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 - (71) Applicant (for all designated States except US): **CY-PRESS SYSTEMS CORPORATION** [US/US]; 198 Champion Court, San Jose, CA 95134 (US).
 - (72) Inventors; and
 - (75) Inventors/Applicants (for US only): **DERKALOUS-DIAN, Moses** [US/US]; 12280 Corte Sabio #4206, San Diego, CA 92128 (US). **SIM, Harray** [CA/US]; 5701 Pogle Court, San Jose, CA 95138 (US). **NAGARAJ, Sundaram** [US/US]; 8282 Bryn Glen Way, San Diego, CA 92129 (US). **KRAMER, Marcus** [US/US]; 12165 Avenida Consentido, San Diego, CA 92128 (US).
 - (74) Agent: **SAKO, Bradley, T.**; Haverstock & Owens, LLP, 162 North Wolfe Road, Sunnyvale, CA 94086 (US).
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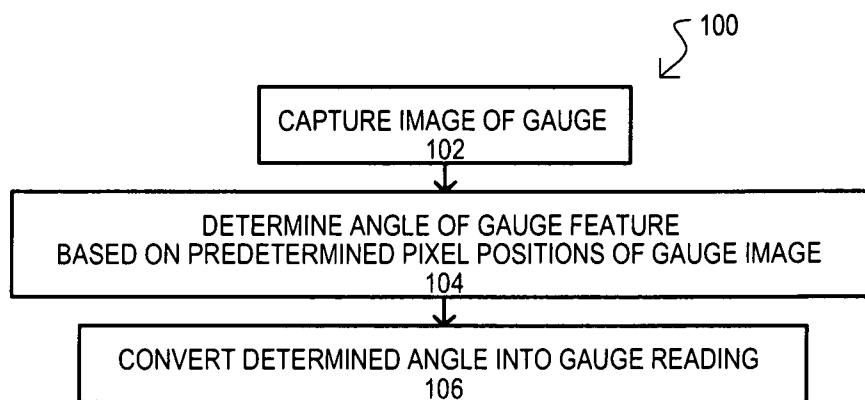


FIG. 1

(57) Abstract: A method of reading a gauge may include capturing a digital image of the gauge with a gauge reading device attached to the gauge, the digital image comprising a plurality of pixels; determining an angle of a gauge feature based on positions of predetermined pixels of the digital image; and converting the angle into a gauge reading. Gauge reader devices and network based systems are also disclosed.

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GAUGE MONITORING METHODS, DEVICES AND SYSTEMS

TECHNICAL FIELD

The present disclosure relates to devices and methods for acquiring a digital image of a gauge and generating a gauge reading from pixels positions of such an
5 image.

BACKGROUND

Industrial and other facilities may include monitor and/or control devices, such as gauges to track parts of processes or systems. Readings from such devices are periodically taken to ensure such processes/systems are operating as desired. This
10 can consume considerable time and manpower.

Systems may be upgraded by replacing an entire device (e.g., gauge) with a replacement device having a built in transmitting capability. A drawback to such an approach can be that replacement of an entire gauge can be invasive. In the event the gauge is utilized in an active process, the process may have to be shut down
15 entirely as the gauge is replaced with a transmitting unit. Further, once a transmitting unit is installed, such a unit may have to be leak tested and also tested to ensure it is transmitting a correct signal. In addition, a transmitting unit may require wiring from the transmitter to a central location. This can require additional labor, and assumes suitable wiring paths are available at the site.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a flow diagram of a method according to an embodiment.

FIGS. 2A to 2C are diagrams showing embodiments of a method like that of
FIG. 1.

FIGS. 3A and 3B are diagrams showing angle conversions according to
25 particular embodiments.

FIG. 4 is a flow diagram of a method according to an embodiment.

FIGS. 5A to 5D are diagrams showing embodiments of a method like that of
FIG. 4.

FIG. 6 is a flow diagram of a method according to an embodiment.

FIGS. 7A to 7D are diagrams showing embodiments of a method like that of
30 FIG. 6.

FIG. 8 is a flow diagram of a method according to an embodiment.

FIGS. 9A to 9D are diagrams showing embodiments of a method like that of

FIG. 8.

FIG. 10 is a flow diagram of a method according to an embodiment.

FIGS. 11A and 11B are histograms showing pixel data classification according to an embodiment.

5 FIGS. 12A and 12B are diagrams showing regions of interest (ROI) in a gauge image according to embodiments.

FIG. 13 is diagram showing an ROI according to an embodiment.

FIG. 14 is a flow diagram of a method according to an embodiment.

10 FIGS. 15A to 15C are embodiments of pixel data analysis according to embodiments.

FIG. 16 is a flow diagram of a method according to an embodiment.

FIGS. 17A and 17B are embodiments of pixel data analysis according to embodiments.

15 FIGS. 18A and 18B are diagrams showing gauge needle pixel filtering according to embodiments.

FIG. 19 is a flow diagram of a method according to an embodiment.

FIG. 20 is a flow diagram of a method according to an embodiment.

FIG. 21 is a flow diagram of a method according to an embodiment.

20 FIG. 22 is a diagram showing a dynamic pixel position filter according to an embodiment.

FIGS. 22A and 22B are diagrams showing gauge images according to embodiments.

FIG. 23 is a cross sectional view of a gauge reader according to an embodiment.

25 FIG. 24 is a cross sectional view of a gauge reader according to an embodiment.

FIG. 25 is a cross sectional view of a gauge reader according to an embodiment.

30 FIG. 26 is a block schematic diagram of a gauge reader according to an embodiment.

FIG. 27 is a block diagram of a system according to an embodiment.

FIG. 28 is a block diagram a web page provided by a system like that of FIG.

27.

DETAILED DESCRIPTION

Various embodiments will now be described that show devices and methods for acquiring a reading from a gauge image. In particular embodiments, an angle of a feature on a gauge may be determined, and such an angle may then be
5 transformed into reading for the gauge.

Referring to FIG. 1, a method for generating a gauge reading is shown in a flow diagram, and designated by the general reference character **100**. A method **100** may include capturing an image of a gauge (**box 102**). Such an action may include capturing a digital image of a gauge that includes a plurality of pixels. Such
10 pixels may be all or a majority of an image acquisition area. Alternative, such an image may be a limited region of an image capture area (i.e., a region of interest or "ROI").

Very particular embodiments of capturing an image according to embodiments are shown in FIGS. 2A to 2B-1. FIG. 2A shows one very particular
15 embodiment of a gauge **200**. Gauge **200** may include a feature that may change in angular orientation to represent different readings. In the particular gauge shown, such a feature may be needle **202**. FIG. 2B-0 shows a "full" image **204** of gauge **200** according to an embodiment. A majority of a gauge face has been captured as a number of pixels. Pixels may be filtered to distinguish features. As but a few of the
20 many possible embodiments, features may be filtered based on luminosity, change in luminosity between pixels, and/or color. FIG. 2B-1 shows an ROI image **206** of gauge **200** according to an embodiment. Only an ROI **208** portion of a gauge image is acquired (or stored or analyzed after acquisition). More particular embodiments of image acquisition, filtering and processing will be described in conjunction with other
25 embodiments shown herein.

Referring back to FIG. 1, a method **100** may further include determining an angle of gauge feature based on predetermined pixel positions of a gauge image (box **104**). Such an action may include determining a line having an angle which best fits a feature of the gauge, or determining a point from one or more pixels from
30 which an angle may be calculated with respect to an anchor point, as but two embodiments.

A very particular embodiment of an angle determination for the embodiments of FIGS. 2A to 2B-1 is shown in FIG. 2C. FIG. 2C shows an angle θ superimposed

on a gauge image. Angle θ matches an angle of needle **202**. It is noted that in the particular embodiment of FIG. 2C, a processing anchor point **210** (a point about which an angular determination is made) may be different from an image anchor point **212** (a point about which a gauge feature (e.g., needle) rotates). However, in
5 alternate embodiments processing anchor point **210** and image anchor point **212** may be the same.

Referring again to FIG. 1, method **100** may also include converting a determined angle into a gauge reading (box **106**). Such a step may include having a predetermined correlation between angles and readings, and generating a reading
10 based on such a correlation. As but a few embodiments, such a correlation may be a mathematical relationship (i.e., $\text{Reading} = \text{Angle} * \text{scale} + \text{offset}$) determined by a processor, or a look-up table (LUT), or dedicated logic.

FIGS. 3A and 3B are diagrams showing how an angle may be transformed into a gauge reading. FIG. 3A shows a gauge **300** having needle **302** that rotates
15 about an image anchor point **312**. As understood, with respect to a reference position **318**, an angle **314-0** corresponds to a reading of 20°F. An angle **314-1** corresponds to a reading of 60°F. Angles in invalid range **316** may be considered invalid angles, as they do not correspond to any reading. FIG. 3B shows another gauge **300'** having a needle **302'** that rotates about an image anchor position **312'**.
20 Unlike FIG. 3A, anchor position **312'** is not located in a central portion of gauge **300'**. Further, visible portions of needle **302'** do not intersect image anchor position **312'**. FIG. 3B shows how an angle **314-0'** may be transformed into a reading "0.10", while an angle **314-1'** may be transformed in a reading "0.80". FIG. 3B also shows regions **316-0** and **316-1** that may be considered invalid angle regions.

25 In particular embodiments, a gauge may be examined to determine the particular angle-to-reading conversion. More particularly, a gauge reader device may be attached to a gauge, a gauge image may be acquired, and from such an image, angle to reading conversion may be determined manually, or automatically.

In this way, a method may convert a gauge image of a physical gauge into a
30 gauge reading based on pixel positions in the gauge image.

Referring now to FIGS. 4 and 5A to 5D, one particular embodiment of an angle determination method is shown in a flow diagram and designated by the general reference character **400**. In very particular embodiments, method **400** may

correspond to box **104** shown in the method of FIG. 1.

Referring to FIG. 4, a method may include determining a pixel set from initial pixel values of a gauge image (box **402**). In one embodiment, positions of pixels having a particular luminosity (e.g., darkest or lightest pixels) may be stored. An angle corresponding to such pixels may then be determined (box **404**). In one very particular embodiment, an ordinary least squares (OLS) method may be used to generate a best line fit. An angle of such a best line may be an initial angle. In other embodiments, other conventional line fitting methods may be used.

A method **400** may also include determining if an initial angle is within a predetermined range (box **406**). In one embodiment, such a range may be based on known accuracies of actions performed in box **404**. In another embodiment, an OLS approach may be used to determine a line angle in box **404**, and a range may be $+45^\circ$ to -45° with respect to a horizontal axis used in such an OLS determination.

FIG. 5A is a diagram showing operations on a particular gauge image following box **404** of method **400**. An initial line **520** may be derived from pixel locations of a set (shown by "dots", one identified as **522**). FIG. 5A also shows an angle range **524** to which line **520** may be compared. In the embodiment shown, an angle range **524** may be from $+45^\circ$ to -45° , which may be a range at which OLS may have a high degree of accuracy.

As shown in FIG. 4, if an initial angle is outside of a range (Y from box **406**), the pixel set may be rotated by a displacement angle. In one embodiment, an amount of angular displacement may also be based on known accuracies of actions performed in box **404**. FIG. 5B is a diagram showing operations on a gauge image from FIG. 5A, following box **408** of method **400**. The set of pixels (e.g., **524**) are rotated from original positions (shown by crosses). In the embodiment shown, a displacement angle may be $+90^\circ$, which may be suitable when OLS approaches are used in box **404**.

Referring back to FIG. 4, a method **400** may include another line determination action (box **410**). Such an action may utilize any of the method described in conjunction with box **404**. In a particular embodiment, such an operation may result in more accurate regression results, than that based on non-rotated data. FIG. 5C is a diagram showing operations on a gauge image from FIG. 5A, following box **410** of method **400**. A line **520'** may be derived from rotated pixel

locations.

A method **400** may include reverse rotating a newly derived line by the displacement angle (box **412**). That is, a newly calculated line may be rotated by an angular opposite to those used to rotate pixel data in box **408**. FIG. 5D is a diagram
5 showing operations on gauge data from FIG. 5A following box **412** of method **400**. A line **520'** may be rotated (in this embodiment by -90°) to arrive at line **520''**.

It is noted that in FIGS. 5A to 5D, an image anchor point **512** is the same as a processing anchor point for calculating line angles and rotating pixel positions.

Further, initial line **520** is included in FIG. 5D for comparison with adjusted **520''** line.

10 As shown in FIG. 4, if an initial line was within an angular range (N from box **406**), or a new line is generated by rotating data (box **412**), an angle of such a line may be selected as an angle of a gauge reading.

In this way, if an initial line is outside of a predetermined angular range, pixel data corresponding to a gauge may be rotated to calculate a new line. Such a new
15 line may be rotated back to give an angle for a gauge reading. Such an arrangement may ensure that less accurate pixel orientations are avoided when deriving a gauge angle.

Referring now to FIGS. 6 and 7A to 7D, another particular embodiment of an angle determination method is shown in a flow diagram and designated by the
20 general reference character **600**. In very particular embodiments, method **600** may correspond to box **104** shown in the method of FIG. 1.

Referring to FIG. 6, a method may include calculating positions for lines, ranging from $0-179^\circ$, and comparing positions of such lines to corresponding pixel positions. Once a best fit line (least position error) has been determined, an angle of
25 such a line may be determined to be a gauge needle angle. This method will be referred to herein as a least sum of error (LSE) method.

The particular embodiment of FIG. 6 includes acquiring image data pixels (box **602**). In very particular embodiments, such a step may include determining which pixels meet a particular luminosity requirement (e.g., are darker than an
30 average luminosity or some other predetermined limit). Optionally, image data pixels may be filtered (box **604**) to further reduce a number of pixels used in a line determination method. A low error value (to be discussed in more detail below), may be set to some maximum value (box **608**).

Pixel locations may then be generated for a line (box **610**). Such a step may generate particular pixel locations for a line having an angle. In one particular embodiment, a method **600** may start at a line at 0° and then step through at 1° increments to 179° . In other embodiments, an initial line may be based on a search
5 approach, with an initial set of lines (having a predetermined angular separation) may be tested for a fit against pixel data. Once a closest fit is found for one of the lines of the initial set, additional testing may be performed at finer increments.

In one particular embodiment, each pixel of the acquired pixel data may have an X and Y coordinate. Pixel locations of a line (as described for box **610**) may be
10 generated for each X location of a pixel value. A single multiplication step (based on line slope) may be used to generate the corresponding Y value for each X location.

Referring back to FIG. 6, a match error value may be generated that corresponds to a distance between image pixels and corresponding line pixel locations (box **612**). In one particular embodiment, such an operation may include
15 determining an absolute value between a Y position of an image pixel and the Y position of the line pixel at a same X location. Alternatively, both X and Y differences between the data sets may be summarized to arrive at a match error value.

A match error (representing an error between a current line and image data) may then be compared to a low error value, first noted for box **608** (box **614**). If a
20 current match error is less than a stored low error (Y from **614**), the current match error may become the new low error (box **616**). A line corresponding to such a new low error may be stored as a current best fit line (box **618**). If a last line has not been reached (N from box **620**), position values for a next line may be generated (box **622**). Such a next line may be rotated with respect to a previous line. As noted
25 above, the increment for such a rotation may be relatively large (initial search approach) or small (sequentially rotate through all angles, or subsequent fine search).

