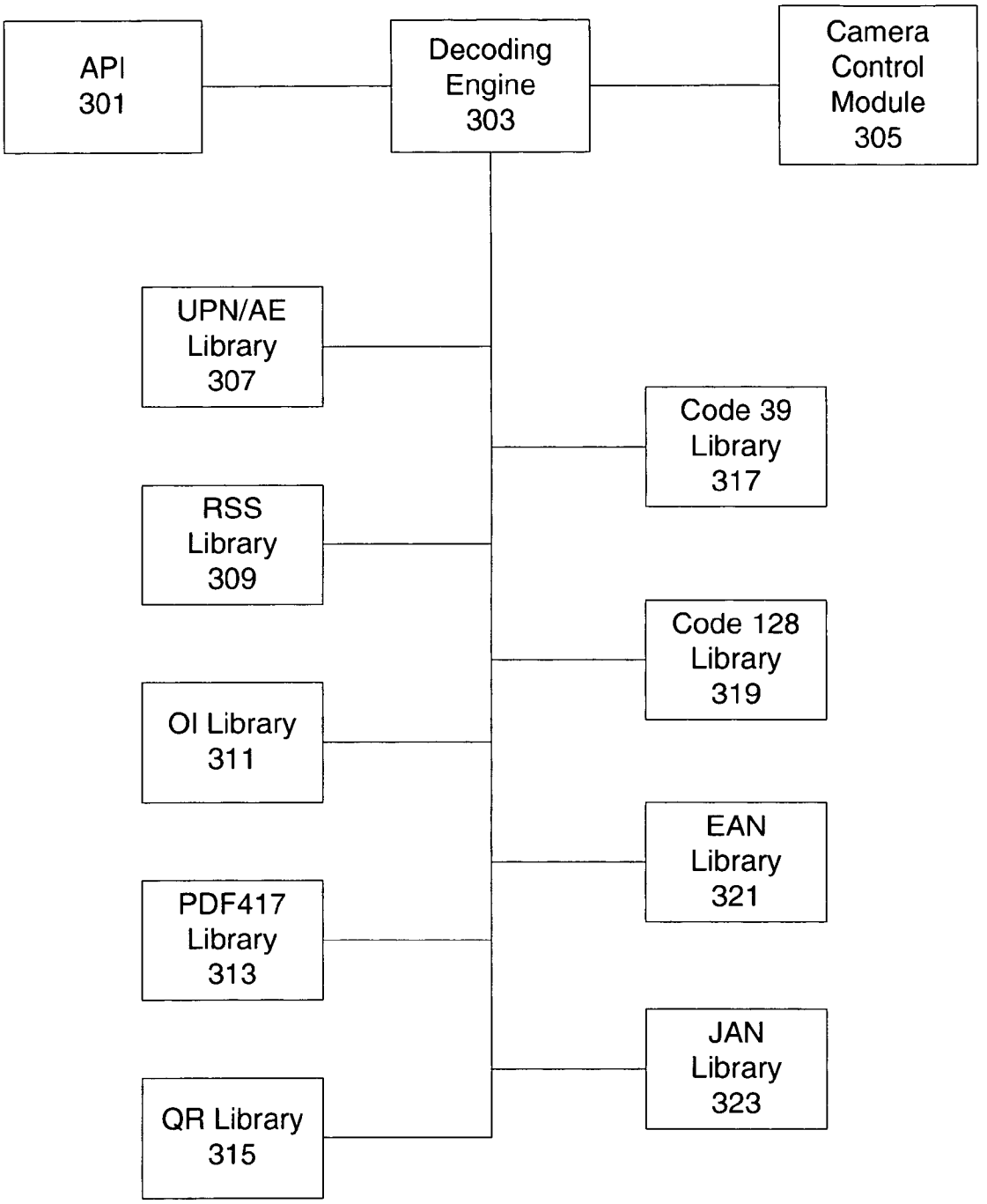
API
301
Decoding
Engine
303
Camera
Control
Module
305
UPN/AE
Library
307
RSS
Library
309
OI Library
311
PDF417
Library
313
QR Library
315
Code 39
Library
317
Code 128
Library
319
EAN
Library
321
JAN
Library
323

FIG. 3A

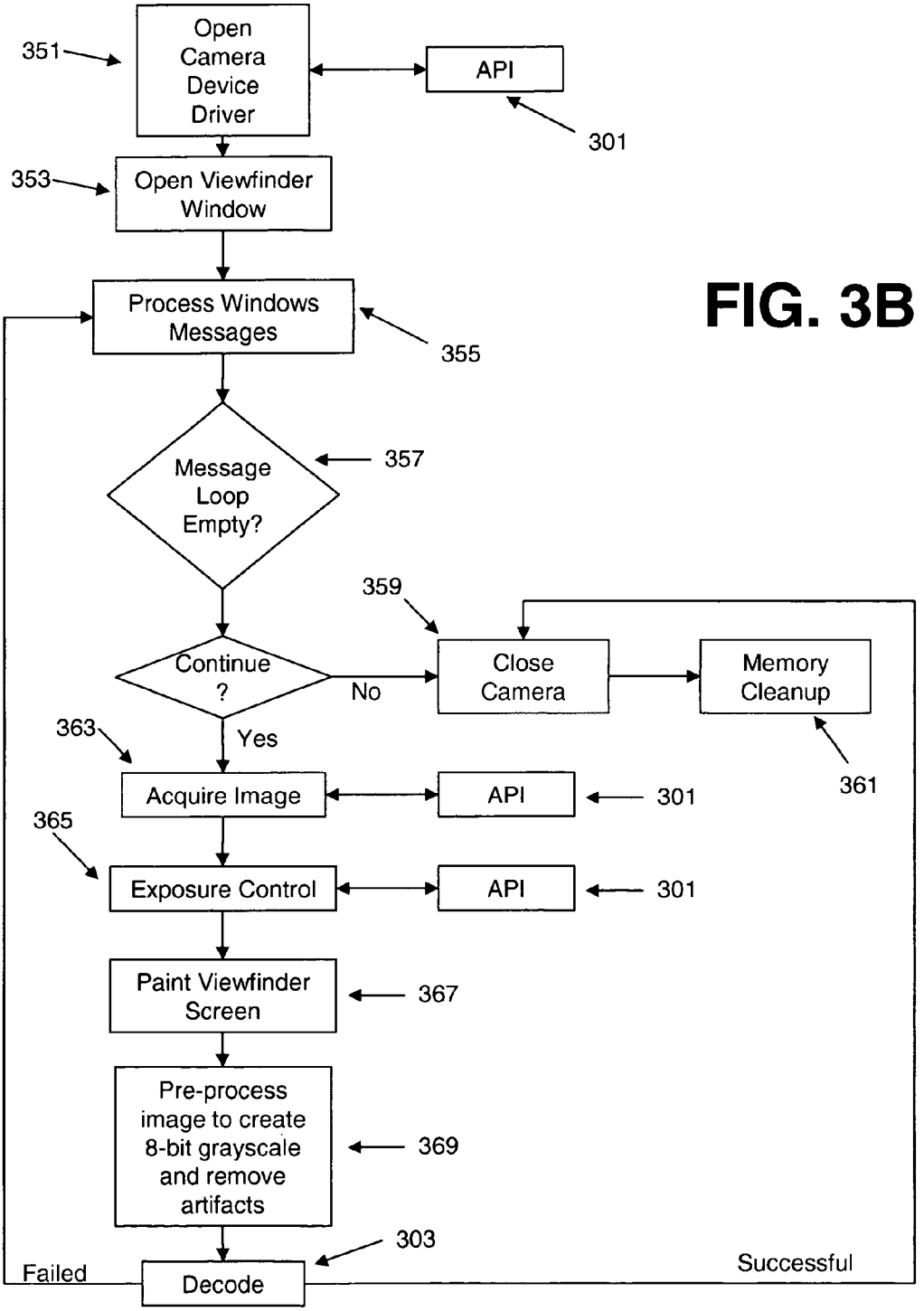
351
Open Camera Device Driver
API
301
353
Open Viewfinder Window
Process Windows Messages
355
Message Loop Empty?
357
359
Continue ?
No
Close Camera
Memory Cleanup
361
363
Yes
Acquire Image
API
301
365
Exposure Control
API
301
Paint Viewfinder Screen
367
Pre-process image to create 8-bit grayscale and remove artifacts
369
303
Failed
Decode
Successful

