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(54) **Title:** IMAGING DEVICE CALIBRATION

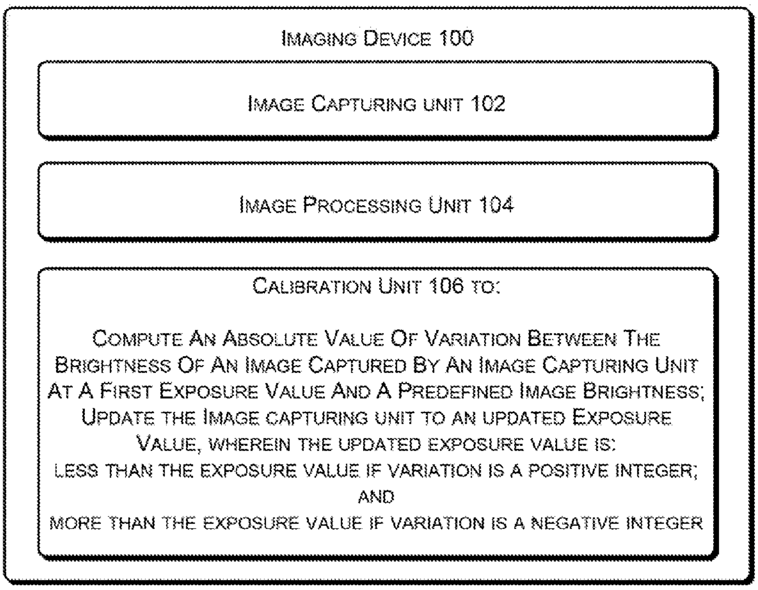

Figure 1

(57) **Abstract:** Techniques of calibrating imaging devices are described. In an example, an image of an object is captured at an exposure value and an absolute value of variation between brightness for the image and a predetermined image brightness is computed. The absolute value is then determined to be greater than a threshold value. Based on variation, the exposure value is recursively updated, and images are recaptured at the updated exposure values. Further, the absolute value of variation of the recaptured image is compared to the threshold value, until the absolute value of variation between the brightness of the recaptured image and the predetermined image brightness is less than the threshold value.

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IMAGING DEVICE CALIBRATION

BACKGROUND

[0001] An imaging device includes a camera coupled to a projector device. In operation, the camera may serve to capture an image of an object and the projector device may serve to supply light to illuminate the object in the field of view (FOV) of the camera. The light serves to construct the 3D geometry of the object and also provides for sufficient and uniform illumination, balanced colour, and temperature to the camera.

BRIEF DESCRIPTION OF DRAWINGS

[0002] Fig. 1 illustrates an imaging device, in accordance with an example of the present subject matter;

[0003] Fig.2 illustrates an imaging device, in accordance with an example of the present subject matter;

[0004] Fig.3 illustrates a method of calibrating an imaging device, in accordance with an example implementation of the present subject matter; and

[0005] Fig.4 illustrates a method of calibrating an imaging device, in accordance with another example implementation of the present subject matter.

DETAILED DESCRIPTION

[0006] An imaging device is assembled by assembling one camera or more than one camera and a projector device as a working pair. Before the camera(s) and the projector device are assembled to create the imaging device, each of the camera and the projector device goes through a number of quality checks. There may be situations where the camera and the projector device may pass their individual quality checks, but their assembly into a single unit may still produce erroneous results due to individual tolerances of the camera and the projector device. A system level calibration may be performed at a system assembly line to remove any variations generated due to individual tolerances of components in the imaging device. The system level calibration may involve finding a combination of a camera exposure and a projector device flash intensity, that may produce a target image quality.

[0007] The system level calibration is done manually for all regions within the field of view (FOV) of the camera. That is, the camera exposure is calculated for each region within the FOV against a fixed projector device flash intensity, until the optimum camera exposure is found. Since the camera exposure is analysed manually, and the steps are repeated again until the optimum camera exposure is found, such system level calibrations are tedious and time consuming. Further, the repeated flashing of the LEDs of the projector device may overheat the LEDs, which may affect the working of the LEDs, for example drop in the flash intensity of the projector device. Thus, even if an optimum camera exposure is found, such an exposure may be calibrated to a reduced flash intensity, leading to a capture of oversaturated or overexposed images at later stages of use of the imaging device.

[0008] According to the example implementation of present subject matter, techniques for calibrating imaging devices are described. The imaging device may comprise an image capturing unit, such as a camera, and a light emitting source.