If a last line has been reached (Y from box **620**), an angle currently stored as a best fit line may be a needle angle.

30 It is noted that in a method like that of FIG. 6, an anchor point for lines may be the same as that of gauge data.

FIGS. 7A to 7D show one very particular embodiment of a method of FIG. 6. Referring to FIG. 7A, a gauge **701** is shown that includes a needle **702** that may

rotate around an image anchor point **712**. Image data from a portion of gauge **701'**, along with examples of fit line data, are shown in FIGS. 7B to 7D.

FIG. 7B shows image pixel data representing a gauge needle position and positions of an initial line **720-0**. Pixel data positions are shown by open squares. Line position data is shown by filled squares, with the line also being represented with a dashed line. In the particular embodiment shown, Y positions are compared. Differences between Y positions of line data and pixel data are shown by dashed lines.

FIG. 7C shows image pixel data representing a gauge needle position and positions of another line **720-1**. Line position data is shown once again by filled squares. In the particular embodiment shown, Y positions are compared once again, and are shown by dashed lines. As shown by comparison between FIG. 7B and 7C, line **720-1** will have a much smaller error than line **720-0**, and thus represents a better fit than line **720-0**.

FIG. 7D shows image pixel data representing a gauge needle position and positions of a third line **720-2**. Line position data and differences in position are the same as FIGS. 7B and 7C. As shown by comparison between FIG. 7C and 7D, line **720-2** will have a much greater error than line **720-1**, and thus represents a worse fit than line **720-1**.

It is noted that FIGS. 7B to 7D show a match between image anchor point **712** and processing anchor point **710**.

In other embodiments, a method like that of FIG. 6 may also include a method like that of FIG. 4. That is, each line determination step may further include rotating pixel data points if a best matching line angle is outside of a predetermined angular range. A new best fit line may then be calculated from such rotated data. A resulting new best fit line may then be rotated back to arrive at a final best line fit.

In this way, gauge image pixel data may be compared against a sequence of rotated lines to find a line having a minimum error with pixel data. An angle of such a line may then be determined to be a gauge needle angle.

Referring now to FIGS. 8 and 9A to 9D, another particular embodiment of an angle determination method is shown in a flow diagram and designated by the general reference character **800**. In very particular embodiments, method **800** may correspond to box **104** shown in the method of FIG. 1.

Referring to FIG. 8, a method may include calculating positions for lines, ranging from 0-179°. Positions of such lines can be compared to corresponding pixel positions. A line having a largest occurrence of the same or similar error amount between line and image positions may be considered to be parallel to an image needle. Consequently, an angle of the line may be considered an angle of a gauge. This method will be referred to herein as a maximum common error (MCE) method.

The particular embodiment of FIG. 8 includes acquiring image data pixels (box **802**) and, optionally, filtering such pixels (box **804**). Such operation may occur in the same or equivalent manner as boxes **602** and **604** of FIG. 6. A max error value may then be set to zero (box **806**). A max error value will be discussed in more detail below.

Pixel locations may then be generated for a line (box **808**). Such actions may occur in the same or equivalent manner as box **610** of FIG. 6.

A method **800** may further include tabulating error values between line positions and pixel data positions (box **810**). That is, a tally may be made that will indicate a most common distance error between line and gauge image pixels.

From tabulated error values, a maximum common error may be determined (box **812**). Such an action may determine which tabulated error has most counts. In one embodiment an error count may be a largest count from all counts. In other embodiments, a largest count may be an average from a sliding window that combines similar errors into a single count value. A sliding window approach may be more robust with respect to noise. Such a maximum common error may then be compared to a max error value, first noted for box **806** (box **814**). If a current max common error is greater than a stored max error (Y from **814**), the current max common error may become the new max error (box **816**). A line corresponding to such a new max error may be stored as a current best fit line (box **818**). If a last line has not been reached (N from box **820**), position values for a next line may be generated (box **822**). Such a next line may be rotated with respect to a previous line. As noted above, the increment for such a rotation may be large (initial search approach) or small (sequentially rotate through all angles, or fine search).

If a last line has been reached (Y from box **820**), an angle of a currently stored best fit line may be a needle angle.

It is noted that in a method like that of FIG. 8, an anchor point for lines may be entirely different as that for gauge image data. This is illustrated in FIGS. 9A to 9D by comparing location of point **912** with **910**.

FIGS. 9A to 9D show one very particular embodiment of a method of FIG. 8. Referring to FIG. 9A, a gauge **901** is shown that includes a needle **902** that may rotate around an image anchor point **912**. Image data from a portion of gauge **901** with various line data positions is shown in FIGS. 9B to 9D.

FIG. 9B shows image pixel data representing a gauge needle position and positions of an initial line **920-0**. Pixel data positions are shown by open squares. Line position data is shown by filled squares, with the line being projected with a dashed line. In the particular embodiment shown, Y positions are compared. Differences between Y positions of line data and pixel data are shown by dashed lines.

FIG. 9C shows image pixel data representing a gauge needle position and positions of a second line **920-1**. Line position data is shown once again by filled squares. In the particular embodiment shown, Y positions are compared once again, and are shown by dashed lines. As shown by comparison between FIG. 9B and 9C, error differences between line **920-1** and pixel data is much closer, so a common error number is likely to be the same for many X locations. Accordingly, line **920-1** represents a better fit than line **920-0**.

FIG. 9D shows image pixel data representing a gauge needle position and positions of a third line **920-2**. Line position data and differences in position are the same as FIGS. 9B and 9C. As shown by comparison between FIG. 9C and 9D, line **920-2** will have a much greater variation in errors than line **920-1**, and thus represents a worst fit than line **920-1**.

It is noted that FIGS. 9B to 9D show how an image anchor point **912** may be different than a processing anchor point **910**.

In this way, gauge image pixel data may be compared against a sequence of rotated lines to find a line having a maximum common error with pixel data. An angle of such a line may then be determined to be a gauge needle angle.

While embodiments may utilize LSE and MCE techniques as noted above, still other embodiments may combine MCE and LSE techniques to transform gauge image pixel data into a gauge needle reading. One particular embodiment of such

an arrangement is shown in FIG. 10.

Referring to FIG. 10, a method for determining a gauge image angle is shown in a flow diagram and designated by the general reference character **1000**. In very particular embodiments, method **1000** may correspond to box **104** shown in the
5 method of FIG. 1.

As shown in FIG. 10, a method **1000** may include performing an MCE analysis (box **1002**). Such an action may include performing an analysis like any of those shown in the embodiments of FIGS. 8 and 9A to 9D, or equivalents. Such an analysis may yield a maximum common error value for a best fit line and gauge pixel
10 positions.

Line pixel positions may then be shifted by a maximum common error value (box **1004**). Such an action may align a generated line over pixel data. Optionally, pixels may be filtered based on MCE results to arrive at a sub-set of pixels (box **1006**) that may eliminate "outliers", which may be image pixels arising from noise, or
15 features unrelated to a gauge needle position.

An LSE analysis may then be performed between locations of pixel image data (which may be filtered) and the shifted line data locations (box **1008**). Such an action may include performing an analysis like any of those shown in the embodiments of FIGS. 6 and 7A to 7D, or equivalents.

In this way, LSE and MCE approaches may be combined to transform gauge image pixel data positions into a reading for the gauge.

Referring to FIGS. 11A and 11B, embodiments of error histograms that may be generated in an MCE analysis according to particular embodiments are shown. Histograms may be physically implemented as arrays in a memory of a gauge reader
25 device.

FIG. 11A shows a first error histogram. Such a histogram may correspond to a gauge pixel-to-line correlation like that shown in FIG. 9B. Errors are positive and evenly distributed. Thus, while an error amount of "4" may have a largest count, it is not significantly larger than other error counts.

FIG. 11B shows another error histogram. Such a histogram may correspond to a gauge pixel-to-line correlation like that shown in FIG. 9C. There is a clear maximum common error (4), and other errors are clustered about such a maximum common error value. As noted above, a window (W) may be used to filter out

“outlier” pixel values. Thus, in the very particular embodiment shown, pixels having distance errors greater than 1 and less than 7 may be retained. The remaining pixels (corresponding to error <2 or >6) may be discarded in a subsequent analysis.

In this way, MCE results may be filtered to eliminate “outlier” pixels of a gauge
5 image.

While embodiments like those of FIGS. 4-10 may analyze pixel values taken from all, or a majority of an image area of a gauge, alternate embodiments may base analysis on a predetermined region of an image, referred to above as an ROI. An ROI may be a small portion of an image that is retained for analysis (after a larger
10 image has been acquired), or alternatively, may be the only pixels values acquired. Two very particular embodiments of ROIs for a gauge are shown in FIGS. 12A and 12B.

FIG. 12A shows a gauge **1200-A** having a needle **1202-A**. A needle **1202-A** may rotate about a location **1212-A**, which may be an image anchor point. Such a
15 point may also be a processing anchor point **1210-A** as it may be utilized to determine a final angle, as will be described below. In the particular embodiment shown, an ROI **1230-A** may be a region defined by concentric circles **1236-0** and **1236-1**. In the particular embodiment shown, circles (**1236-0** and **1236-1**) may only overlap a needle **1202** within a gauge image. Further, in the embodiment shown,
20 circles (**1236-0** and **1236-1**) may have centers aligned at image anchor point **1212-A**. Said in another way, radii of circles (**1236-0** and **1236-1**) may be larger than a radius of a monitored gauge (assuming a gauge shape is circular).

In some arrangements, defining a ROI with concentric circles may not be possible due to background features of a gauge face. Accordingly, in alternate
25 embodiments, an ROI may be defined by one or more line segments. One such embodiment is shown in FIG. 12B.

FIG. 12B shows a gauge **1200-B** having a needle **1202-B**, and image and anchor processing points (**1210-B**, **1212-B**) like those in FIG. 12A. In the particular
30 embodiment shown, an ROI **1230-B** may be a region defined by line segments **1234-0** to **1234-4**. Each of line segments (**1234-0** to **1234-4**) may be a set of pixels arranged generally along a defined slope. In a very particular embodiment, line segments may be defined with a pixel start location (SL) followed by a set of vectors, each vector corresponding to a line segment. In one embodiment, each vector may

include a delta X (dX), a delta Y (dY) and count (n). Starting at SL, dX and dY may be added to determine a next pixel location. This is repeated "n" times to arrive at an end of a segment. A next segment may be defined by starting with a new vector at the end location of the previous segment.

5 Once an ROI has been defined, a needle position within such an ROI may be determined. From such a position, an angle may be calculated with respect to a processing anchor point.

In this way, region of interest may be defined in a gauge image to determine a gauge angle needle location.

10 Referring now to FIG. 13, an ROI according one embodiment is shown in a diagram and designated by the reference character **1330**. Such an ROI **1330** may be formed by a region defined by concentric circles, or by a number of line segments. ROI **1330** includes pixels P0 to P15. According to embodiments, starting at one end of a ROI **1330** (e.g., P0 or P15) and moving to the opposing end
15 (e.g., P15 or P0), each pixel may be examined to determine if it is a needle pixel (i.e., contains an image of a gauge needle). FIG. 13 shows an embodiment where such a method has determined that a pixel P5 may be a needle pixel.

In one embodiment, if a needle has a different color than features in the ROI, a color filter may be used to identify a pixel(s) containing a needle.

20 In another embodiment, a luminosity threshold may be used. One very particular embodiment having this feature is shown in FIG. 14.

Referring to FIG. 14, a method **1400** may include calculating an average luminosity of pixels of an ROI (or sub-set of ROI) (box **1402**). A pixel threshold may be established (box **1404**). In the particular embodiment shown, a pixel threshold
25 Pth may be an average luminosity Lave minus an offset Loff. If a pixel luminosity is less than Pth (Y from **1406**) such a pixel may be determined to be a needle pixel (box **1408**). A next pixel in an ROI may then be examined (box **1414**). Once a last pixel of an ROI is reached (Y from **1410**), an angle may be calculated based on the needle pixel (box **1412**).

30 In particular embodiments, an ROI may be stored as a data structure in a system memory. In one very particular embodiment, an ROI may be an array structure, with array position corresponding to one coordinate (e.g., X position), and array element storing the other coordinate (e.g., Y position) as well as pixel value for

examination (e.g., luminosity).

For gauges in which a color or luminosity alone may not be sufficient to detect a needle pixel within an ROI, edge detection may be used to find a gauge needle pixel. In one embodiment, known edge detection algorithms such as a Canny filter
5 or Prewitt filter may be used to determine an edge of needle in an ROI.

In another embodiment, a method may distinguish a needle by detecting a suitable "dip" in pixel values. For example, if a needle is darker than a background, a dip represents a sudden transition from dark and back. In contrast, a "negative" dip may be a sudden transition from to light and back. Finally, dips may be
10 distinguished from "edges" which may represent a transition from light to dark (or vice versa), where such a transition does not return to the previous luminosity within a set spacing.

To distinguish a desired dip from other transition types, a method may determine derivatives of pixels (differences between adjacent pixels), as an ROI is
15 examined from one end to the other. Embodiments of such operations are shown in FIGS. 15A to 15C.

Referring to FIGS. 15A to 15C graphs of pixel data values for a portion of an ROI are shown. Each graph shows a luminosity values (L) of pixels, as well as derivatives (Dx) for adjacent pixel positions.

20 FIG. 15A shows one embodiment of a negative dip. As shown, Dx data shows a rapid change to darkness followed by a corresponding rapid change back to a lighter value. Such a negative dip may indicate a gauge needle position in cases where a gauge needle is mostly darker than a back ground.

FIG. 15B shows one embodiment of an "edge". The Dx data shows a negative change, but such a negative change is not accompanied by a rapid positive change.
25

FIG. 15C shows one embodiment of a positive dip. As shown, Dx data shows a rapid change to a lighter value followed by a corresponding rapid change back to a darker value. Such a positive dip may indicate a gauge needle position in cases where a gauge needle is mostly lighter than a back ground.

30 According to luminosity derivative data, a method may determine a needle position in an ROI. One particular embodiment of such method will now be described.

Referring to FIG. 16, a method **1600** may include storing pixel data in an array

(box **1602**). In one particular embodiment, such an operation may include storing pixels of an ROI in an array, where array position corresponds to a pixel's X position, and a Y position and luminosity of a pixel are stored in an array element. When an ROI does not match extents of an array (i.e., there are no pixels corresponding to X position at a start or end of an array), such array elements can be marked as empty or otherwise flagged. Use of an array may avoid the need to sort pixels.

A method **1600** may start at a first array position (box **1604**). In this way, a method **1600** may work across an ROI from one end to the other. If an array position is empty or otherwise flagged (Y from **1606**), a next position may be examined (box **1608**). This may continue until a first valid pixel is found.