FIG. 3B

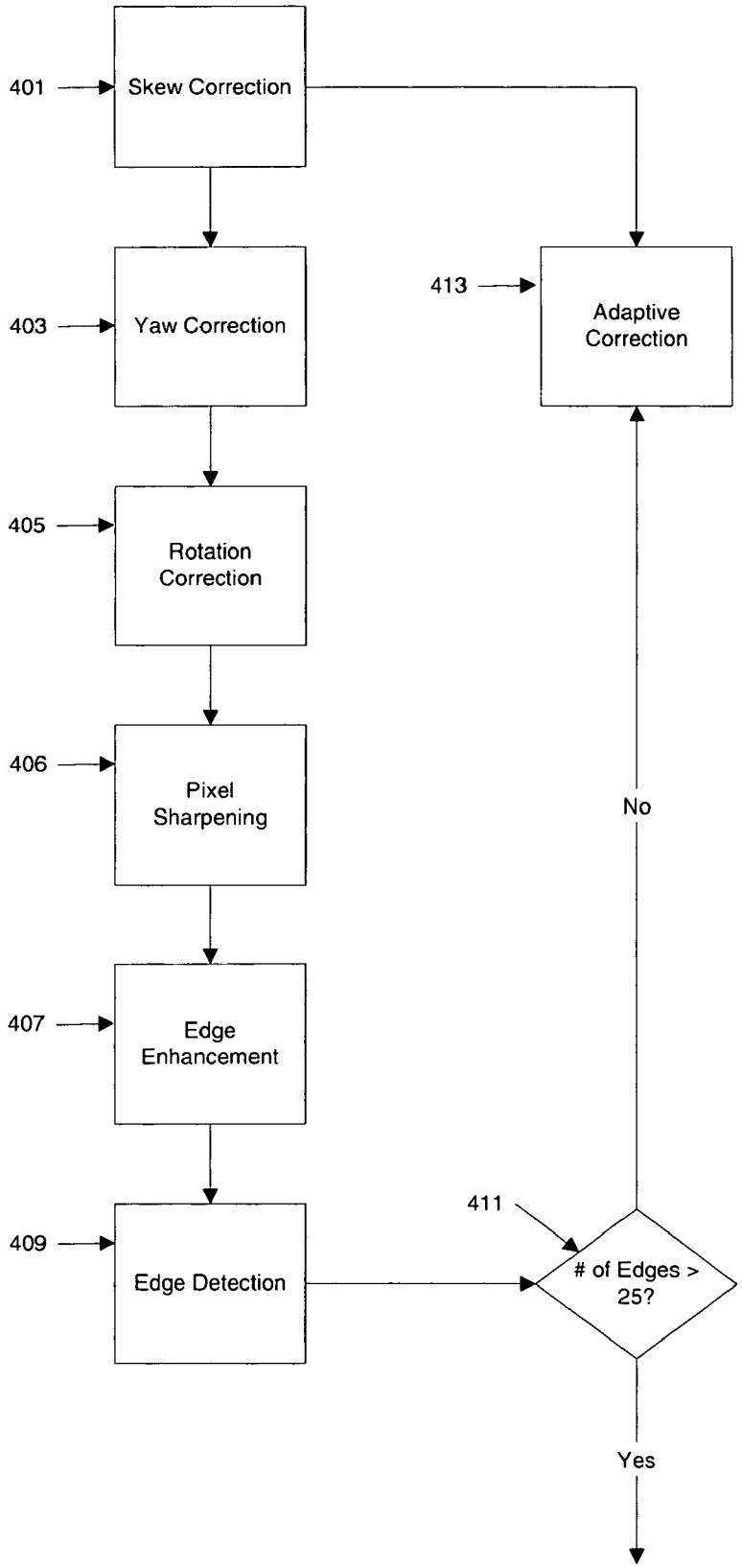
401
Skew Correction
403
Yaw Correction
405
Rotation Correction
406
Pixel Sharpening
407
Edge Enhancement
409
Edge Detection
413
Adaptive Correction
411
# of Edges > 25?
No
Yes

FIG. 4A

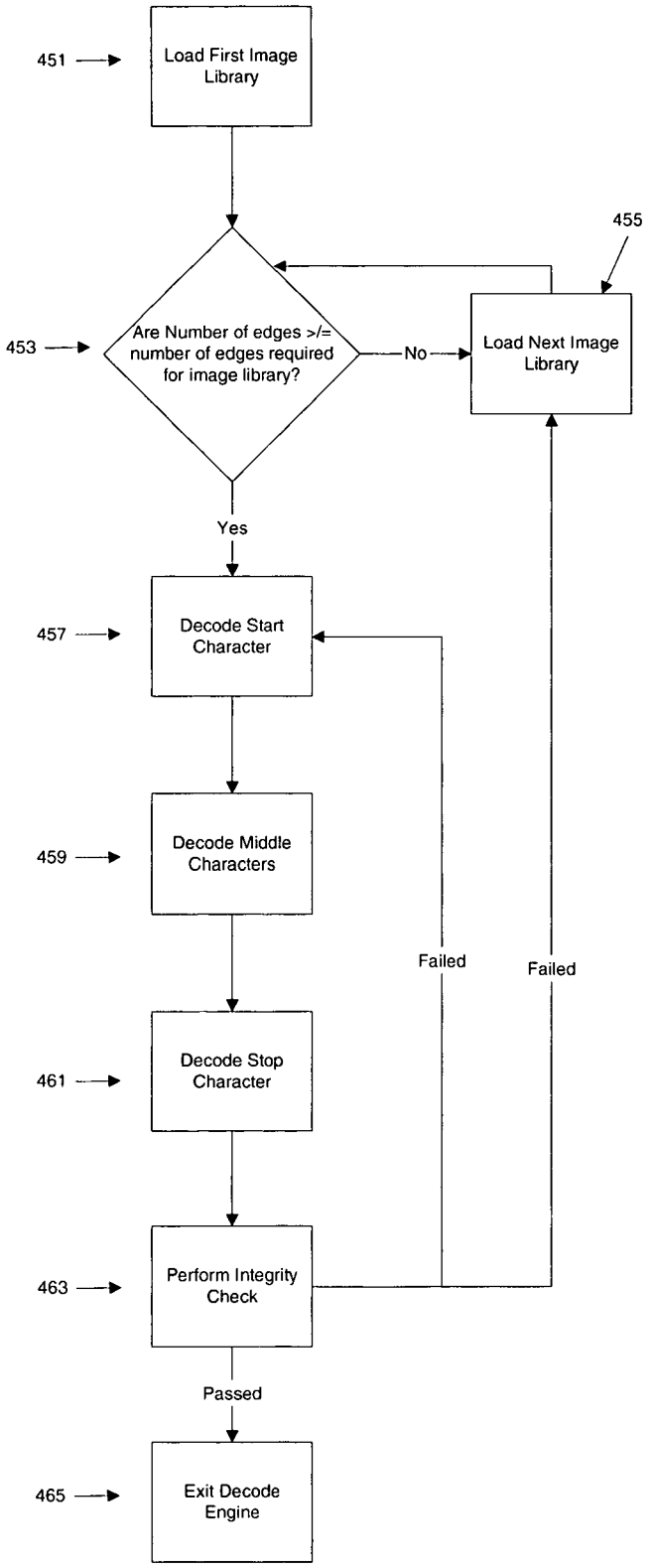
451
Load First Image Library
455
453
Are Number of edges >/= number of edges required for image library?
No
Load Next Image Library
Yes
457
Decode Start Character
459
Decode Middle Characters
Failed
Failed
461
Decode Stop Character
463
Perform Integrity Check
Passed
465
Exit Decode Engine