[0009] In an example, the imaging device may be calibrated by updating an exposure value of the image capturing unit at a fixed flash intensity of the light emitting source until a target image quality is achieved.

[0010] In an example implementation, an image is captured at a first exposure value and a brightness of the image is determined. The brightness of the image is then compared to a predefined image brightness and a variation between the former and the later brightness is computed. Further, in case an absolute value of the variation is determined to be greater than a threshold value of variation, the image capturing unit is set to an updated exposure value. In an example, if the variation is found to be a positive integer, the updated exposure value is set at a value less than the first exposure value. Otherwise, the updated exposure value is set at a value greater than the first exposure value.

[0011] The image is recaptured at the updated exposure value recursively. Further, an absolute value of variation between the brightness of the recaptured image and predefined image brightness is compared, until the absolute value of variation between the brightness of the recaptured image and the predefined image brightness is less than the threshold value.

[0012] Since the updated exposure value is determined based on the variation between the brightness of the last captured image and the predefined image brightness, the number of iterations performed to attain the exposure value corresponding to the predefined image brightness may be reduced. The reduction in number of iterations results in a faster calibration of the imaging device. Further, the reduction in the number of iterations lead to a reduction in the number of instances the LEDs of the projector device are flashed, thus preventing the overheating of the LEDs of the projector device.

[0013] Although the description herein is described with reference to a configuration where the exposure value of the image capturing unit is being updated while keeping the flash intensity of the light emitting source at a fixed value, in an example, the imaging device may be calibrated by updating the flash intensity of the light emitting source at a fixed exposure value of the image capturing unit until the target image quality is achieved.

[0014] The above techniques are further described with reference to Figure 1 to Figure 4. It should be noted that the description and the figures merely illustrate the principles of the present subject matter along with examples described herein and should not be construed as a limitation to the present subject matter. It is, thus understood that various arrangements may be devised that although not explicitly described or shown herein, embody the principles of the present subject matter. Moreover, all statements herein reciting principles, aspects, and implementations of the present subject matter, as well as specific examples thereof, are intended to encompass equivalents thereof.

[0015] Figure 1 illustrates an imaging device 100, in accordance with an example implementation of the present subject matter. The imaging device 100 may comprise an image capturing unit 102, an image processing unit 104, and a calibration unit 106. Examples of the image capturing unit 102 may include, but not limited to, a camera mounted on a desktop, laptop, smartphones, PDA and other similar devices, a single-lens reflex camera (SLR), a Digital Single Lens Reflex camera (DSLR), a digital rangefinder, a line scan camera.

[0016] In an example implementation, an image capturing unit 102 may capture an image of an object. The image may be captured at an exposure value of the image capturing unit 102. The image processing unit 104 may then process the image to determine brightness of the image. The image processing unit 102 may then compute a variation between the brightness of the image and a predefined image brightness. In an example, the predefined image brightness may be the brightness of an image having a target image quality. The calibration unit 106 may then compute an absolute value of the variation. The calibration unit 106 may further determine the absolute value of the variation to be greater than a threshold value. In an example, the threshold value may be the maximum permissible value of variation between the brightness of the captured image and the predefined image brightness.

[0017] If the absolute value of the variation is found be greater than the threshold value, the calibration unit 106 may update the image capturing unit 102 to capture a subsequent image at an updated exposure value. In an example, the updated exposure value takes a value less than the exposure value of the image if the variation is a found to be positive integer. Further, the updated exposure value takes a value more than the exposure value of the image if the variation is found to be a negative integer.

[0018] The calibration unit 106 may then set the image capturing unit 102 to an updated exposure value and may recapture an image of the object based on the updated exposure value. The calibration unit 106 may further compare an absolute value of variation of the brightness of the recaptured image with the threshold value and may again update the exposure value of the image capturing unit 102 to a further updated value.

[0019] In an example, the exposure value of the image capturing unit 102 is recursively updated and an image at the updated exposure value is captured. The absolute value of variation of the recaptured image is further compared with the threshold value recursively. Further, based on the absolute value of variation of the recaptured image, the image capturing unit 102 is recursively updated to the updated exposure value, until the absolute value of variation between the brightness of the recaptured image and the predefined image brightness is less than the threshold value of variation.