A method **1600** may select a first "pixel window" of *i* array elements (box **1610**). For each element in the window, a *Dx* between adjacent pixels may be calculated (moving in a same direction) (box **1612**). For the *Dx* values within the pixel window, a maximum (*MxD*) and minimum (*MnD*) *Dx* value may be determined (box **1614**). An average *Dx* (*Av*) may also be determined (box **1616**). It is noted that a pixel window for an average *Dx* value (*Av*) may be derived from more than "*i*" array elements (i.e., pixels). Such an arrangement may make a method less susceptible to noise.

A weight may then be assigned to a window if "*i*" gauge image pixels. A weight may represent a likelihood that the pixels of the window include the gauge needle. In the embodiment of FIG. 16, it is assumed that a needle is generally darker than a background. Accordingly, to filter out "positive dips" (i.e., sudden increases in luminosity), a method may set a window weight value (*W*) to zero (box **1620**) if an *MxD* value precedes and *MnD* value (Y from **1618**) within the window. However, if an *MxD* value follows and *MnD* value (indicating a "negative dip"), a weight value (*W*) may be calculated (box **1622**).

In the very particular embodiment of FIG. 16, a weight value (*W*) may be calculated according to

$$W = MxD - MnD - (|(MxD-Av) - (Av-MnD)|).$$

The term "*MxD-MnD*" will vary according to the change in luminosity. Such a value may vary for edges, positive dips and negative dips in the same manner. In contrast, the term " $|(MxD-Av) - (Av-MnD)|$ " decreases the weight in the event of an edge. If a one slope (e.g., *MxD*) is not accompanied by a correspondingly large opposite slope

(e.g., MnD), then a weight will be reduced.

Once a weight value (W) for a window has been determined, a next window may be examined (box **1626**). Once a last window has been reached (Y from box **1624**), a window having a largest weight may be considered a window with a needle pixel (box **1628**). If more than one window have equal weight, a "winning" window may be selected arbitrarily, or may be selected based on a previous processing result, or may selected based on a processing result of a redundant ROI.

Once a window having a greatest weight has been determined, a pixel position within such a window may be selected as a needle location. Various embodiments for selecting a needle position within a highest weight window will now be described.

In one embodiment, a center pixel position within a window may be selected as a needle position pixel. Such an arrangement is shown in FIG. 17A. FIG. 17A shows three windows W_0 , W_1 , and W_2 . In the case of window W_0 , pixel P_7 may be determined to be a needle location. In the cases of windows W_1 and W_2 , pixels P_9 and P_{11} , respectively, may be determined to be needle locations.

In another embodiment, a needle position pixel may be that pixel situated between MnD and MxD values of the window. Such an arrangement is shown in FIG. 17B. FIG. 17B shows an MnD occurring at the transition from pixel P_8 and P_9 , and an MxD occurring at the transition from pixel P_9 to P_{10} . Accordingly, pixel P_9 may be selected as a needle position pixel. It is noted that the embodiment of FIG. 17B also shows three windows W_0 , W_1 and W_2 . In this embodiment, pixel P_9 may be selected even in the event all windows ($W_0 - W_2$) have an equal weight value (W).

In this way, pixel locations in an ROI may be grouped into windows and weighted based on luminosity transitions within such windows. A highest weighted window may be determined to have a needle position.

While dips may be used to indicate a needle position, a contrast between a needle and its background may vary according to an overall brightness of an acquired image. Further, a needle contrast may vary according to needle speed, with a fast needle having less contrast than a slow needle. According to particular embodiments, a dip results may be filtered depending upon a brightness value to help optimize valid dip detection.

Referring to FIGS. 18A and 18B, a contrast filter may be included to ensure that a detected dip is a valid needle position. FIG. 18A shows a graph for a static contrast threshold. FIG. 18A shows a graph with needle contrast versus brightness for a slow needle **1802** and a fast needle **1804**. In such an embodiment, any reading falling below a static contrast level **1806** will not be considered a valid "dip". FIG. 18B shows a graph for a dynamic contrast threshold. FIG. 18B shows a same needle response as FIG. 18A, however, a dynamic contrast level **1806'** may now be used to filter out invalid dips.

In this way, a contrast level may be filtered to ensure variations in contrast arising from variations in brightness and differences in needle speed.

According to embodiments herein and equivalents, sets of pixel positions can be derived that indicate positions of a needle location. In particular embodiments, such pixel positions may be filtered to reduce such a pixel set and then generate a needle angle value.

Referring now to FIG. 19, a method **1900** for filtering needle pixel positions and generating a needle angle will now be described. A method **1900** may include calculating an average X value (X_{av}) and Y value (Y_{av}) for all pixel values of a pixel set (box **1902**). Each pixel value may then be subject to a distance filter (box **1904**). In the embodiment of FIG. 19, if a pixel X value is farther from an average value by an offset (e.g., $X > X_{av} + X_{offset}$), such a pixel will be discarded from subsequent processing steps. Similarly, if a pixel Y value is farther from an average value by an offset (e.g., $Y > Y_{av} + Y_{offset}$), such a pixel will be discarded from subsequent processing steps. In the very particular embodiment of FIG. 19, if a desired precision is not met (N from **1906**), boxes **1902** and **1904** may be repeated with the reduced pixel set (assuming pixels are discarded according to filtering **1904**). If a desired precision is met (Y from **1906**), an angle value may be calculated (**1908**). In the particular embodiment shown, an arctangent (arc tan) function may be executed on value Y_{av}/X_{av} (offset by the image anchor point, if necessary). In one embodiment, such an arc tan function may be implemented as a scaled lookup table to avoid the need for a floating point processing operation.

Referring now to FIG. 20, another method **2000** for filtering needle pixel positions and generating a needle angle will now be described. A method **2000** may include sorting X and Y positions of pixel locations according to value (box **2002**).

For such sorted values first quartiles (Q1) and third quartiles (Q3) may be determined (box **2003**). A first quartile Q1 may be a data point $\frac{1}{4}$ through a sorted data set. A third quartile Q3 may be a data point $\frac{3}{4}$ through a sorted data set. An interquartile range (IQR) may also be calculated (box **2004**). An IQR may be Q3-Q1.

5 Each pixel value may then be examined and filtered based on quartile values (box **2006**). In the embodiment of FIG. 20, if a pixel X value is less than the first quartile by a predetermined factor ($A \cdot \text{IQR}_x$), or greater than a third quartile by the factor, such a pixel will be discarded from subsequent processing steps. A value "A" may be a variable amplification factor which may be larger for less strict filtering, or

10 smaller for tighter filtering. A same type of filtering may be performed based on Y values. A method **2000** may also include calculating an average X value (X_{av}) and Y value (Y_{av}) for the filtered set of points (box **2008**). An angle may be calculated (box **2010**) in a same fashion as box **1908** of FIG. 19, or an equivalent way.

Referring now to FIG. 21, a further method **2100** for filtering needle pixel

15 positions and generating a needle angle will now be described. A method **2100** may include calculating an average X value (X_{av}) and Y value (Y_{av}) for all pixel positions of a set (box **2102**). Each pixel value may then be filtered (box **2104**). In the embodiment of FIG. 21, if a difference between a pixel X value and X_{av} is larger than a filter window value FT_x , such a pixel will be discarded from subsequent

20 processing steps. Similarly, if a difference between a pixel Y value and Y_{av} is larger than a filter window value FT_y , such a pixel will be discarded from subsequent processing steps. In an alternate embodiment, a total distance between a pixel value and average may be calculated (box **2104'**). It is noted in an action like that of box **2104'**, while actual pixel distance may be calculated by taking a square root of

25 the distance, in the embodiment shown, such values may be retained in squared form for reduced calculation steps. If a desired precision is not met (N from **2106**), boxes **2102** and **2104** may be repeated with the reduced pixel set. If a desired precision is met (Y from **2106**), an angle value may be calculated (**2108**) in a same fashion as box **1908** of FIG. 19, or an equivalent way.

30 While filter values FT noted in FIG. 21 may be constant values, in other embodiments, calculations may be repeated and FT values modified dynamically. In particular, a method like that of FIG. 21 may be performed with a first FT value to arrive at an initial angle. Based on such an angle, a new FT value may be

generated. An embodiment of such a dynamic FT values is shown in FIG. 22.

FIG. 22 shows how filter values FT may vary according to a region of an initial angle. In particular, in a region 2 (R2), an FT_x value may be considerably smaller than an FT_y value. However, in other regions R0 and R1, values FT_x and FT_y may be increased to account for needle pixel distributions changing according to needle angle.

In this way, once pixel values for a gauge needle have been determined, such values may be further filtered and a needle angle generated from such values.

While the present invention may include methods for determining a gauge reading, other embodiments may include gauge reader devices and systems for generating a gauge reading, and/or methods for monitoring systems that includes such gauge readers device. Various such embodiments will now be described.

While the above embodiments have described methods that acquire an image from a direction perpendicular to (or substantially perpendicular) to a gauge face, other embodiments may acquire an image at non-perpendicular angles to a gauge face.

FIG. 22A shows an image of a gauge **2200-A** taken perpendicular to the gauge face. In FIG. 22A, a gauge may include a reading needle **2202** (i.e., a needle from which a gauge reading is determined). However, a gauge **2200-A** may further include set point needles **2240-0** and **2240-1**. In some image processing approaches it may be difficult to differentiate between set point needles (**2240-0** and **2240-1**) from reading needle **2202**.

In one particular embodiment, when a reading needle **2202** has a different color than set point needles (**2240-0** and **2240-1**), a color filtering step may be implemented after pixel data is acquired, to filter out set point needle pixels. An angle for reading needle **2202** may then be derived according to the embodiments shown herein or equivalents.

In another embodiment, set point needles (**2240-0** and **2240-1**) may cast different shadows than a reading needle **2202**. In such an embodiment, different light sources may generate different shadows for various needle types. A method may process signatures of such shadows to determine which is a reading needle versus which is a set point needle. In one particular embodiment, a needle with a smallest shadow offset may be further from the light sources.

In a further embodiment, as shown in FIG. 22B, an image of a gauge **2200-B** may be acquired at an angle to thereby distinguish positions of a reading needle with respect to set point needles. In particular, when a reading needle rotates in a different plane than the set point needles, its position will be distinguishable from such set point needles when viewed from an angle. FIG. 22B shows an example
5 when a reading needle **2202** is directly behind a set point needle **2240-0**. In a non-angled view, like that of FIG. 22A, it may be difficult to distinguish the reading needle **2202** from the set point needle **2240-0**. However, as shown in FIG. 22B, when viewed at an angle, it is easily determined that reading needle **2202** is behind set
10 point needle **2240-0** and not set point needle **2240-1**.

Accordingly, in one very particular embodiment, when a reading needle **2202** is not aligned with a set point needle, it may be determined to be the line interest due to differences with the set point needles (**2240-0** and **2204-1**), such as color or size, as but two examples. When reading needle **2202** is aligned with a set point needle
15 (**2240-0** and **2204-1**), an angled view may be sampled. The position having two lines at such an angled view is understood to be the appropriate reading.

Referring to FIGS. 23 and 24, embodiments of gauge reader devices that may acquire an image of a gauge at an angle will now be described.

Referring to FIG. 23, a gauge reader device according to one embodiment is
20 shown in a cross sectional view and designated by the general reference character **2300**. A gauge reader device **2300** may be mechanically connected to a gauge **2342**. A gauge reader device **2300** may position an image sensor **2346** at a non-perpendicular angle with respect to a face of gauge **2342**. In the very particular embodiment shown, a gauge reader device **2300** may include a monitoring section
25 **2344-0** and an adapter section **2344-1**. A monitoring section **2344-0** may include gauge reading device electronics for acquiring and processing an image into a gauge reading. An adapter section **2344-1** may angle monitoring section **2344-0** with respect to gauge **2342**.

Referring to FIG. 24, a gauge reader device according to another embodiment
30 is shown in a cross sectional view and designated by the general reference character **2400**. A gauge reader device **2400** may be mechanically connected to a gauge **2442**. A gauge reader device **2400** may include a mirror **2448** for providing an angled view of a gauge **2442**. In the very particular embodiment shown, a gauge

reader device **2400** may include a monitoring section **2444-0** and an adapter section **2444-1**. A monitoring section **2444-0** may include gauge reading device electronics for acquiring and processing an image into a gauge reading. An adapter section **2444-1** may include mirror **2448**.

5 It is understood that while FIG. 24 shows an arrangement in which an image sensor captures both a gauge image and a reflected gauge image, other embodiments may include gauge readers having an image sensor that only captures an angled reflection of a gauge.

10 In this way, a gauge reader device may acquire a gauge image at an angle to distinguish set point needles from a reading needle.

15 While embodiments above have shown how a reading needle may be distinguished from a set point needle by acquiring an angled image of a gauge, in other embodiments, a gauge reader may include multiple image sensors to acquire a stereo view of such a gauge. According to variances in needle position, set point needles may be distinguished from reading needles. In one very particular embodiment, when a reading needle is behind a set point needle, a set point needle may have greater variance in position between two images.

20 Referring to FIG. 25, a gauge reader device according to another embodiment is shown in a cross sectional view and designated by the general reference character **2500**. A gauge reader device **2500** may be mechanically connected to a gauge **2542**. A gauge reader device **2500** may include two image sensors **2546-0** and **2546-1**. In the very particular embodiment shown, a gauge reader device **2500** may include a monitoring section **2544-0** and an adapter section **2544-1**. A monitoring section **2544-0** may include gauge reading device electronics for
25 acquiring and processing an image into a gauge reading. An adapter section **2544-1** may physically connect monitoring section **2544-0** to gauge **2542**.

 In this way, a gauge reader may include more than one image sensor to acquire two different images that may distinguish set point needles from reading needles.

30 As noted above, embodiments of the invention may include various methods for performing any of: acquiring gauge image data, filtering gauge image data, transforming gauge image pixel locations into an angle value, and/or transforming an angle value derived from gauge image pixel data into a gauge reading. In very

particular embodiments, any such methods may be undertaken by a processor executing instructions stored in one or more machine readable media included within a self-contained gauge reader device.

Referring now to FIG. 26, a gauge reader device according to one
5 embodiment is shown in a block schematic diagram and designated by the general reference character **2600**. A gauge reader **2600** may include an image sensor **2646-0** (and optionally, one or more additional image sensors **2646-1** for an embodiment like that of FIG. 25) and a control section **2650**. In the particular embodiment shown, a control section **2650** may include a microcontroller (MCU) **2650-0** as well as
10 memory **2650-1**. An MCU **2650-0** may include a processor for executing instructions that may be stored in dedicated processor memory, in memory **2650-1**, or in both as but a few examples. In response to such instructions, an MCU **2650-0** may generate control signals on control signal paths **2652** to control the operation image sensor(s) **2646-0** (and optionally **2646-1**). The embodiment of FIG. 26 also shows an
15 address/data bus **2654** that may allow image sensor(s) **2646-0/1** and MCU **2650-0** to access memory **2650-1**. It is understood that MCU **2650-0** could access memory **2650-1** via a bus separate from that utilized by image sensor(s) **2646-0/1**. Still further such address/data buses may allow for the transfer of data in a serial, and/or parallel fashion. An image sensor **2646-0/1** may transfer image data to memory **2650-1**.
20 Such a transfer may involve an entire image, or a portion of an image.

An MCU **2650-0** may execute instructions stored in an internal memory and/or memory **2650-1** that includes any of the method embodiments shown herein, or equivalents.