FIG. 4B

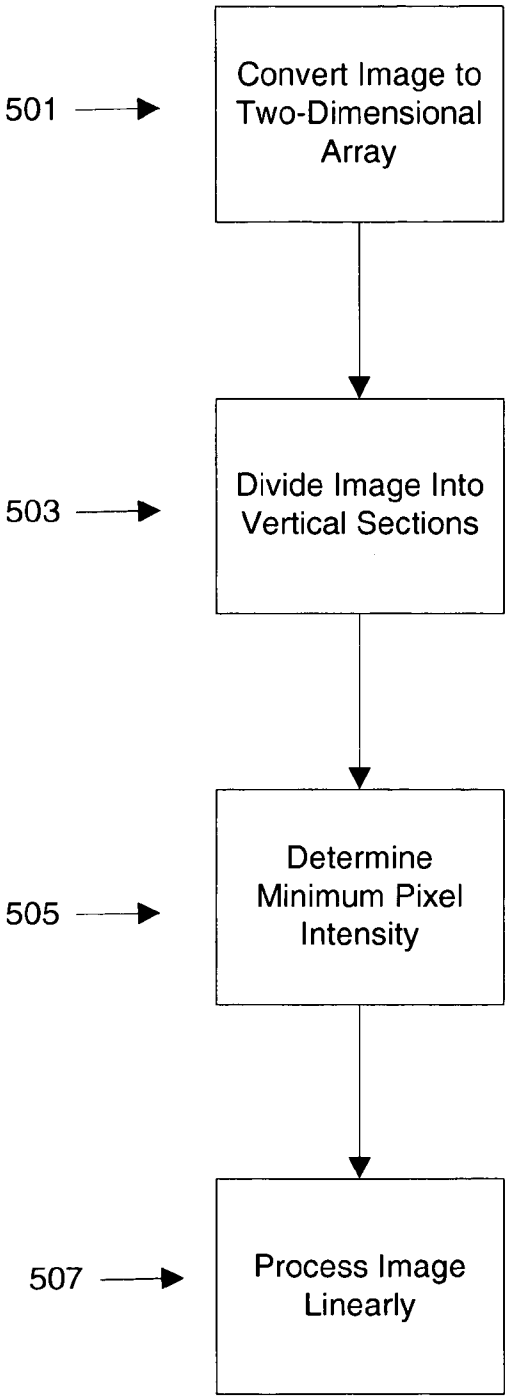
501
Convert Image to Two-Dimensional Array
503
Divide Image Into Vertical Sections
505
Determine Minimum Pixel Intensity
507
Process Image Linearly

FIG. 5A

FIG. 5B

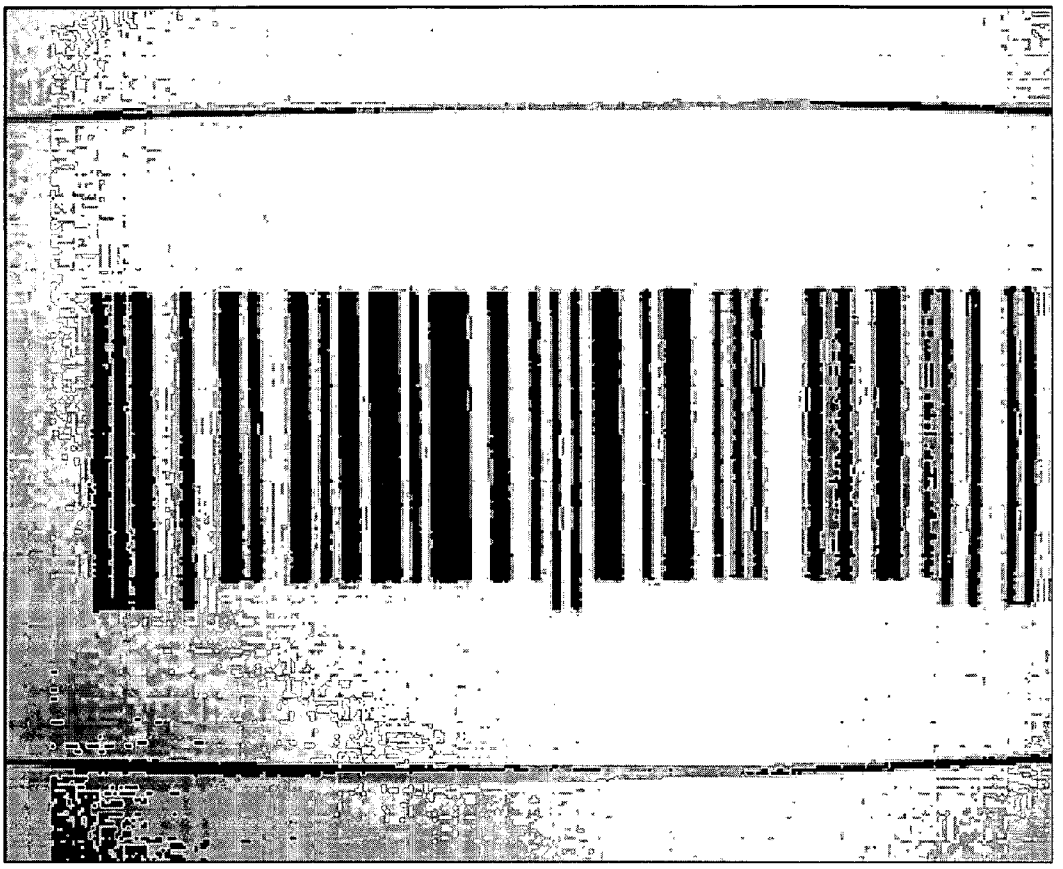

FIG. 5C

SYSTEM AND METHOD FOR DECODING AND ANALYZING BARCODES USING A MOBILE DEVICE

PARENT CASE TEXT

This application claims the benefit of provisional application No. 60/487,237 filed Jul. 16, 2003.

FIELD OF THE INVENTION

The present invention relates generally to the field of barcode scanning and decoding using a mobile device. More specifically, the present invention uses optical decoding techniques to decode barcodes acquired via a camera phone or other similarly equipped device.

BACKGROUND OF THE INVENTION

Barcodes have been utilized for identifying and pricing objects for more than thirty years. Most typically, barcodes are used in retail to identify the item of merchandise. For example, a gallon of milk may contain a barcode that, when scanned, will notify the cashier of the price of the milk.

Yet in recent years, barcodes have acquired new purposes as computers and barcode scanners have become more portable. The circuitry required to scan a conventional one-dimensional barcode can now be housed in a device as small as a typical keychain. As a result, many mobile telephones, personal digital assistants ("PDAs"), and pagers can be retrofitted with or connected to a laser-based scanning device. This allows the mobile device to function as a scanner capable of storing hundreds or thousands of scanned barcodes.