[0020] Figure 2 illustrates an imaging device 200, in accordance with an example of the present subject matter. The imaging device 200 includes an image capturing unit 102 and a light emitting source 206. Examples of light emitting source may include, but not limited to, an LED flash, a built-in pop up camera flash, a dedicated camera flash, a macro ring light camera flash, and a hammerhead flash.

[0021] The imaging device 200 may further include processor(s) 202, interface(s) 204 coupled to the processor(s) 202, and a memory 208. The functions of the various elements shown in the Figures, including any functional blocks labelled as "processor(s)", may be provided through the use of dedicated hardware as well as hardware capable of executing instructions. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term "processor" would not be construed to refer exclusively to hardware capable of executing instructions, and may implicitly include, without limitation, digital signal processor (DSP) hardware, network processor, application specific integrated circuit (ASIC), field programmable gate array (FPGA), read only memory (ROM) for storing instructions, random access memory (RAM), non-volatile storage. Other hardware, conventional and/or custom, may also be included.

[0022] Further, the memory 206 may include any computer-readable medium including, for example, volatile memory (e.g., RAM), and/or non-volatile memory (e.g., EPROM, flash memory, etc.). The interface(s) 208 may include a variety of programmed or hardware interfaces that enable the computing device to communicate with image capturing unit and touch surface.

[0023] The imaging device 200 may further include the image processing unit 104 along with the calibration unit 106, other units 210, and data 212. In an example, the image processing unit 104, the calibration unit 106, and the other units 210 may reside in the memory 208. In another example, the image processing unit 104, the calibration unit 106, and the other units 210 may be implemented as separate hardware capable of performing different functionalities of the imaging device 200. The image processing unit 104, the calibration unit 106, and the other units 210 may include routines, programs, objects, components, data structures, and the like, which perform particular tasks or implement particular abstract data types. The image processing unit 104, the calibration unit 106, and the other units 210 may further include electronic circuitry or a combination of electronic circuitry and control programs that operate the components according to the functions described herein. In an example, the other units 210 may perform functionalities that supplement other functions of the imaging device 200.

[0024] The data 212 serves, amongst other things, as a repository for storing data that may be fetched, processed, received, or generated by the image processing unit 104, the calibration unit 106, and the other units 210. In an example, the data may include image capturing data 214, image processing data 216, calibration data 218, and other data 220. The image capturing data 214 may include the exposure values of the image capturing unit 102. Further, the image processing data may include brightness of the images captured by the image capturing unit 102. Furthermore, the calibration data 218 may include values of variation for multiple images captured by the image capturing unit 102, a value of the predefined image brightness, and a threshold value of variation between the brightness of an image captured by the image capturing unit 102 and the predefined image brightness.

[0025] In an example implementation, an image capturing unit 102 may capture an image of an object. The image may be captured at an exposure value of the image capturing unit 102. In an example, the exposure value may be the median of a range of exposure values available for the image capturing unit 102. While the first exposure value has been described to be equal to the median of the range of the exposure values available for the image capturing unit 102, it may be noted that the first exposure value may take other different values based on the conditions in which the image is captured. In an example, the exposure value of the image capturing unit 102 may be computed at a predetermined flash light power of the light emitting source 106. The image processing unit 102 may then determine the brightness of the image and store the determined brightness in the image processing data 216. The calibration unit 102 may then compute a variation between the brightness of the image and a predefined image brightness. As explained earlier, the predefined image brightness may be the brightness of an image having the target image quality. The calibration unit 106 may further compute an absolute value of the variation and determine the absolute value of the variation to be greater than a threshold value of variation. Based on the variation, the calibration unit 106 may calibrate the image capturing unit 102 to capture a subsequent image at an updated exposure value. The calibration unit 106 may further store the updated exposure value in the image capturing data 214. As explained earlier, the threshold value may be the maximum permissible value of variation between the brightness of the captured image and the predefined image brightness.

[0026] If the variation is found to be a positive integer, the calibration unit 106 may calibrate the image capturing unit 102 to the updated exposure value, where the updated exposure value may lie in a range of exposure values less than the first exposure value. That is, the updated exposure value may be less than the first exposure value. Further, if the variation is found to be a negative integer, the calibration unit 106 may calibrate the image capturing unit 102 to the updated exposure value, where the updated exposure value may lie in a range of exposure values greater than the first exposure value. That is, the updated exposure value may be more than the first exposure value.