In this way, a gauge reader device may include a self-contained processor
25 and memory for acquiring a gauge image, and transforming such an image into a gauge reading.

While embodiments described above may include gauge reading methods and devices, still other embodiments may include systems including and interconnecting such gauge reader devices and methods. One such embodiment is
30 shown in FIG. 27.

Referring to FIG. 27, a system according to an embodiment is shown in a block diagram and designated by the general reference character **2700**. A system **2700** may include central server **2702**. A central server **2702** may provide a central

location for monitoring numerous gauge reader devices (one shown as **2704**) located at sites remote from central server **2702**. In such an arrangement, gauge reader values may be periodically received, stored and made accessible to users in a variety of communication methods.

5 In the very particular embodiment of FIG. 27, a central server **2702** may include a remote site service **2706**, a firewall **2708**, and a central database **2710**. A remote site service **2706** may interact with remote sites (any of **2712-0** to **2712-n**) through firewall **2708** by way of a network **2714**. In particular, a remote site service **2706** may receive "node" data from sites (any of **2712-0** to **2712-n**). Node data may
10 include gauge readings generated according to any of the embodiments herein, or equivalents. In one particular embodiment, a remote site service may be a simple object access protocol (SOAP) based web service hosted by central server **2702** that may access remote site device (one shown as **2716**) via the Internet (i.e., network **2714** may be the Internet).

15 A central database **2710** may store information related to remote sites (any of **2712-0** to **2712-n**). In the particular embodiment of FIG. 27, a central database **2710** may store site data **2710-0** and user data **2710-1**. Site data **2710-0** may include, but is not limited to, status and data provided by various nodes at accessed sites (any of **2712-0** to **2712-n**). User data **2710-1** may include data for identifying users when
20 central server **2702** is accessed, and for forwarding data to users via other networks, such as text message data, as will be described in more detail at a later point herein. In one very particular embodiment, a central database **2710** may be an SQL server database.

 A central server **2702** may be passive, responding to communications from
25 behind firewalls at remote sites (any of **2712-0** to **2712-n**). In one embodiment, a central server **2702** may maintain an open communication port. Remote sites (any of **2712-0** to **2712-n**) may initiate messages to such a port. Such messages may include data (i.e., push data), or may include a poll message. A poll message may enable central server **2702** to respond through a remote firewall, as it is the remote
30 site that has initiated the request. In one very particular embodiment, a remote site service **2706** may be a web service, and remote sites may access such a service via http at the appropriate communications port (i.e., port 80).

In this way, a secure bi-directional data path may be created to central server

2702 through a remote site firewall.

A central server **2702** may include additional services that may form part of, or be separate from, remote site service **2706**. In the embodiment of FIG. 27, central server **2702** may include a backup service **2718**, a control service **2720**, an update
5 service **2722** and a text message handling service **2724**. A backup service **2718** may backup data received from remote sites. Such a backup service **2718** may be periodically executed by accessing remote sites and/or may be in response to remote site requests. In particular embodiments, backup data may be stored on at least central database **2710**.

10 A control service **2720** may access remote sites to thereby control remote devices (e.g., **2716**) at such sites. Such a service may enable diagnosis and troubleshooting of the remote device (e.g., **2716**) and/or node devices (e.g., gauge readers **2704**) in communication with such remote device. In a similar fashion, an update service **2722** may enable instruction data to be updated on remote devices
15 (e.g., **2716**) and/or node devices (e.g., gauge readers **2704**).

A text message handling service **2718** may be in communication with a text message service **2726** (described at a later point herein), and may receive text message data, send text message data, archive text message data, and provide user data to a text message service **2726**.

20 A text message service **2726** may be hosted by a different server than central server **2702**. In alternate embodiments, however, such a service may be hosted by central server **2702**. In particular embodiments, a text message service **2726** may be part of system **2700**, but in other embodiments may not be part of system **2700**. A text message service **2726** may transfer text message data between remote sites
25 (any of **2712-0** to **2712-n**) and an endpoint **2728** of a text message network, such as a cell phone or the like. In one particular embodiment, in response to predetermined events, a remote site (any of **2712-0** to **2712-n**) may issue an alarm. Such an alarm may be sent directly to text message service **2726** via network **2714**, or alternatively, may be sent to text message handler **2724** within central server **2702**, which may
30 then forward an alarm to text message service **2726**. Text message service **2726** may then forward a predetermined text message to endpoint **2728**.

In addition or alternatively, commands may be sent from an endpoint **2728** that are intended for a remote site (any of **2712-0** to **2712-n**). In one particular

embodiment, a command text message received by text message service **2726** may be forwarded to central server **2702** and handled by text message handling service **2718**. In response to such a command text message, central server **2702** may wait for an appropriate polling message from a remote site, and then forward the
5 command to the remote site in response. As but one very particular embodiment, in response to a text message command a remote site may push data for a node, including a captured gauge image, to an endpoint **2728**, and/or allow central server **2702** to pull such data from the remote site.

A text message service **2726** may store, or have access to, user data **2710-1**
10 to thereby ensure any given endpoint may only access predetermined remote site(s). In one particular embodiment, a text message service **2726** may be an SMS web service.

Referring still to FIG. 27, one embodiment of a remote site **2712-0** will now be described. In some embodiments, any of remote sites (**2710-0** to **2710-n**) may form
15 part of system **2700**. However, in alternate embodiments remote sites are separate from a system **2700**.

A remote site (e.g., **2712-0**) may include a one or more gauge readers (one shown as **2704**) connected directly, or indirectly, to a remote device **2716**. In a very particular embodiment, a gauge reader may be a wireless gauge reader (WGR) and
20 a remote device may be a remote site server. WGRs (e.g., **2704**) may transmit gauge reading and image data to a site server **2716**, via a direct wireless communication path, or via one or more wireless signal repeaters (not shown).

A site server **2716** may include a local site service **2730** and a local text service **2732**. A local site service **2730** may interact with a remote site service **2706**
25 through a local firewall **2734** to provide access to WGR data. A local text service **2732** may interact with text message service **2726** and/or a text message handler **2724** to enable text messages to be sent from, or received by, the remote site **2712-0**.

While the above has described an embodiment in which text messages may
30 be transferred via a text message service **2726**, in other embodiments, a local site may alternatively (or in addition) include a local text message modem **2736**. A local text message modem **2736** may enable a local device **2716** (e.g., local server), to directly send text messages to, and receive text messages from, an endpoint **2738** of

a corresponding text message network.

In particular embodiments, a remote site service **2706** may provide web pages based on stored node data, and/or concurrent node data. Such a feature may allow users to access data from nodes of remote sites. In very particular
5 embodiments, such a web page may include an image of a gauge that is refreshable. One embodiment of such a web page is shown in FIG. 28.

It should be appreciated that in the foregoing description of exemplary embodiments of the invention, various features of the invention are sometimes grouped together in a single embodiment, figure, or description thereof for the
10 purpose of streamlining the disclosure aiding in the understanding of one or more of the various inventive aspects. This method of disclosure, however, is not to be interpreted as reflecting an intention that the claimed invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed
15 embodiment. Thus, the claims following the detailed description are hereby expressly incorporated into this detailed description, with each claim standing on its own as a separate embodiment of this invention.

It is also understood that the embodiments of the invention may be practiced in the absence of an element and/or step not specifically disclosed. That is, an
20 inventive feature of an embodiment may be elimination of an element.

Accordingly, while the various aspects of the particular embodiments set forth herein have been described in detail, the present invention could be subject to various changes, substitutions, and alterations without departing from the spirit and scope of the invention.

25

IN THE CLAIMS

What is claimed is:

1. A method of reading a gauge, comprising:
5 capturing a digital image of the gauge with a gauge reading device attached to the gauge, the digital image comprising a plurality of pixels;
determining an angle of a gauge feature based on positions of predetermined pixels of the digital image; and
converting the angle into a gauge reading.
- 10 2. The method of claim 1, wherein:
the gauge feature comprises a needle; and
determining the angle includes
determining an initial angle of the needle from the image pixel locations,
if the initial angle is outside predetermined limits, rotating all the pixel
15 locations in a first direction about an anchor point by a displacement angle,
determining a rotated angle of the needle from the rotated image pixel locations, and
modifying the rotated angle by the displacement angle to generate the angle of the
gauge feature.
- 20 3. The method of claim 1, wherein:
the gauge feature comprises a needle; and
determining the angle includes generating line pixel locations corresponding
to a plurality of lines at different angles, determining differences between line pixel
locations and image pixel locations, determining the angle of the gauge feature
25 based on the differences between the line pixel locations and image pixel locations.
4. The method of claim 3, wherein:
determining the angle of the gauge feature based on the differences between
the line pixel locations and image pixel locations includes
30 selecting one of the plurality of lines as a best fit line when the line has the
smallest difference between predetermined line pixel locations and predetermined
image pixel locations, and

assigning an angle of the best fit line as the angle of the gauge feature.

5. The method of claim 3, wherein:
determining the angle of the gauge feature based on the differences between the line pixel locations and image pixel locations includes
5 selecting one of the plurality of lines as a best fit line when the line has a largest number of predetermined image pixel locations within a location difference range to predetermined image pixel locations, and
assigning an angle of the best fit line as the angle of the gauge feature.
- 10 6. The method of claim 1, wherein:
the gauge feature comprises a needle; and
determining the angle of the gauge feature includes
establishing a region of interest (ROI) that is a portion of the digital image
including a travel path of the needle,
15 storing at least position and intensity values for each pixel in the ROI,
assigning a pixel location as a pixel needle position based on variance in intensity within the ROI, and
calculating the angle of the gauge feature from the location of the pixel needle position.
- 20 7. The method of claim 6, wherein:
the ROI comprises pixel positions having X and Y coordinate locations within the digital image, and
storing at least position and intensity values for each pixel in the ROI includes
25 forming an array, and
storing Y locations and intensity values at each location of the array, each array location corresponding to, but not storing, a different X location.
8. The method of claim 6, wherein:
30 starting at one end of the ROI, determining an intensity difference between adjacent pixels of the ROI, averaging intensity differences for groups of adjacent pixels in the ROI, and assigning a pixel location as a pixel needle position based on

a greatest increase in intensity difference and a greatest decrease in intensity difference with respect to one of the average intensity differences.

9. The method of claim 6, wherein:

5 establishing the ROI includes defining a plurality of line segments, each comprising a plurality of pixels, the plurality of segments forming the ROI.

10. The device of claim 9, wherein:

10 capturing the digital image of the gauge includes capturing an image that includes a reading needle and a set point needle, the reading needle being the gauge feature; and

determining the angle of the gauge feature includes distinguishing pixels corresponding to the set point needle from pixels corresponding to the reading needle.

15

11. A gauge reader system, comprising:

at least one gauge reader device that includes an adapter section that couples to a gauge,

15 at least one image sensor that acquires image data of the gauge, the image data comprising a plurality of pixels,

20 an angle determination section that determines an angle corresponding to a gauge feature, and

a conversion section that transforms the angle into a gauge reading.

25 12. The system of claim 11, wherein:

the at least one gauge reader further includes a processor, and

the angle determination section comprises an angle determination routine embodied on a machine readable media executable by the processor, including instructions for

30 determining an initial angle of a gauge needle from the image data, if the initial angle is outside of a predetermined range, rotating all the pixel locations in a first direction about a predetermined position by a displacement angle, determining a modified angle for the gauge needle, and determining a gauge needle angle from the

modified angle and the displacement angle.

13. The system of claim 11, wherein:

the at least one gauge reader further includes a processor, and

5 the angle determination section comprises an angle determination routine embodied on a machine readable media executable by the processor, including instructions for

generating pixel positions for a plurality of lines at different angles, and comparing predetermined pixel positions of each line to predetermined pixel
10 positions of the gauge image.

14. The system of claim 13, wherein:

the angle determination routine further includes instructions for

15 matching one of the plurality of lines with a gauge needle orientation based on a minimum distance between the predetermined pixel positions of the gauge image and the matching line, and

setting the angle of the matching line as the angle for translation into the gauge reading.

20 15. The system of claim 13, wherein:

the angle determination routine further includes instructions for

matching one of the plurality of lines with a gauge needle orientation based on a distance range between predetermined pixel positions of the gauge image and the matching line, and

25 setting the angle of the matching line as the angle for translation into the gauge reading.

16. The system of claim 11, further including:

30 a central web server system that monitors gauge readers at locations remote from the web server system, the web servers system comprising

a data base, and

a web service that accesses site data from the gauge readers through a firewall in response to poll requests from remote locations and stores such data in a

database, the site data including at least gauge identifying data and a gauge reading, and provides web pages for providing the site data.

17. The system of claim 16, further including:

5 a text message sending system coupled to receive predetermined notifications from a site, and forwarding corresponding text messages to network endpoints in response to such notifications.

18. A gauge reading system, comprising:

10 at least one gauge reader in communication with a site server, the gauge reader being a self-contained device comprising
an image sensor that acquires an image of a corresponding gauge,
an image processor that generates pixel locations corresponding to a plurality of lines, and determines an angle of a gauge needle by comparing predetermined
15 pixel positions of each line to predetermined image pixel positions to arrive at a matching line, and
a reading generator that generates a gauge reading based on the angle of the matching line; and
a central web server coupled to the site server by a communication firewall to
20 receive at least gauge readings from the gauge reader device in response to predetermined requests from the site server.

19. The system of claim 18, wherein:

25 the central web server includes a monitoring service that periodically stores readings from a plurality of gauges for access via a network .

20. The system of claim 18, further including:

a text message service that forwards text messages to predetermined network end points in response to at least a gauge reading, and forwards text
30 messages from network endpoints to the central web server; and

the central web server forwards received text message data in response to a poll request from the site server.