Mobile devices with attached scanners have allowed for the development of a new niche in the wireless electronics business. Some companies have developed software and hardware which allows a user to scan any barcode and be redirected to media information (e.g., a website, product description, price, etc.) about the scanned product. These programs provide a link between the physical and online world which previously did not exist.

However, mobile devices with attached scanners possess some drawbacks which have curtailed their expansion into the mobile marketplace. First, there are few mobile devices produced for the general public that contain integrated laser-based scanners. Therefore, for a user to acquire scanning capability for a mobile device, he/she must purchase additional equipment. The additional scanning equipment also adds size and weight to the mobile device, thereby reducing its mobility.

Currently, many cell phones and mobile devices are available with built-in cameras. The explosion of the availability of affordable digital cameras and their inclusion into mobile devices is driven by several factors. One of the most important is the recent availability of inexpensive image sensors based on CMOS technology. The cameras on these devices provide a means for capturing the barcode information which was previously only accessible via a laser-based scanner. Decoding barcode images from digital cameras included in mobile devices presents several difficult problems. These problems go well beyond the challenges addressed in commercial barcode readers. Barcode decoding algorithms from commercial products will not consistently decode images from a consumer portable device. Some of these problems are addressed below:

Lighting:

Most mobile devices with integrated digital cameras do not have built-in flashes and rely solely on the ambient light for illumination. Using highly variable ambient light makes pattern recognition much more difficult. Shadows, shading across the length of a barcode, overexposure, underexposure, and similar problems that are typical of any camera not utilizing a flash can foil traditional barcode decoding algorithms that are designed for highly controlled lighting environments.

Size:

The distance between a digital camera and its target object is not usually rigidly controlled. This translates into a large range of possible sizes (magnifications) that a barcode can have on a fixed size image sensor.

Skew:

As any photographer knows, taking pictures at an angle changes the apparent shape of the object to a viewer. A barcode with a rectangular shape, when viewed straight-on, can look like a trapezoid (or irregular quadrilateral) when viewed from an angle. The location and addressing of image pixels for a barcode change dramatically when viewed from the side, or tilted. Algorithms to decode barcodes from digital images must be able to address images distorted from skewed viewing angles, but must do so within the constraints of limited hardware, processing power, and memory typically found in mobile devices such as PDAs and handsets.

Battery Power:

Portable devices run on batteries—the smaller the better. Barcode decoding algorithms for cameras must be very efficient so as to use low amounts of CPU power. Charge coupled diode ("CCD") devices and barcode scanners using laser light generally require a large amount of power, and are not well suited for battery powered, handheld devices.

Color Imagers:

Consumer oriented devices such as mobile handsets generally are designed with color image sensors. However, barcode scanning typically operates best with gray-scale information. Color data typically requires three times the amount of storage and handling required by gray-scale. Data needs to be transferred through the camera's CPU and memory to be processed. For color imagers, specific image processing algorithms are required in order to avoid problematic image artifacts during the translation from color to grayscale.

Focus:

Digital cameras for portable devices are usually designed to work at a variety of distances. The need for a wider range of focus in cameras results in a trade off between the cost of the lens component and the sharpness of a typical image. Decoding algorithms for embedded digital cameras must be able to cope with a moderate degree of focus problems.

Low-Cost Lens Components:

In order to meet cost constraints of many portable device markets, manufacturers often compromise on the optical quality of camera lenses. This can present decoding technology with a different set of challenges from the simple focal length based focus problem noted above. Low-cost lens components can produce image distortions that are

localized to a specific region or form a changing gradient across the image. This requires additional sophistication for decoding algorithms.

Limited Resolution:

The cost of a digital imaging CMOS sensor increases as the number of image pixels increases. Although the Asian market has seen the release of general purpose consumer devices like PDAs and cell phones with "megapixel" image resolution, it is unlikely these devices will be released in the mainstream European and North American markets in the near future. With fewer pixels to work with, it is significantly more difficult to reliably decode barcodes from images.

Based on the aforementioned described problems with mobile digital imaging, there clearly exists a need for a system capable of capturing, decoding, and analyzing barcode information obtained from a digital camera enabled mobile device. Such a system would enable the average mobile device user to accurately and reliably scan and decode any barcode available.

SUMMARY OF THE INVENTION

The present invention provides a software application and system (hereinafter referred to as "ScanZoom") designed to successfully process and decode barcodes acquired via digital imaging techniques. ScanZoom software empowers a user to use a cell-phone or PDA equipped with a digital camera as a scanner of barcodes (one-dimensional and two-dimensional) or any other similar machine-readable code. It seamlessly integrates the barcode scanning technology with the digital camera (built-in or attached) of the cell phones/PDAs/Pocket PCs.

To utilize the ScanZoom software, a user downloads the ScanZoom onto his/her cell phone or PDA through wireless access protocol ("WAP"), infrared, or Bluetooth® connectivity. However, any protocol which allows a user to download a program to a mobile device may be utilized to download ScanZoom. Once the user has downloaded ScanZoom, the user launches the application. This causes ScanZoom to properly initialize the digital camera coupled to the mobile device to accept input. It starts the digital camera by calling its Application identification.

The user then takes a picture of the barcode using the digital camera. As soon as the barcode is captured, the ScanZoom software decodes the barcode utilizing a decoding engine integral to the ScanZoom software. Alternatively, the Scanzoom software may send the image of the barcode to a central server for decoding by sending a multimedia message service ("MMS") message to the server containing the barcode image.

If ScanZoom sends a MMS message to the server, it launches the MMS Application Id, composes the appropriate message on the fly, and then sends the message to the SMS/MMS server. On the server side, a global system for mobile communications ("GSM") modem connected to the server has the appropriate security identity module ("SIM") card and takes the services from any mobile service provider. The server fetches the MMS message from the GSM modem queue and performs appropriate action depending upon the message. The server can then send back a simple SMS message or can send back a multimedia message service ("MMS") message which can launch a WAP browser on the mobile device and direct it to the appropriate website, or send back information to the user through any other existing wireless protocol.

The location of the decoding depends entirely upon the processing capabilities of the mobile device utilized. For example, if the ScanZoom software is operating on a mobile device with lower system capabilities, such as a first generation camera phone, the mobile device will automatically send the digital image of the barcode to a server for decoding.

The barcode decoding engine continuously runs in a loop until it's able to decode the image taken by the digital camera into a barcode. If the barcode cannot be properly resolved, the user is prompted to take another picture of the desired barcode.

Additionally, the barcode decoding may also be performed in real time. The ScanZoom software accomplishes this by constantly capturing and processing the image of the barcode until it is correctly decoded. This eliminates the extra step of the user having to press a button to capture an image of the barcode.

After the barcode has been correctly resolved either by the mobile device or the server, the mobile device displays the appropriate media content to the user. The media content displayed to the user depends entirely on the barcode scanned. For example, if a user scans a barcode on a compact disc, the ScanZoom application may launch a WAP browser and direct the user to a site which allows the user to purchase the compact disc electronically. As another example, if a user scans a barcode located on a food item, the server may return a SMS message to the mobile device indicating the nutritional contents of the scanned item.

Therefore, it is an object of the present invention to provide a software application and system capable of accurately and reliably decoding barcodes and other machine-readable codes acquired via a digital camera connected to a mobile device.

Another object of the present invention is to provide a software application and system which allows for the decoding of barcodes in a wide range of conditions.

An additional object of the present invention is to provide a software application and system for decoding barcodes which is quick and responsive.

Yet another object of the present invention is to provide a software application and system for decoding barcodes which is robust under adverse lighting, imaging, and focusing conditions.