[0027] In an example, the imaging device 200 may recursively update the exposure value of the image capturing unit 102 and capture an image of the object at updated exposure value. The image device may store the updated exposure values in the image capturing data 214, every time the exposure value for the image capturing unit 102 is updated. The imaging device 200 may then compute an absolute value of variation between the brightness of the image captured at the updated exposure value and the predefined image brightness. The absolute value of variation between the brightness of the recaptured images and the predetermined image brightness may be stored in the calibration data 218. Further, based on the absolute value of the variation, the imaging device 200 may recursively update the exposure value of the image capturing unit 102 and capture the image at the updated exposure values until the absolute value of variation between the brightness of the recaptured image and the predefined image brightness is less than the threshold value of variation.

[0028] Once the absolute value of variation between the brightness of the recaptured image and the predefined image brightness is less than the threshold value of variation, the calibration unit 106 may store an exposure value, say a final exposure value, corresponding to the which variation between the brightness of the recaptured image and the predefined image brightness is less than the threshold value of variation. The calibration unit 106 may then store the final exposure value in a non-volatile memory (not shown).

[0029] In another example implementation, techniques involving predictive data model may be used to find the updated exposure value for the image capturing unit 102. In operation, the image capturing unit 102 may capture the first image of the object at the first exposure value. The brightness of the first image may then be determined and stored in the image processing data 216. The calibration unit 106 may then determine variation between brightness of a first image captured by an image capturing unit and the predefined image brightness. The variation between brightness of a first image captured by an image capturing unit and the predefined image brightness may then be saved in the calibration data 218.The calibration unit may further determine if the absolute value of the variation is greater than a threshold value of variation. Based on the variation, the calibration unit 106 may calibrate the exposure value of the image capturing unit 102 to a median exposure value. If the variation is found to be a positive integer, the calibration unit 106 may calibrate the image capturing unit 102 to the median exposure value, where the median exposure value may be the median of a range of exposure value less than the first exposure value. Further, if the variation is found to be a negative integer, the calibration unit 106 may calibrate the image capturing unit 102 to the median exposure value, where the median exposure value may be the median of a range of exposure value more than the first exposure value. Once the median exposure value is determined, the median exposure value may be stored in the image processing data 216.

[0030] Although the median exposure value has been described to be equal to the median of the range of the exposure values available for the image capturing unit 102, it may be noted that the median exposure value may take other different values based on the conditions in which the image is captured.

[0031] Subsequently, the image capturing unit 102 may capture a second image at the median exposure value. Further, the calibration unit 106 may determine variation between the brightness of the second image and the predefined image brightness. The calibration unit 106 may further compute an absolute value of variation between the brightness of the second image and the predefined image brightness. If the absolute value of the variation is found to be greater than the threshold value, the calibration unit may recalibrate the image capturing unit 102 to an updated exposure value and store the updated exposure value in the image processing data 216.

[0032] In an example, the image capturing unit 102 may be recalibrated to the updated exposure value using predictive data model. The predictive data model may use the brightness of the images captured at the first exposure value and median exposure value respectively, along with the first exposure value and the second exposure value to calculate the value of the updated exposure value, say a predictive exposure value, for the image capturing unit 102.

[0033] In an example, the first exposure value and the second exposure values, along with the brightness of the images captured at the first exposure value and median exposure value may be written in the form of ordered pairs. A linear regression technique may then be applied to the ordered pairs and a linear equation may be obtained. The predictive exposure value may then be obtained by finding a solution to the linear equation. The predictive exposure value may then be stored in the image capturing data 214. The image capturing unit 102 may then capture the image of the object at the predictive exposure value. Further, the image processing unit 104 may determine the brightness of the image at the predictive exposure value and store the brightness in the image processing data 216. The calibration unit 106 may then compute a variation between the brightness of the image captured at the predictive exposure value and the predefined brightness. The variation between the brightness of the image captured at the predictive exposure value and the predefined brightness may then be saved in the calibration data 218. An absolute value of the variation may then be computed by the calibration unit 106.

[0034] Based on the variation, a subsequent median exposure value may be computed. In an example, the subsequent median exposure value may be computed based on the range of exposure values on which the last predictive model was based. The image capturing unit 102 may then capture a subsequent image at the subsequent median exposure value. The calibration unit 106 may further compute an absolute value of variation between the brightness for the image at the subsequent exposure value and the predefined brightness. The calibration unit 106 may then determine if the absolute value of the variation is greater than the threshold value. Based on the variation, the calibration unit 106 may determine subsequent exposure values. Based on the subsequent exposure values, the calibration unit 106 may determine a subsequent predictive exposure value and save the subsequent exposure value in the image capturing data 214. The calibration unit 106 may then capture a subsequent image at the subsequent predictive exposure value.