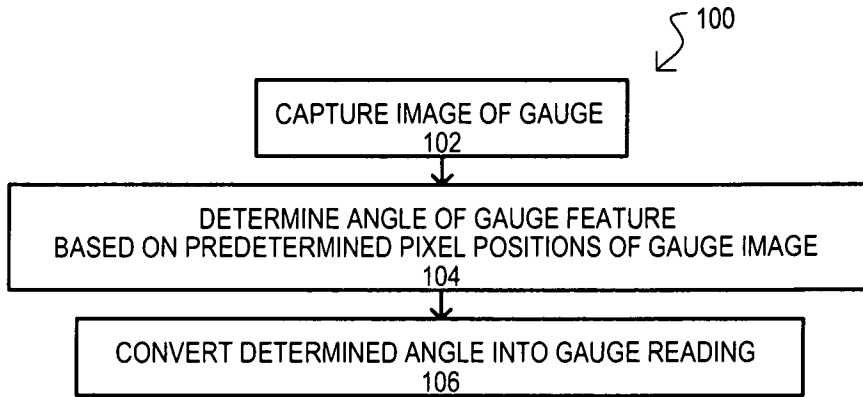
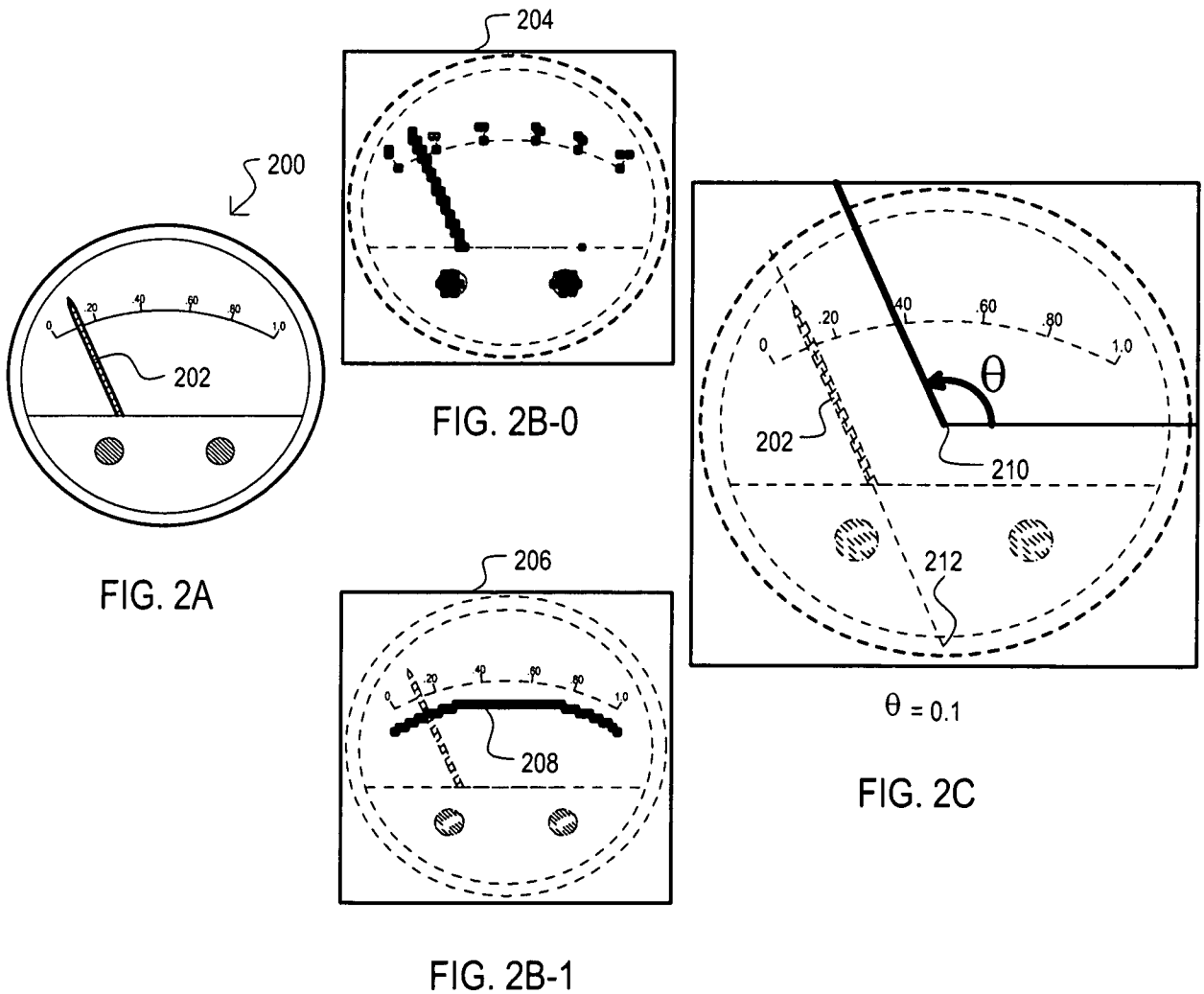


FIG. 1



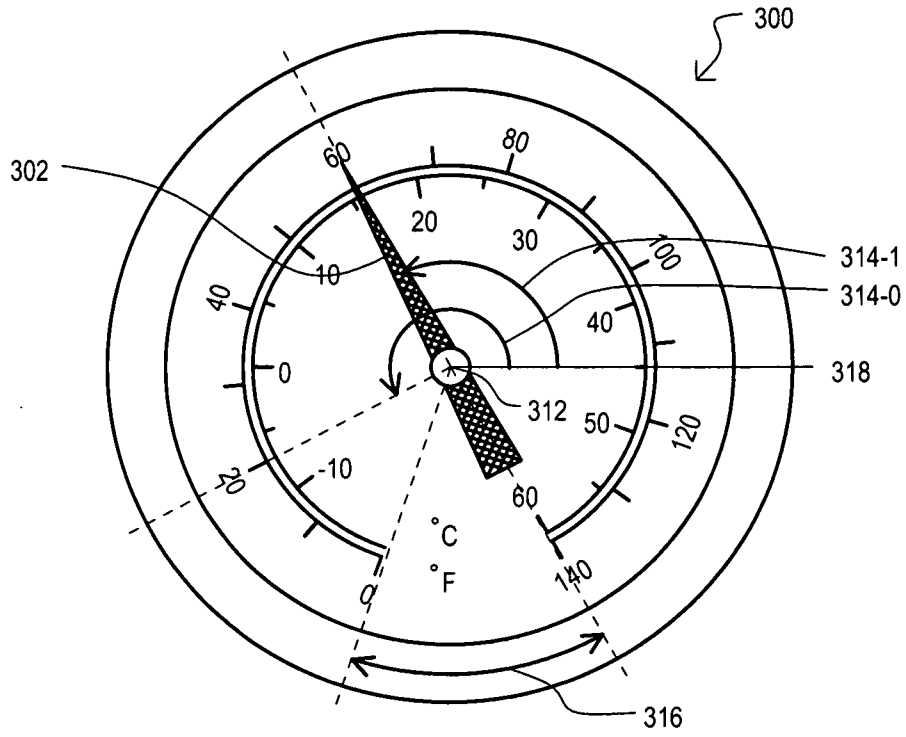


FIG. 3A

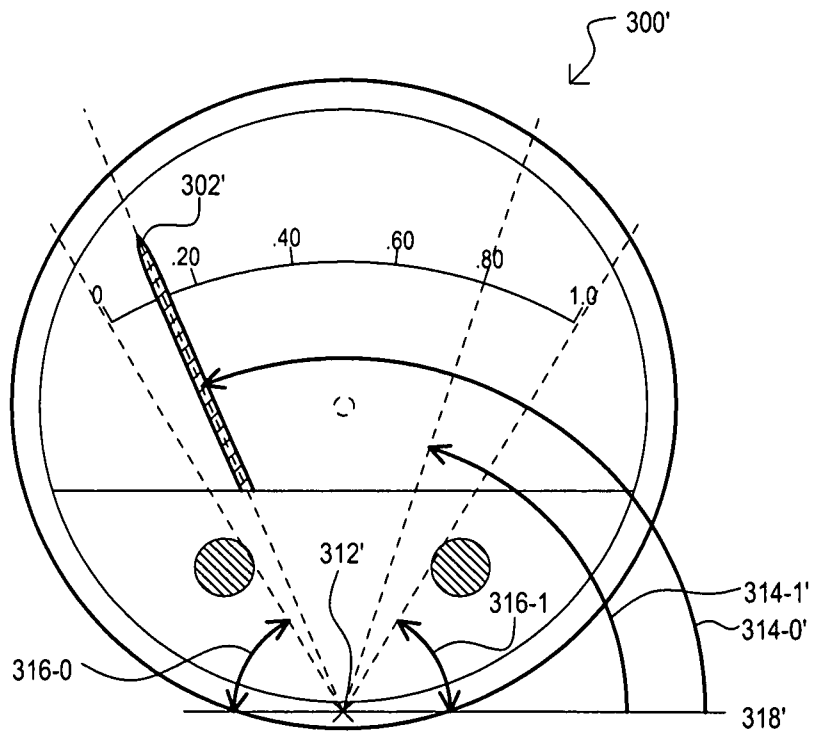


FIG. 3B

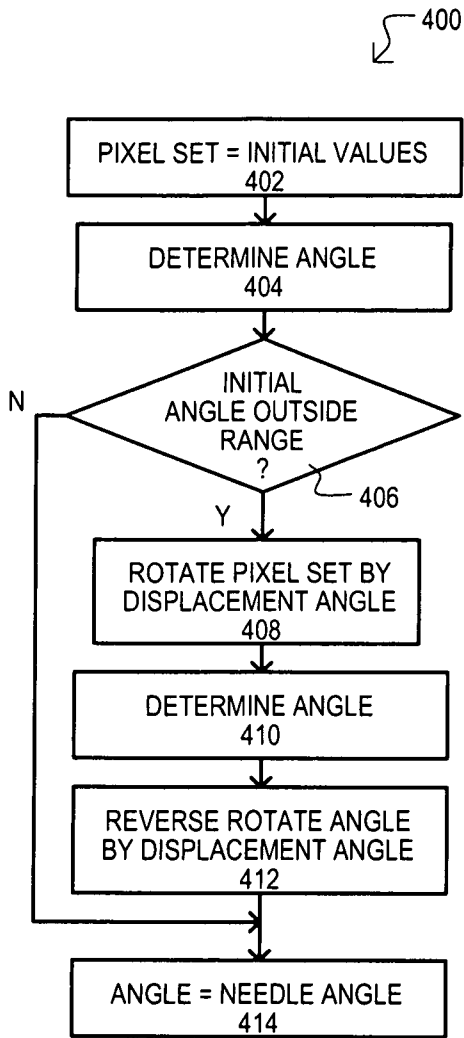


FIG. 4

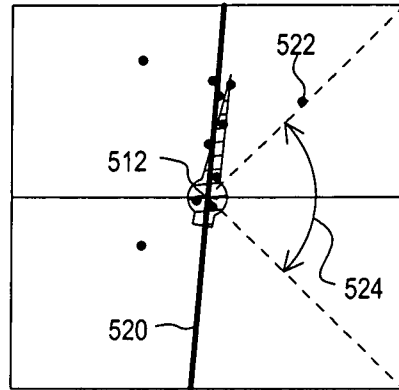


FIG. 5A

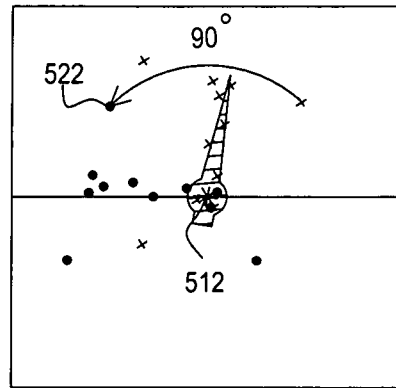


FIG. 5B

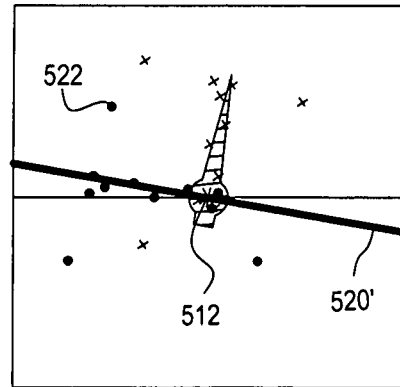


FIG. 5C

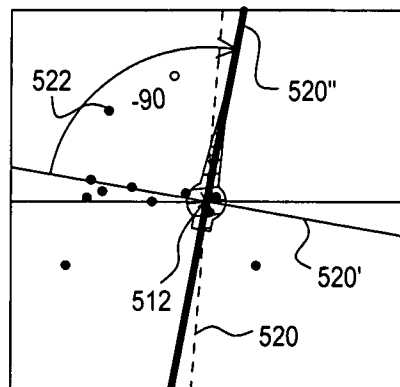


FIG. 5D

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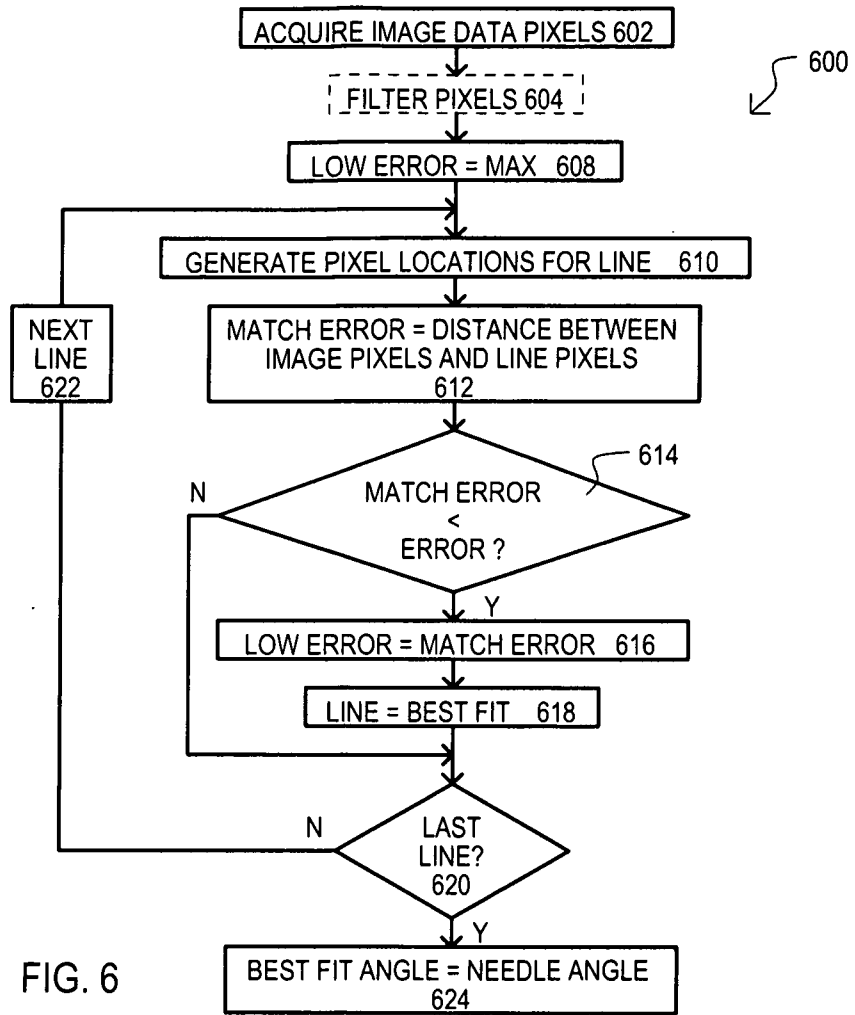