Still another object of the present invention is to provide a software application and system for decoding multiple barcode formats.

Another object of the present invention is to provide a software application and system which does not adversely affect device performance, usability, or form factor.

Furthermore, an object of the present invention is to provide a software application and system for decoding barcodes which does not significantly impact device power consumption nor degrade general camera performance.

It is another object of the present invention to provide a barcode decoding system which requires minimal or no changes to the manufacturing process of the mobile devices.

An additional object of the present invention is to provide a barcode decoding system having a low incremental cost per device.

Another object of the present invention is to provide a highly reliable barcode decoding system requiring minimal user support.

These and other objects of the present invention will be made clearer with reference to the following detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts a schematic diagram of the network configuration utilized in the preferred embodiment of the invention.

FIG. **2**A depicts a flowchart showing the steps the ScanZoom software utilizes to image and decode a barcode.

FIG. **2**B depicts a flowchart that the ScanZoom software utilizes if MMS messaging is utilized to transmit the captured barcode.

FIG. **2**C depicts a flowchart that the ScanZoom software utilizes if WAP messaging is utilized to transmit the scanned barcode.

FIG. **3**A depicts a schematic diagram showing the product architecture of the ScanZoom software application.

FIG. **3**B depicts a flowchart showing the steps utilized by ScanZoom to acquire the barcode image and prepare it for decoding.

FIG. **4**A depicts a flowchart showing the process utilized by the decoding engine to enhance an image before decoding.

FIG. **4**B depicts a flowchart showing the process utilized by the decoding engine to decode a barcode.

FIG. **5**A depicts a flowchart showing the process utilized by the ScanZoom software to sharpen an image.

FIG. **5**B depicts a typical barcode image acquired using a digital camera.

FIG. **5**C depicts the barcode of FIG. **5**B after it has undergone sharpening utilizing the sharpening filter depicted in FIG. **5**A.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

The following presents a detailed description of a preferred embodiment (as well as some alternative embodiments) of the present invention. However, it should be apparent to one skilled in the art that the described embodiment may be modified in form and content to be optimized for a wide variety of situations.

With reference first to FIG. **1**, shown is a schematic diagram of the network configuration utilized in the preferred embodiment of the present invention. In this figure, product **101** contains barcode **103** which may be placed on product **101** in a variety of ways. For example, barcode **103** may be printed directly onto product **101** utilizing conventional printing techniques. Alternatively, barcode **103** may be affixed to product **101** utilizing a sticker, tag, etc.

Barcode **103** may be any machine-readable code utilizing either a public standard encoding symbology or a proprietary symbology. Some examples of one and two dimensional symbologies include, but are not limited to, UPC-A, UPC-E, ISBN, RSS-14, RSS-14E, RSS-14L, Interleaved 2 of 5, EAN/JAN-8, EAN/JAN-13, Code 39, Code 39 Full ASCII, Code 128, PDF417, QR Code, Data Matrix, and Optical Intelligence 2D.

To scan barcode **103**, a user utilizes mobile device **105** with attached or embedded digital camera **107**. The user first launches the ScanZoom application on mobile device **105**. If the ScanZoom software has not yet been loaded onto mobile device **105**, a user may do so by downloading the program via WAP, Bluetooth, or infrared connectivity.

Mobile device **105** may be any device capable of digitally imaging barcode **103** such as a camera phone, mobile phone with camera attachment, PDA, PDA with camera attachment, Pocket PC, Palm device, laptop, desktop, etc.

Once an image of barcode **103** has been acquired by mobile device **105**, the ScanZoom software loaded on mobile device **105** decodes the barcode directly utilizing mobile device **105**'s internal circuitry. The ScanZoom software can be ported to most any mobile device operating system including, but not limited to, Symbian OS, Palm OS, Windows CE, Windows Mobile, and SmartPhone. The decoded barcode information is then sent to wireless network **109** via SMS/MMS message **111**. Wireless network **109** routes SMS/MMS message **111** to the appropriate server **113**. Server **113** then processes the received barcode information and relays the appropriate media content **115** to mobile device **105** via wireless network **109**.

Alternatively, mobile device **105** may not process the barcode image at all. In this situation, mobile device **105** would send the entire barcode image to server **113** via MMS message **111**. ScanZoom software loaded onto server **113** would be responsible for correctly decoding barcode **103**.

Yet in another embodiment, mobile device may scan barcode **103** in real time, thereby eliminating the step of capturing a photo of the barcode. In this embodiment, the ScanZoom software located on mobile device **105** constantly acquires images of barcode **103** and stores them in memory. Each of these images is subsequently processed until the barcode is correctly decoded. Once barcode **103** has been decoded, mobile device **105** stops acquiring images of barcode **103**.

Server **113** may process SMS/MMS message **111** in many different ways. In a first embodiment, server **113** may use relational database **114** to pull up product information pertaining to product **101**. The server would then forward the product information to mobile device **105** via a SMS/MMS message. If a MMS message is sent to mobile device **105**, this may cause a WAP browser loaded on mobile device **105** to be redirected to the appropriate site.

In a second embodiment, server **113** may process SMS/MMS message **111** by using relational database **114** to pull up product information related to product **101** and then utilize search engine **117** to search for similar products or information pertaining to it. The results of the search would then be sent to mobile device **105** via a SMS/MMS message. As should be evident from these two described embodiments, the barcode information can be utilized in an almost limitless amount of ways.

To provide additional security, a user of mobile device **105** may be prompted to provide a username and/or password to access server **113**. Server **113** would use user database **119** to properly authenticate users. Users not having an account contained in user database **119** would not be granted access to server **113** in any capacity.

Referring next to FIG. **2**A, shown is the process utilized by ScanZoom to acquire and decode barcode **103** once the application has been launched. A user first launches the ScanZoom program on mobile device **105** by selecting its icon from a list of programs located on the device in step **201**. Generally, this will initialize the camera and all the network resources needed by ScanZoom for the application to function properly. Once the user has started the program, a message appears directing the user to take a picture of barcode **103** in step **203**. ScanZoom provides the user with a "preview" window which functions as a viewfinder, allowing the user to properly center and align the barcode before taking a picture. Once the barcode image has been acquired by digital camera **107**, ScanZoom attempts to decode the barcode utilizing its proprietary barcode decoding algorithm in step **205**. If the software cannot decode barcode **103** on a first attempt in step **205**, the ScanZoom software attempts to

decode the image a finite amount of times. The number of decoding attempts can either be fixed or able to be altered by the user. Once barcode **103** has been properly decoded as verified in step **207**, mobile device **105** prepares the decoded information for transfer to server **113** to undergo further processing in step **209**.

FIG. **2**B depicts the process utilized by the ScanZoom software if the decoded barcode information is sent to server **113** via SMS/MMS message **111**. In this scenario, mobile device **105** first encodes the decoded barcode information into SMS/MMS message **111** in step **221**. SMS/MMS message **111** is then processed by server **113** in step **223**. As previously discussed with respect to FIG. **1**, server **113** may utilize any combination of relational database **114**, search engine **117**, or user database **119** to process the barcode information. Once the barcode has been processed in step **223**, server **113** sends the resulting media content **115** back to mobile device **105** in step **225**. Media content **115** is then displayed on the screen of mobile device **105** in step **227**.

Alternatively, if a WAP connection is utilized to send the barcode information to server **113** via wireless network **109**, the process depicted in FIG. **2**C is utilized. First, mobile device **105** conditions the barcode information for transfer via WAP in step **241**. Once the barcode information arrives at server **113**, the barcode information is depacketized and processed by server **113** in step **243**. Once the barcode has been processed in step **243**, server **113** sends the resulting media content **115** back to mobile device **105** in step **245**. Media content **115** then causes the proper site to be displayed on the screen of mobile device **105** in step **247**.