[0035] In an example, the imaging device 200 may determine subsequent median exposure values and subsequent predictive exposure values and compare the brightness of the images at the subsequent median exposure values and subsequent predictive exposure values, until the absolute value of variation between the brightness of the recaptured image and the predefined image brightness is less than the threshold value of variation.

[0036] Once the value of variation between the brightness of the recaptured image and the predefined image brightness is less than the threshold value of variation, the calibration unit 106 may store an exposure value, say a final camera exposure value, corresponding to the which the variation between the brightness of the recaptured image and the predefined image brightness is less than the threshold value of variation. The calibration unit 106 may then store the final camera exposure value in a non-volatile memory (not shown).

[0037] In one example, at the start of calibration, the light emitting source 206 of the imaging device 200 emits neutral, white light over the image capturing unit's field of view. An image at the median value of the range of exposure values available for the image capturing unit 102 is then captured. For instance, if the range of exposure values lies in the range of [0, 8192], the image is taken at a first exposure value equal to 4096. A variation between the brightness of the image and predetermined image brightness is then determined. In an example, the brightness of the image may be α and the predetermined brightness may be 200. An absolute value of the variation $|\alpha\text{-}200|$ for the image may further be computed. If $|\alpha\text{-}200|$ is found to be smaller than a threshold value of variation V_{Th}, i.e., $|\alpha\text{-}200| < V_{Th}$, the target brightness has been achieved by the image capturing unit, based on exposure value 4096. As the absolute value of the variation has been met, the process ends, and the exposure value 4096 is saved into non-volatile memory for future use. On the other hand, if $\alpha < 200$, the process adjusts the range of the exposure values to [4096, 8192], i.e., the updated exposure value is greater than the first exposure value. Alternatively, if $\alpha > 200$, the process sets the range of the exposure values to [0, 4096], i.e., the updated exposure value is less than the first exposure value.

[0038] In a situation when $\alpha > 200$, say $\alpha \sim 224$, the range of the exposure values is set to [0, 4096]. As described earlier, another image, say a second image, is again captured at the median of the range of exposure values [0, 4096], i.e., at 2048. Further, an absolute value of variation $|\beta\text{-}200|$ between the brightness of the second image and the predetermined image is computed. If $|\beta\text{ -}200|$ is found to be smaller than a threshold value of variation V_{Th}, i.e., $|\beta\text{ -}200| < V_{Th}$, the target brightness has been achieved. In a situation when $|\beta\text{ -}200| > V_{Th}$ and $\beta < 200$, say $\beta \sim 150$, the process adjusts the range of the exposure values to [2048, 4096], i.e., the updated exposure value is greater than the first exposure value.

[0039] Before the process continues and a third image capture is taken in the range of the exposure values [2048, 4096], the process uses the two data points: (4096, 224) and (2048, 150) to model the trajectory of the brightness in response to exposure. In one example, linear regression is used to establish a linear equation which passes through both points. With the linear equation, a predictive exposure value x is computed which has brightness y = 200 (the predetermined brightness value). The image capturing unit then captures an image at exposure value x, say x = 3368. The brightness γ of the image captured at the predictive exposure is then determined. Further, an absolute value of variation $|\gamma-200|$ between the brightness of the image captured at the predictive exposure value and the predetermined image is computed. If $|\gamma-200| < V_{Th}$, the process terminates and the predictive exposure value x = 3368, is saved into the non-volatile memory for future use. However, if $|\gamma-200| > V_{Th}$, the process goes back to the range of exposure values [2048, 4096]. A median value in the range of exposure values [2048, 4096] is selected, and an updated range of the exposure values is determined. Further, the predictive data model is again applied on the updated range of exposure values. The process described in the example is iteratively updated until the absolute value of the variation is found to be less than the threshold value of variation.

[0040] Figure 3 illustrates a method 300 for calibrating an imaging device, such as an imaging device 100, in accordance with an example of the present subject matter. Although the method 300 may be implemented in a variety of devices, but for the ease of explanation, the description of the exemplary method 300 is provided in reference to the above-described imaging device 100. The order in which the method 300 is described is not intended to be construed as a limitation, and any number of the described method blocks may be combined in any order to implement the method 300, or an alternative method.