FIG. 6

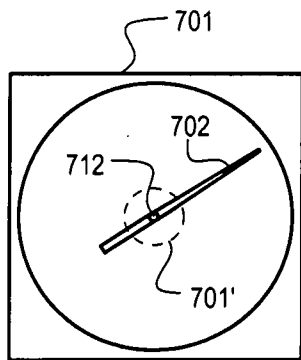


FIG. 7A

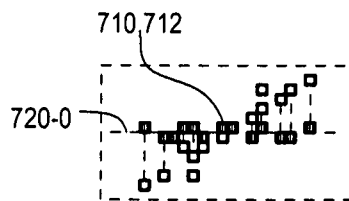


FIG. 7B

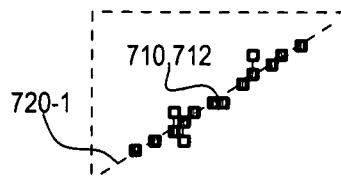


FIG. 7C

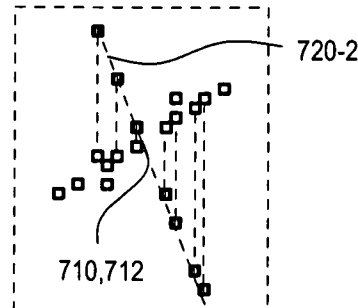


FIG. 7D

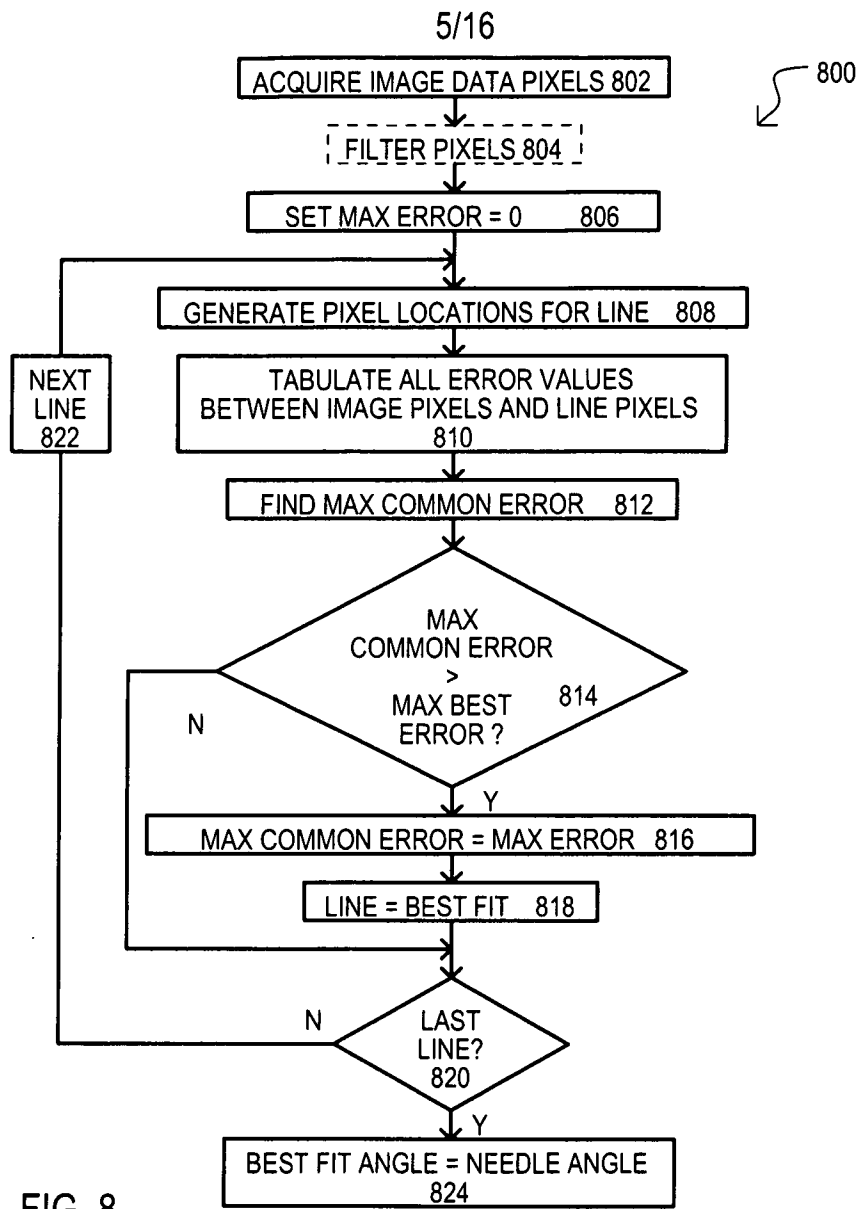


FIG. 8

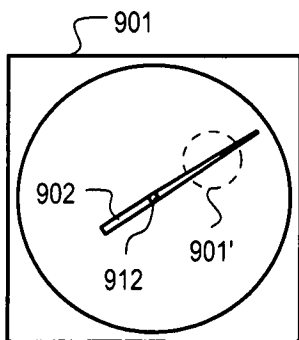


FIG. 9A

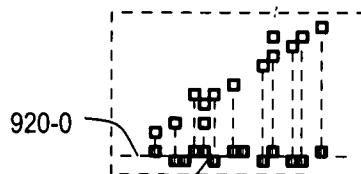


FIG. 9B

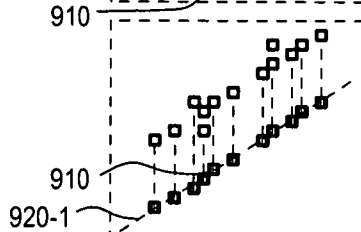


FIG. 9C

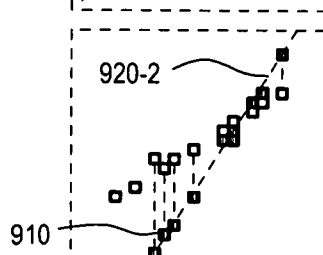


FIG. 9D

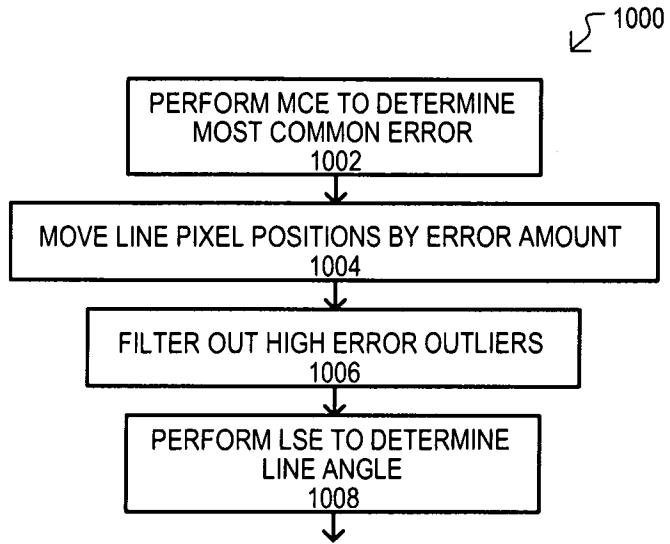


FIG. 10

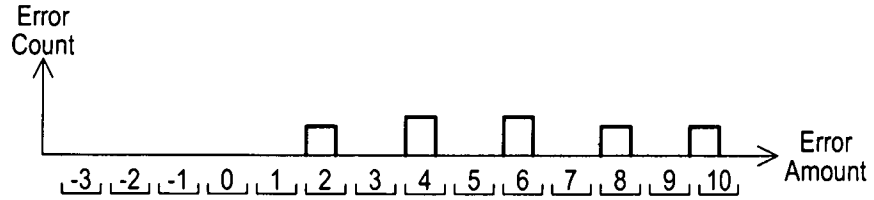


FIG. 11A

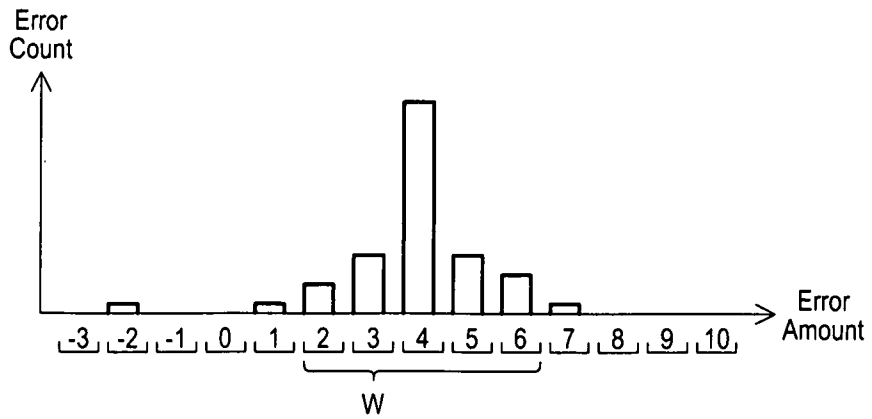


FIG. 11B

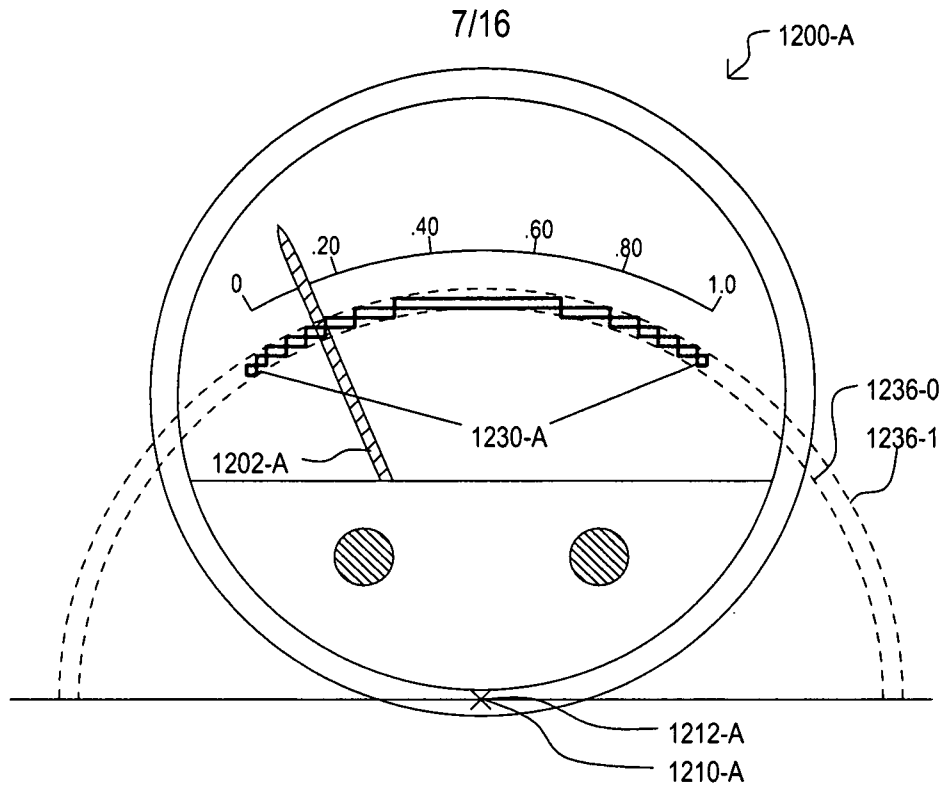


FIG. 12A

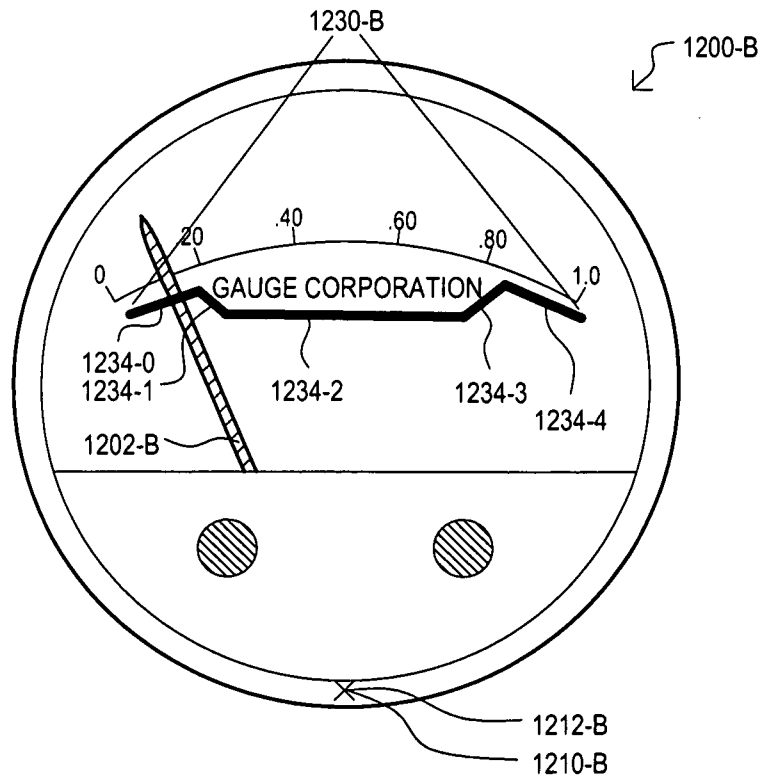


FIG. 12B

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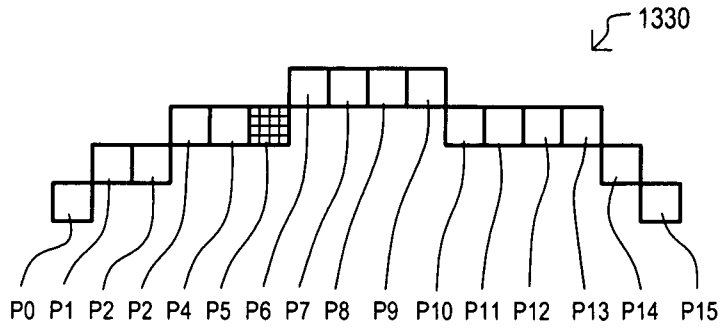