Turning next to FIG. **3**A, shown is a schematic diagram depicting the product architecture of the ScanZoom software. The ScanZoom software is composed of three main modules: the application program interface ("API") **301**, decoding engine **303**, and camera control module **305**. API **301** is the interface which the user utilizes to interact with the ScanZoom software. API **301** guides the user through all the steps required to decode and process barcode **103**.

The steps utilized to acquire the barcode image and prepare it for decoding are shown in greater detail in FIG. **3**B. As shown, API **301** first directs camera control module **305** to initialize the application ID for digital camera **107** in step **351**. This sets up digital camera **107** to accept input. Next, API **301** causes a "viewfinder" window to open on mobile device **105**'s display in step **353**. This allows the user to make sure that barcode **103** is in proper focus and amply illuminated.

API **301** next processes the windows messages in step **355**. Windows messages are messages from the camera that interrupt the ScanZoom program if certain events have occurred. For example, a windows message may indicate that a new SMS message has been received or there is an incoming telephone call. Once the windows messages have been properly processed, API **301** checks to see if the windows message loop is empty in step **357**. If the windows message loop is not empty, camera control module **305** closes digital camera **107***s* application ID in step **359**. All message and pictures are then cleared from the camera's active memory in step **361**.

However, if the windows message loop is empty, the user is then directed to push a button on mobile device **105** to take an image of barcode **103** in step **363**. Alternatively, the image may be acquired automatically by mobile device **105** for "on-the-fly" decoding. Camera control module **305** interacts directly with API **301** to perform this step since the user must physically push a button on mobile device **105** to take the image. Alternatively, this feature may be fully automated.

Once the image of barcode **103** has been acquired and stored in memory, the image undergoes exposure control in step **365** to correctly compensate for the illumination. More specifically, this step correctly adjusts camera features such as the shutter speed. For example, if the ambient light is low, exposure compensation step **365** may compensate for this by increasing the shutter speed.

At this point in the image acquisition process, the acquired image is displayed to the user for review in step **367**. If the user chooses to accept the acquired image, camera control module **305** next converts the image to an eight-bit grayscale image in step **369**. Camera control module **305** additionally removes artifacts from the image which are typical of digital images. The artifacts are removed using pattern recognition because barcodes have definite shapes and alien features may be easily eliminated using pattern recognition.

The processed image is then passed to decoding engine **303** for decoding. If the decoding is not successful, API **301** returns the user to step **355** so that a new image can be acquired. However, if decoding is successful, API **301** closes the camera in step **359** and clears the camera's memory in step **361**.

Now referring back to FIG. **3**A, decoding engine **303** (utilized in step **205** of FIG. **2**A) is responsible for decoding barcode **103** acquired via digital camera **107**. Decoding engine **303** is designed to accommodate variations in brightness and contrast in the scanned image of barcode **103**. This is done through use of globally and locally adaptive image processing operations. Exposure levels can be very high or very low, without significant adverse affect on success of decoding. If contrast is low either because the ink presents little contrast with the substrate, or because the lighting conditions are poor, decoding engine **303** may still decipher barcode **103**. Even highly variable shading within an image is recognized and compensated for. The underlying technique utilized by decoding engine **303** to recognize features of barcode **103** is the detection of local pixel intensity patterns that may signal the presence of particular barcode features. This is in contrast to the approach of typical decode algorithms for more highly controlled commercial scanner or laser gun environments which typically do fixed thresholding or limited digital filtering which presumes a highly controlled environment and lighting configuration.

Decoding engine **303** is able to decode one and two dimensional barcodes with a CIF (typically 352×288) imager, and essentially all commonly used barcodes with a VGA (640×480) imager. Increasing the imager resolution generally improves the usability, decoding speed, and accuracy while increasing the range of viable barcodes.

In ordinary application usage, decoding engine **303** does not require special illumination sources due to its ability to decode barcodes from images with low contrast. For color imagers, decoding engine **303** utilizes specific image processing algorithms in order to avoid problematic image artifacts during the translation from color to grayscale. Decoding engine **303** utilizes fast image processing algorithms to perform the conversion so that the maximum amount of information is preserved, making for a robust, easy to use reader.

Decoding engine **303** is also able to cope with moderate amounts of image focus global impairment due to distance and lens focal length issues. Additionally, the decoding

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algorithm is optimized to work reliably even with appropriate low-cost lenses in inexpensive consumer cameras.

Decoding engine **303** is also designed to perform reliably in difficult decoding situations. It is successful in variable light, low contrast, low resolution, focus, and other impaired conditions. These abilities make decoding engine **303** perfectly suited to capture and decode barcode images in a variety of "real world" embedded digital camera device conditions.

More specifically, key technical decoding features used in decoding engine **303** include:

Rotation:

Decoding engine **303** enables identification and decoding of most barcodes at any degree of rotation from the normal orientation. Decoding engine **303** is designed for the more general "any orientation" case.

Geometric Distortions:

Decoding engine **303** is tolerant of "aspect ratio," "shear," "perspective," and other geometric image distortions. These distortions can be caused by a number of things such as the camera line of focus not being perpendicular to the plane of the barcode. Specific algorithms can tolerate deviations from the perpendicular in any direction.

Adaptive Correction:

One of the techniques used in several ways by decoding engine **303** is an adaptive, "multiple hypotheses" approach to detect the presence of specific features within barcode **103**. In general, while decoding an image of barcode **103**, a number of assumptions are made by decoding engine **303** about how characteristic features of barcode **103** are likely to appear in an image. For example, the precise width and intensity of a minimal bar in an image and the threshold at which a data bit in a matrix code is counted as on or off are critical to decoding an image. Initial default estimates of these parameters may be wrong, and only by adaptively correcting them can the image be decoded. Where appropriate, decoding engine **303** will re-examine an image that has failed to decode under one set of assumptions and introduce revised assumptions to improve the likelihood of correctly decoding barcode **103**.

Error Correction:

Decoding engine **303** additionally makes use of sophisticated error correction technology for two-dimensional barcode formats. The standard technique for error correction in dense barcodes is some variant of a "Reed-Solomon" algorithm. Decoding engine **303** uses the full power of this approach. Reed-Solomon techniques can correct a limited number of errors in these guesses. Decoding engine **303** makes guesses on most elements, but also identifies elements that are too poorly imaged or printed to make a reasonable guess. These are "erasures." Reed-Solomon error correction techniques can detect and correct more errors and thus has improved general results when erasures are identified.

Sub-Pixel Precision:

Decoding engine **303** also allows barcode information to be resolved to sub-pixel precision. The algorithms need to, and can, with certain barcode types, retrieve information from a code element occupying an area less than 1.5×1.5 pixels. Among the techniques employed by decoding engine **303** are specialized adaptive interpolation algorithms that take into account the precise local conditions surrounding the data feature being examined. Local conditions may include differences in lighting or printing quality, or secondary light scattering. Various image kernel operations are available to enhance the local image quality. The resulting outcome is better decoding accuracy, support for higher density codes and more robust performance.

Decoding engine **303** may utilize any number of symbol libraries to resolve the correct barcode information. As shown, decoding engine **303** may access UPN-A/E library **307**, RSS library **309**, OI library **311**, PDF417 library **313**, QR code library **315**, Code 39 library **317**, Code 128 library **319**, EAN library **321**, and JAN library **323**.

Finally, camera control module **305** operates in conjunction with API **301** to enable a user to take a photograph of barcode **103** with digital camera **107**.

Now referring to FIG. **4**A, shown is a flowchart of the steps utilized by decoding engine **303** to enhance the image of barcode **103**. Decoding engine **303** first attempts to de-skew the barcode image in step **401**. Generally, skew occurs when the barcode picture is taken at an angle. To compensate for this effect, decoding engine **303** first identifies the angle(s) of skew in the image and processes the picture accordingly to remove the skew.

Next, decoding engine **303** attempts to repair images which exhibit yaw in step **403**. Yaw occurs when the barcode or camera is moved during exposure, causing the image to exhibit streaks. Decoding engine **303** removes the yaw from images by using a filter specifically designed to remove such effects.

Once the skew and yaw in the image has been corrected, decoding engine **303** attempts to remove any rotation of the barcode from the normal orientation which may have occurred during imaging. This may be accomplished in a variety of ways in step **405**. For example, decoding engine **303** may first identify the angle of rotation of the image. This is much simpler for one-dimensional barcodes, but is also possible for two-dimensional barcodes. For one-dimensional barcodes, decoding engine **303** only has to calculate the angle at which the parallel bars in the barcode are rotated from the normal orientation. Once this has been determined, decoding engine **303** can apply a rotation function to the image to return the barcode image to the normal orientation.

Returning two-dimensional barcodes to a normal orientation requires much more processing because two-dimensional barcodes contain data in both the horizontal and vertical directions. To determine the angle of rotation, the barcode must be analyzed from at least two orientations, preferably perpendicular to each other. The results of the two analyzations can then be utilized to determine the angle of rotation of the two-dimensional barcode. The same rotation function used for one-dimensional barcodes, previously described, can also be used for two-dimensional barcodes to return the barcode image to the normal orientation.

Next, decoding engine **303** sharpens the image using either a standard sharpening filter or a proprietary filter in step **406**. The sharpening filter algorithm, described in FIG. **5**A, has been shown to be effective for sharpening images containing barcodes. First, the sharpening algorithm converts the gray-scale barcode image is broken down into a two-dimensional array in step **501**. Each entry in the two-dimensional array stores the horizontal and vertical coordinates (i.e., the "x" and "y" coordinates) of a single pixel. The image is then divided into an equal number of vertical sections in step **503**. The number of sections ("ns") is equal to the width of the image (in pixels) divided by the desired

width of the sections ("ws"). The width of the sections can either be user defined or automatically defined depending upon the size of the image. This converts the image to a three-dimensional array since each pixel also has an assigned section.

After the image has been divided into sections, the sharpening algorithm determines the minimum intensity of a pixel in each section in step **505**. The image is then processed linearly section by section in step **507**. This is done by assigning a pixel intensity of zero to all pixel intensities which are below a threshold black level. The threshold black level is user-defined and may be changed for each image or section being processed. In contrast, all pixel intensities having a pixel value above a threshold white value are assigned a pixel intensity of 255.

A pixel is also assigned a zero intensity if:

1. The value of the pixel lies within a predetermined range of the minimum pixel intensity for that section; or
2. The intensity of pixels surrounding a certain pixel has an intensity that lies within the predetermined range of minimum pixel intensity for that section.

After the image of the barcode has been processed in step **507**, the sharpening algorithm renders the processed image sections back into an image. An example input and output barcode which have been processed by the aforementioned sharpening algorithm are shown in FIG. **5**B and FIG. **5**C, respectively. The outputted image of FIG. **5**C has a much higher chance of being properly decoded than the inputted image of FIG. **5**B.

Now referring back to FIG. **4**A, decoding engine **303** applies an edge enhancement filter to the image in step **407**. This further removes any image anomalies which may have occurred during imaging or conversion to black and white. Once the edges are enhanced, decoding engine **303** counts the number of edges which occur in the barcode image in step **409**. An edge is a point in the image where there is a sudden change in the color values of the image. An edge that defines a transition from white to black (light to dark) is called a rising edge and an edge that defines the transition from black to white (dark to light) is called a falling edge. Since the quality of the image returned by the camera of the cell phone isn't of a very good quality, the edge detection process relies on the series of approximations and sub processes. Thus the edge detection of step **409** returns a collection of edges (i.e., points where it is believed that the value of the color changed from dark to light or light to dark).

If the number of detected edges is less than 25 as checked in step **411**, decoding algorithm **303** attempts to adjust the barcode image again using a new set of assumptions in step **413**. The image is then reprocessed using an unaltered version of the image stored in a buffer. If more than 25 edges are not detected after a number of iterations, the ScanZoom application informs the user that a barcode could not be located and the application terminates.

However, if the number of edges if found to be greater than or equal to 25, decoding engine **303** advances to the flowchart of FIG. **4**B. As shown in the flowchart, decoding engine **303** loads a first symbology library in step **451**. The symbology library may be UPN-A/E library **307**, RSS library **309**, OI library **311**, PDF417 library **313**, QR code library **315**, Code 39 library **317**, Code 128 library **319**, EAN library **321**, and JAN library **323** (see FIG. **3**A). Decoding engine then compares the number of edges a barcode needs to be in this library to the number of edges detected in the actual scanned barcode in step **453**. If the number of edges does not match, decoding engine **303** loads the next symbology library in step **455** and repeats the edge comparison with the new library. Detection engine **303** continues this comparison until a match is found.

When a match is found in step **453**, detection engine **303** proceeds to decode the start character of the barcode from the barcode image in step **457**. Typically, the first character in a barcode indicates the use of the code. For example, in UPC codes, if the start character is a six, it indicates that it the barcode is a standard UPC code. Detection engine **303** then decodes the middle characters of the barcode in step **459** and the stop character of the barcode in step **461**.

Each barcode font relies on static tables of values to decode each character. These tables are designed using the bit patterns in the barcode font's specification. Each barcode consists of both dark and light elements. The combination of the dark and light elements and their thickness decides the value of the character. The difference of two consecutive edges provides the width of an element. The widths of the elements are then converted into bit patterns and mapped against the static tables to derive the character value. If a good value is returned then the next set of edges is passed. A bad value signifies that the barcode character could not be decoded.

In many barcode formats, the stop character is used as a check digit to ensure that the barcode has been decoded correctly. Detection engine **303** performs such an integrity check in step **463**. If the integrity check fails, detection engine either loads another symbology library in step **455** or attempts to re-decode the image in step **457**. If the integrity check is passed in step **463**, decoding engine **303** is terminated in step **465** and the barcode data is forwarded to the messaging system (see FIG. **2**A, step **209**).

While the foregoing embodiments of the invention have been set forth in considerable detail for the purposes of making a complete disclosure, it should be evident to one skilled in the art that multiple changes may be made to the aforementioned description without departing from the spirit of the invention.

We claim:

1. A method of decoding a barcode, comprising:

imaging a barcode with a mobile device equipped with a digital camera;

converting said barcode image to an array of pixels;

dividing said array of pixels into vertical sections;

determining a first intensity for at least one pixel in each of said vertical sections;

assigning a second intensity to said at least one pixel if said first intensity is at least one of below a first threshold intensity and above a second threshold intensity to enhance said barcode image;

decoding said enhanced barcode image to obtain barcode information;

transmitting at least one of said barcode image and said barcode information from said mobile device to a server via a wireless network;

receiving media content associated with said barcode information from said server via said wireless network;

calculating the number of edges in said enhanced barcode image;

loading a first symbology library;

comparing said number of edges to a predetermined threshold require for said symbology library; and

decoding said barcode from said barcode image utilizing said symbology library.

2. A method of decoding a barcode according to claim 1, wherein at least one other symbology library is loaded if said number of edges is less than said predetermined threshold.