FIG. 13

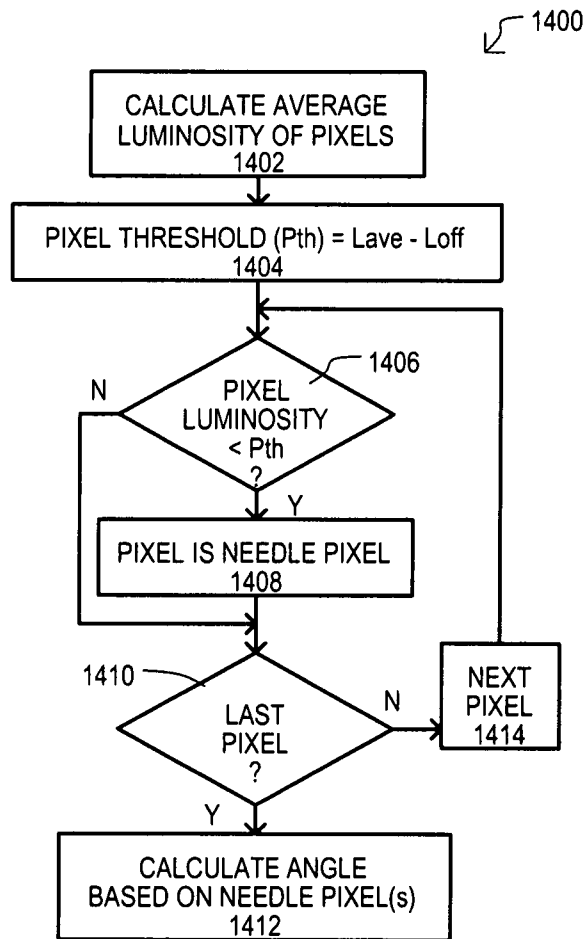


FIG. 14

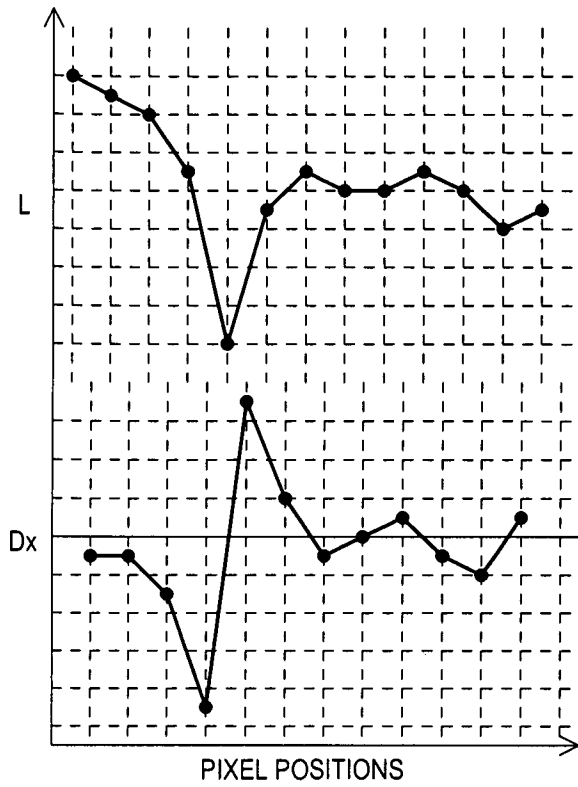


FIG. 15A

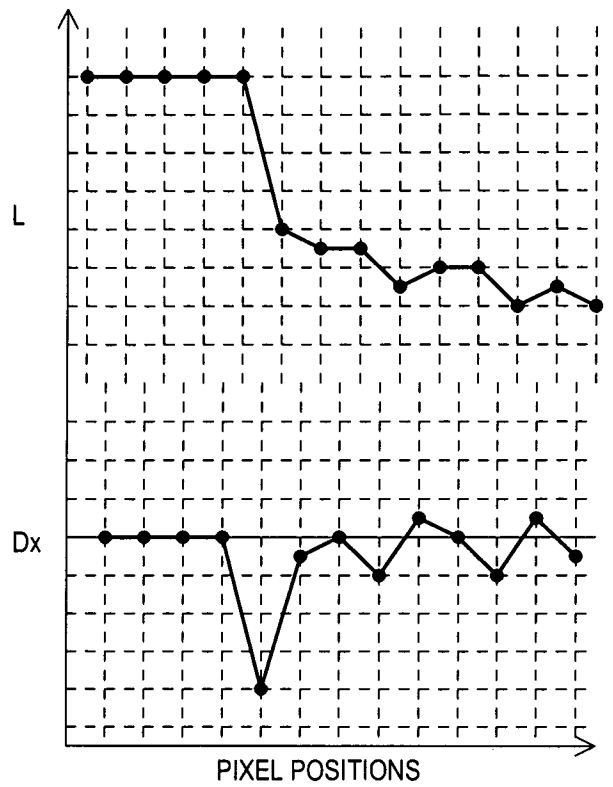


FIG. 15B

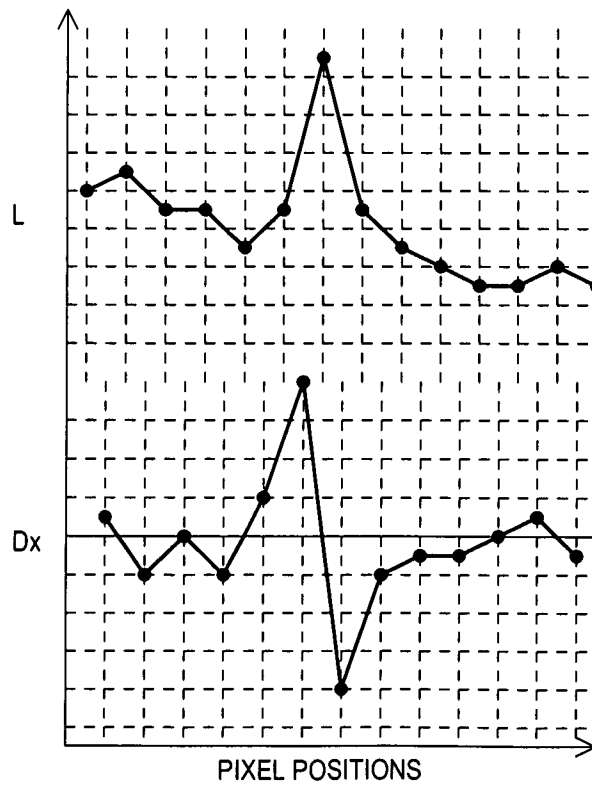


FIG. 15C

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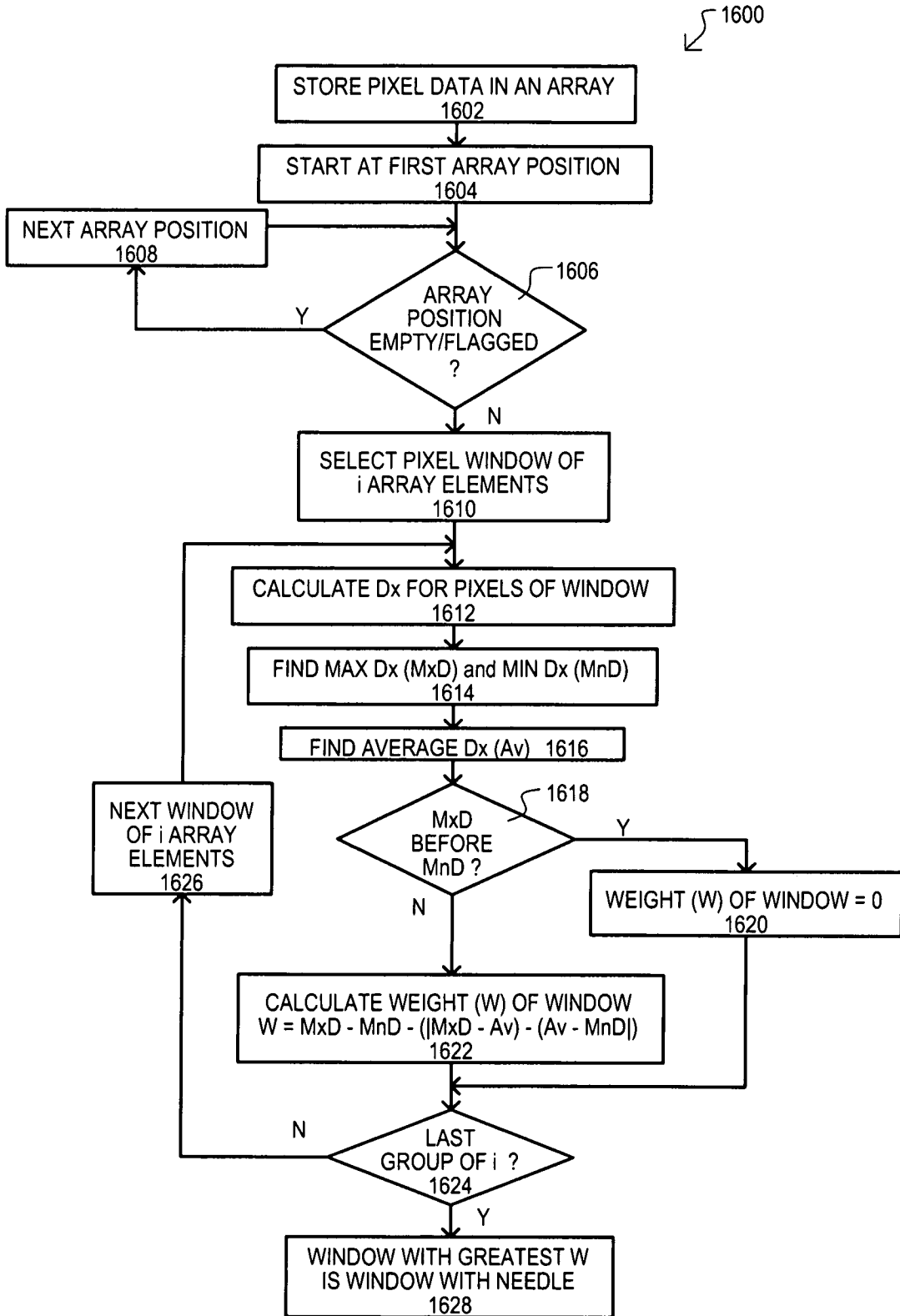


FIG. 16

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FIG. 17A

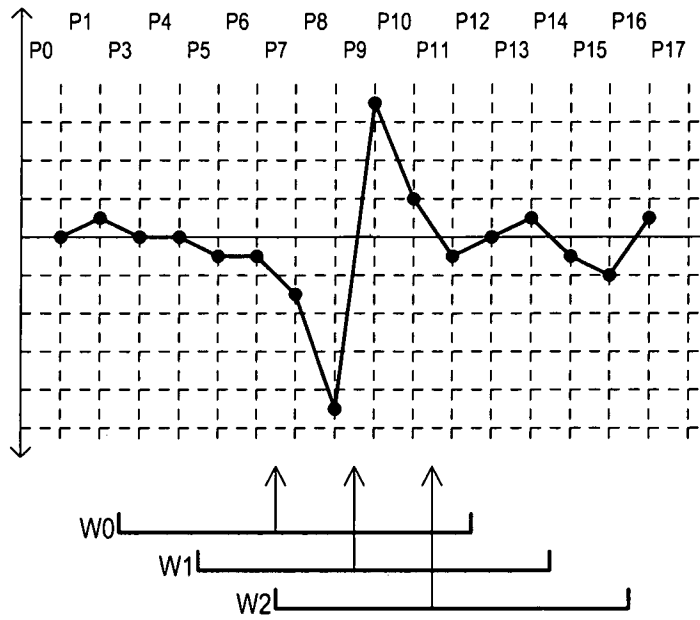
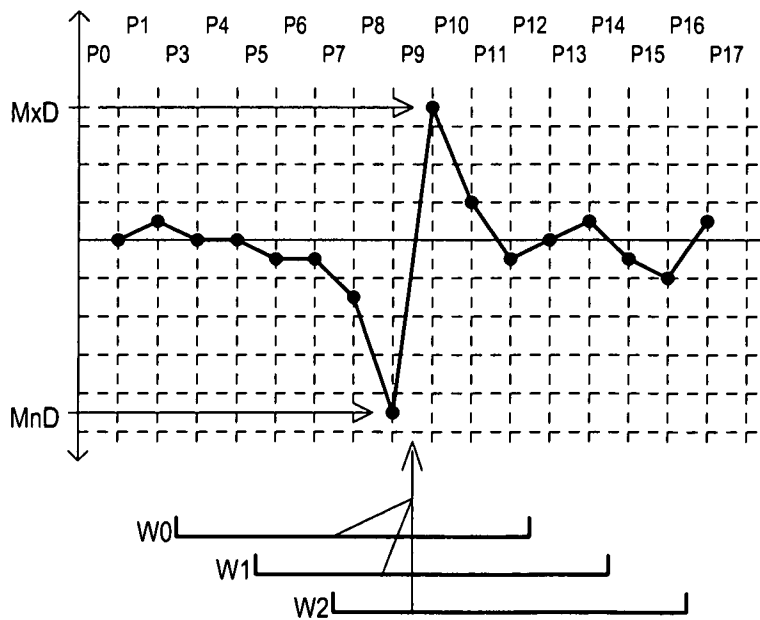


FIG. 17B



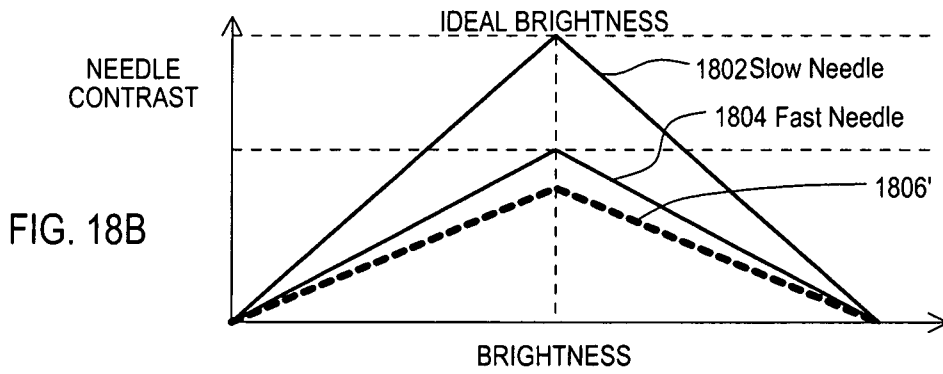
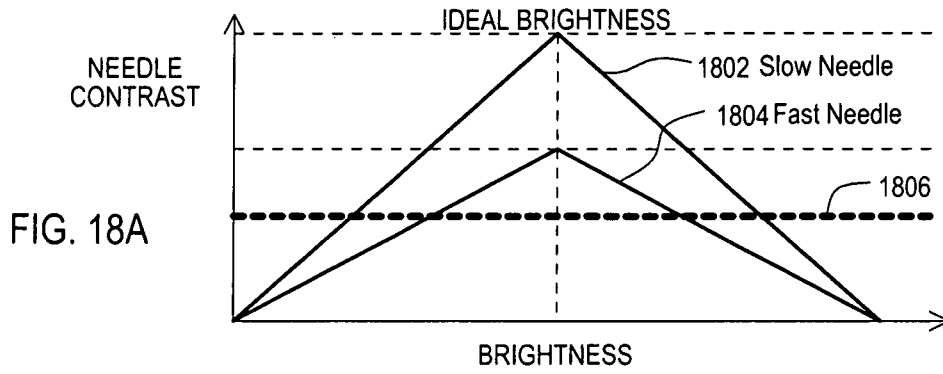


FIG. 19

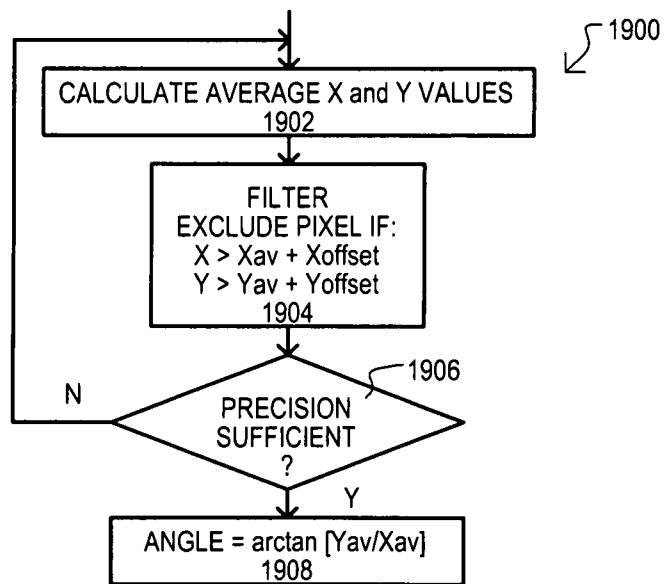
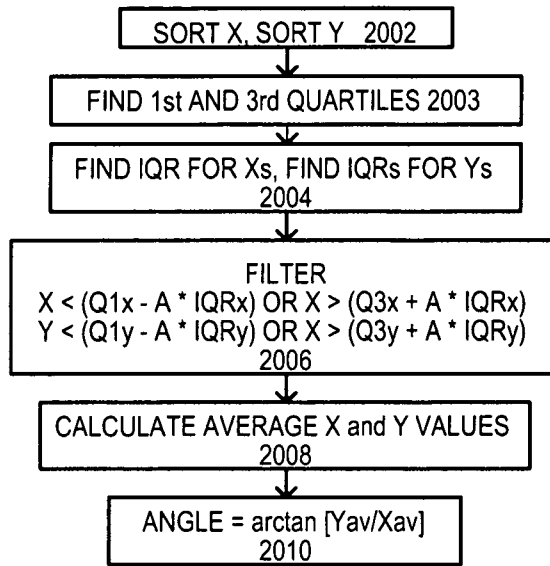
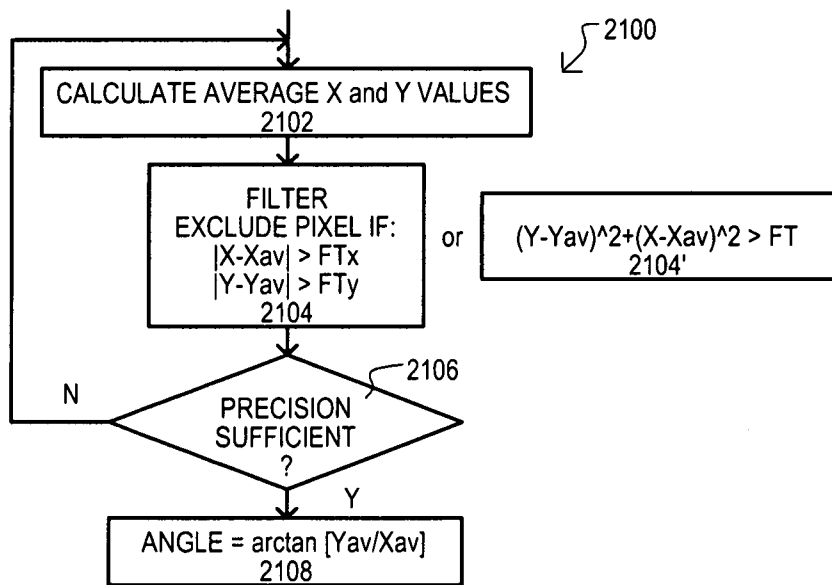


FIG. 20



2000

FIG. 21



2100

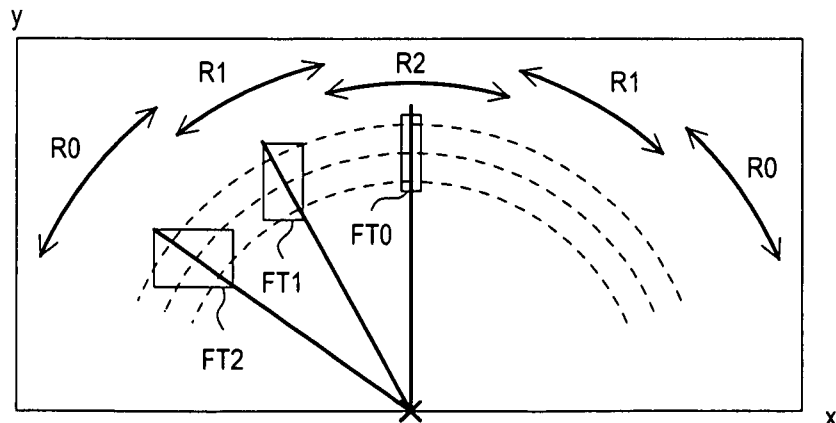


FIG. 22

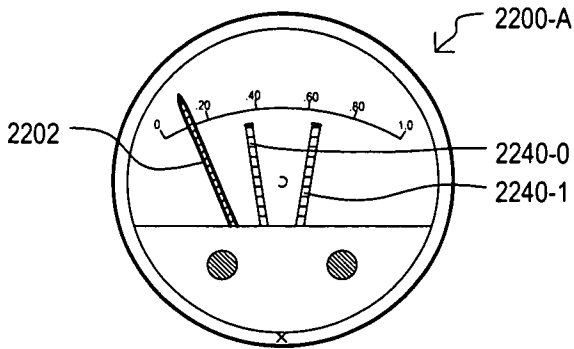


FIG. 22A

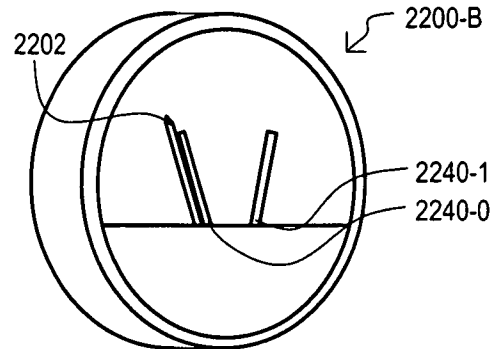


FIG. 22B

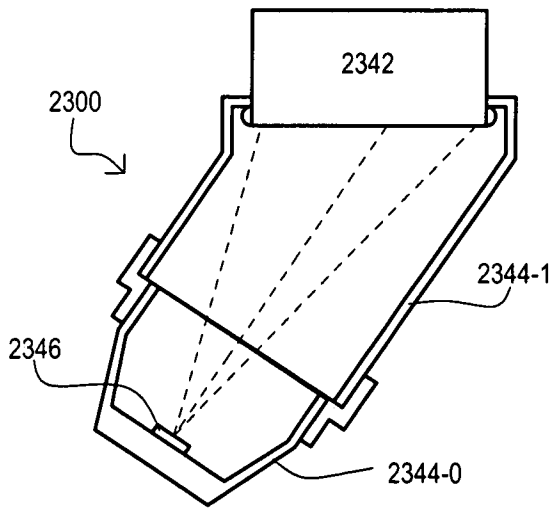


FIG. 23

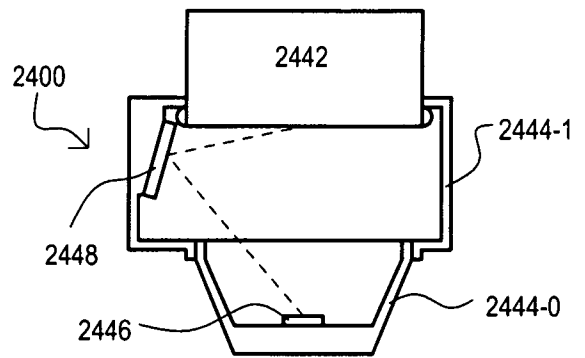


FIG. 24

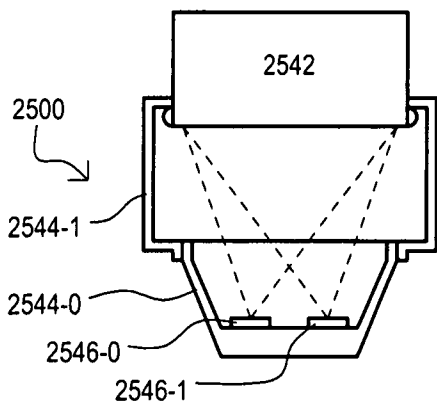


FIG. 25

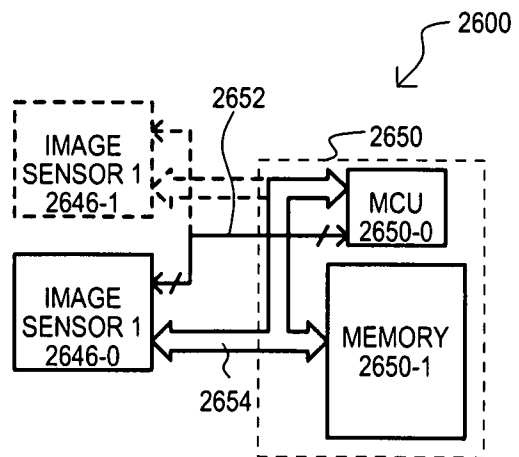


FIG. 26

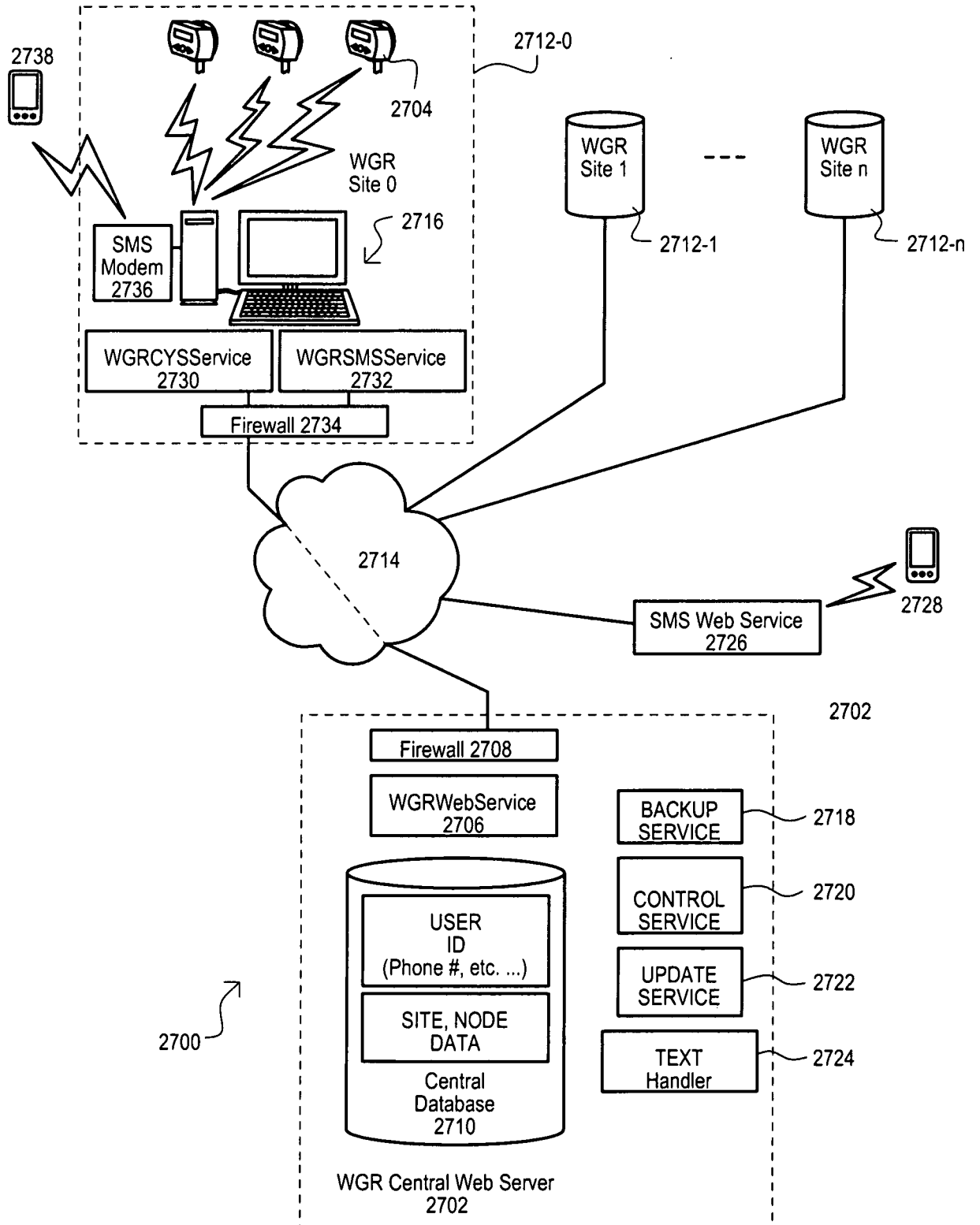


FIG. 27

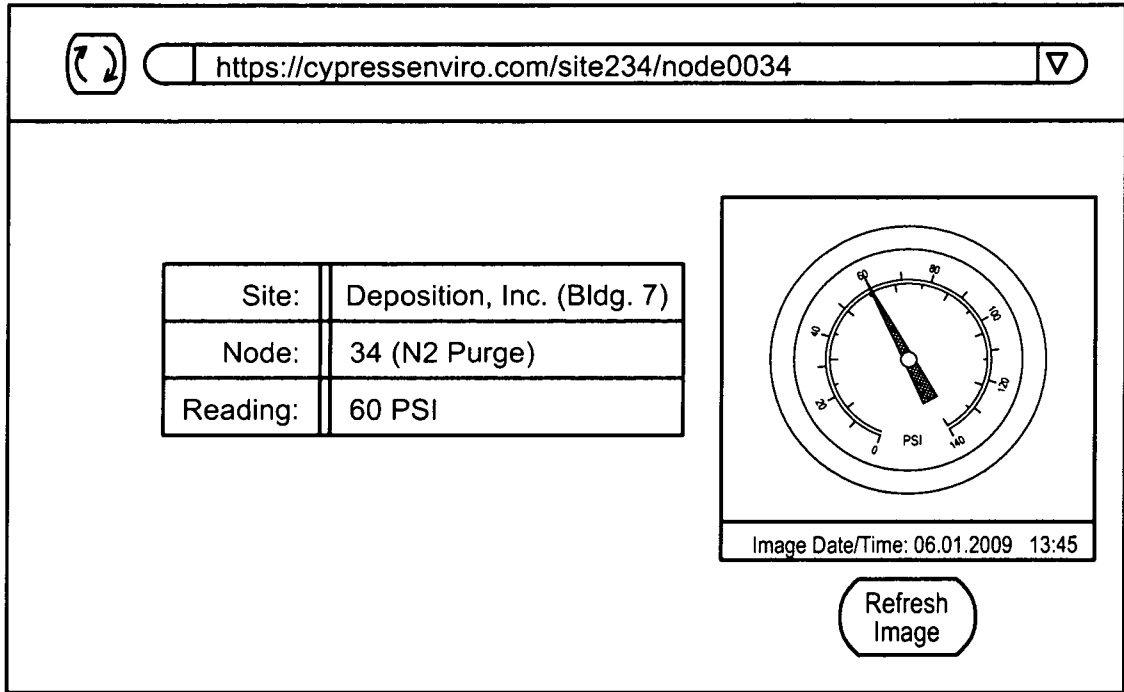


FIG. 28

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2009/000643

A. CLASSIFICATION OF SUBJECT MATTER IPC(8) - G06K 9/46 (2009.01) USPC - 382/190 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC(8) - G06K 9/46 (2009.01) USPC - 382/190 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) PatBase, Google Patents		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2001/0055425 A1 (CHIU) 27 December 2001 (27.12.2001) entire document	1-15
Y		16-20
Y	US 6,891,838 B1 (PETITE et al) 10 May 2005 (10.05.2005) entire document	16-20
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/>		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 06 March 2009		Date of mailing of the international search report 17 MAR 2009
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201		Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774