3. A method of decoding a barcode, comprising:
imaging a barcode with a mobile device equipped with a digital camera;
converting said barcode image to an array of pixels;
dividing said array of pixels into vertical sections;
determining a first intensity for at least one pixel in each of said vertical sections;
assigning a second intensity to said at least one pixel if said first intensity is at least one of below a first threshold intensity and above a second threshold intensity to enhance said barcode image;
decoding said enhanced barcode image to obtain barcode information;
transmitting at least one of said barcode image and said barcode information from said mobile device to a server via a wireless network; and
receiving media content associated with said barcode information from said server via said wireless network;
wherein said wireless network is a WAP network.

4. A method of decoding a barcode, comprising:
imaging a barcode with a mobile device equipped with a digital camera;
converting said barcode image to an array of pixels;
dividing said array of pixels into vertical sections;
determining a first intensity for at least one pixel in each of said vertical sections;
assigning a second intensity to said at least one pixel if said first intensity is at least one of below a first threshold intensity and above a second threshold intensity to enhance said barcode image;
decoding said enhanced barcode image to obtain barcode information;
transmitting at least one of said barcode image and said barcode information from said mobile device to a server via a wireless network; and
receiving media content associated with said barcode information from said server via said wireless network;
wherein said barcode information is transmitted to said server via an SMS message.

5. A method of decoding a barcode, comprising:
imaging a barcode with a mobile device equipped with a digital camera;
converting said barcode image to an array of pixels;
dividing said array of pixels into vertical sections;
determining a first intensity for at least one pixel in each of said vertical sections;
assigning a second intensity to said at least one pixel if said first intensity is at least one of below a first threshold intensity and above a second threshold intensity to enhance said barcode image;
decoding said enhanced barcode image to obtain barcode information;
transmitting at least one of said barcode image and said barcode information from said mobile device to a server via a wireless network; and
receiving media content associated with said barcode information from said server via said wireless network;
wherein said barcode information is transmitted to said server via an MMS message.

6. A system for decoding a barcode, comprising:
at least one machine readable barcode;
at least one mobile device equipped with a digital camera for imaging said machine readable barcode, wherein said system converts said barcode image to an array of pixels; divides said array of pixels into vertical sections; determines a first intensity for at least one pixel in each of said vertical sections; assigns a second intensity to said at least one pixel if said first intensity is at least one of below a first threshold intensity and above a second threshold intensity to enhance said barcode image; decodes said enhanced barcode image to obtain barcode information; calculates the number of edges in said enhanced barcode image; load a first symbology library; compares said number of edges to a predetermined threshold require for said symbology library; and decodes said barcode from said barcode image utilizing said symbology library; and
a wireless network in communication with said mobile device and in communication with a server, wherein said mobile device sends at least one of said barcode information and said barcode image to said server and receives media content associated with said barcode information from said server.

7. A system for decoding a barcode according to claim 6, wherein at least one other symbology library is loaded if said number of edges is less than said predetermined threshold.

8. A system for decoding a barcode, comprising:
at least one machine readable barcode;
at least one mobile device equipped with a digital camera for imaging said machine readable barcode, wherein said system converts said barcode image to an array of pixels; divides said array of pixels into vertical sections; determines a first intensity for at least one pixel in each of said vertical sections; assigns a second intensity to said at least one pixel if said first intensity is at least one of below a first threshold intensity and above a second threshold intensity to enhance said barcode image; and decodes said enhanced barcode image to obtain barcode information; and
a wireless network in communication with said mobile device and in communication with a server, wherein said mobile device sends at least one of said barcode information and said barcode image to said server and receives media content associated with said barcode information from said server;
wherein said wireless network is a WAP network.

9. A system for decoding a barcode, comprising:
at least one machine readable barcode;
at least one mobile device equipped with a digital camera for imaging said machine readable barcode, wherein said system converts said barcode image to an array of pixels; divides said array of pixels into vertical sections; determines a first intensity for at least one pixel in each of said vertical sections; assigns a second intensity to said at least one pixel if said first intensity is at least one of below a first threshold intensity and above a second threshold intensity to enhance said barcode image; and decodes said enhanced barcode image to obtain barcode information; and
a wireless network in communication with said mobile device and in communication with a server, wherein said mobile device sends at least one of said barcode information and said barcode image to said server and receives media content associated with said barcode information from said server;
wherein said barcode image is transmitted to said server via an SMS message.

10. A system for decoding a barcode, comprising:
at least one machine readable barcode;
at least one mobile device equipped with a digital camera for imaging said machine readable barcode, wherein said system converts said barcode image to an array of pixels; divides said array of pixels into vertical sections; determines a first intensity for at least one pixel

in each of said vertical sections; assigns a second intensity to said at least one pixel if said first intensity is at least one of below a first threshold intensity and above a second threshold intensity to enhance said barcode image; and decodes said enhanced barcode image to obtain barcode information; and

a wireless network in communication with said mobile device and in communication with a server, wherein said mobile device sends at least one of said barcode information and said barcode image to said server and receives media content associated with said barcode information from said server;

wherein said barcode information is transmitted to said server via an MMS message.

11. A system for decoding a barcode, comprising

at least one machine readable barcode;

at least one mobile device equipped with a digital camera for imaging said machine readable barcode, wherein said system converts said barcode image to an array of pixels; divides said array of pixels into vertical sections; determines a first intensity for at least one pixel in each of said vertical sections; assigns a second intensity to said at least one pixel if said first intensity is at least one of below a first threshold intensity and above a second threshold intensity to enhance said barcode image; and decodes said enhanced barcode image to obtain barcode information; and

a wireless network in communication with said mobile device and in communication with a server, wherein said mobile device sends at least one of said barcode information and said barcode image to said server and receives media content associated with said barcode information from said server;

wherein said mobile device utilizes an operating system from the list consisting of Symbian OS, Java, embedded VC++, Windows CE, and Palm OS.

12. A computer program product residing on a computer readable medium, the computer program product comprising instructions for causing a computer to:

convert a barcode image to an array of pixels, wherein said barcode is imaged with a mobile device equipped with a digital camera;

divide said array of pixels into vertical sections;

determine a first intensity for at least one pixel in each of said vertical sections;

assign a second intensity to said at least one pixel if said first intensity is at least one of below a first threshold intensity and above a second threshold intensity to enhance said barcode image;

decode barcode information from said enhanced barcode image;

transmit at least one of said enhanced barcode image and said barcode information from said mobile device to a server via a wireless network;

receive media content associated with said barcode information from said server via said wireless network;

calculate the number of edges in said enhanced barcode image;

load a first symbology library;

compare said number of edges to a predetermined threshold require for said symbology library; and

decode said barcode from said barcode image utilizing said symbology library.

13. A computer program product according to claim **12**, wherein at least one other symbology library is loaded if said number of edges is less than said predetermined threshold.

14. A wireless device, comprising:

means for imaging a barcode;

means for converting said barcode image to an array of pixels;

means for dividing said array of pixels into vertical sections;

means for determining a first intensity for at least one pixel in each of said vertical sections;

means for assigning a second intensity to said at least one pixel if said first intensity is at least one of below a first threshold intensity and above a second threshold intensity to enhance said barcode image;

means for decoding said enhanced barcode image to obtain barcode information;

means for transmitting at least one of said barcode image and said barcode information to a server;

means for receiving media content associated with said barcode information from said server;

means for calculating the number of edges in said enhanced barcode image;

means for loading a first symbology library;

means for comparing said number of edges to a predetermined threshold require for said symbology library; and

means for decoding said barcode from said barcode image utilizing said symbology library.

15. A wireless device according to claim **14**, further comprising means for loading at least one other symbology library if said number of edges is less than said predetermined threshold.

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