[0041] It may be understood that blocks of the method 300 may be performed in the imaging device 100. The blocks of the method 300 may be executed based on instructions stored in a non-transitory computer-readable medium, as will be readily understood. The non-transitory computer-readable medium may include, for example, digital memories, magnetic storage media, such as magnetic disks and magnetic tapes, hard drives, or optically readable digital data storage media.

[0042] The method 300 starts at block 302 and proceeds to block 304. At block 302, a first image is captured at a first exposure value. In an example, the image may be captured through an image capturing unit, such as image capturing unit 102 of an imaging device 100, at a first exposure value of the image capturing unit 102.

[0043] At block 306, a brightness of the first image is determined. In an example, the brightness of the first image may be determined by an image processing unit, such as an image processing unit 104 of the imaging device 100.

[0044] At block 308, a variation between the brightness of the first image and a predefined image brightness is computed. In an example, the variation may be computed by the image processing unit 104.

[0045] At block 310, an absolute value of the variation is determined to be greater than a threshold value. In an example, the absolute value of the variation may be determined by a calibration unit, such as calibration unit 106 of the imaging device 100.

[0046] At block 312, it is determined whether variation is a positive integer. If the variation is found to be a positive integer, the method proceeds to block 314. Otherwise, the method proceeds to block 316.

[0047] At block 314, the exposure value of the image capturing unit is updated to an updated exposure value, where the updated exposure value is less than the first exposure value. In an example, the calibration unit 106 may update the exposure value of the image capturing unit 102 to the updated exposure value, in response to determination of the variation to be the positive integer. The method then proceeds to block 318.

[0048] At block 316, the exposure value of the image capturing unit is updated to an updated exposure value, where the updated exposure value is less than the first exposure value. In an example, the calibration unit 106 may updated the exposure value of the image capturing unit 102 to the updated exposure value, in response to determination of the variation to be a negative integer. The method then proceeds to block 318.

[0049] At block 318, an image of the object is recaptured on the updated exposure value. In an example, the image of the object may be recaptured by the image capturing unit 102.

[0050] At block 320, the absolute value of variation of brightness of the image recaptured at the updated exposure value is compared with the threshold value. In an example, the calibration unit 106 may compare the absolute value of variation of brightness of the image recaptured at the updated exposure with the threshold value.

[0051] At block 322, it is determined whether the absolute value of variation of the recaptured image is greater than the threshold value. If the absolute value of variation of the recaptured image is found greater than the threshold value, the method 300 proceeds to block 312. Otherwise, the method 300 finishes at block 324.

[0052] Figure 4 illustrates a method 400 of calibrating an imaging device, in accordance with another example implementation of the present subject matter. Although the method 400 may be implemented in a variety of devices, but for the ease of explanation, the description of the exemplary method 400 is provided in reference to the above-described imaging device 100. The order in which the method 400 is described is not intended to be construed as a limitation, and any number of the described method blocks may be combined in any order to implement the method 400, or an alternative method.

[0053] It may be understood that blocks of the method 400 may be performed in the imaging device 100. The blocks of the method 400 may be executed based on instructions stored in a non-transitory computer-readable medium, as will be readily understood. The non-transitory computer-readable medium may include, for example, digital memories, magnetic storage media, such as magnetic disks and magnetic tapes, hard drives, or optically readable digital data storage media.

[0054] At block 402, a variation between a brightness of a first image captured by an image capturing unit and a predefined image brightness is first computed. The first image is captured at a first exposure value. In an example, the first image may be captured by an image capturing unit, such as, an image capturing unit 102 and the variation may be computed by an image processing unit, such as an image processing unit 104 of the imaging device 100.

[0055] At block 404, an absolute value of variation with respect to a threshold value is determined. In an example, the absolute value of the variation may be determined by a calibration unit of the imaging device, such as the calibration unit 106.

[0056] At block 406, it is determined whether variation is a positive integer. If the variation is found to be a positive integer, the method 400 proceeds to block 408. Otherwise, the method proceeds to block 410.

[0057] At block 408, the exposure value of the image capturing unit is updated to a second exposure value, where the second exposure value is less than the first exposure value. In an example, the calibration unit 106 may updated the exposure value of the image capturing unit 102 to the second exposure value, in response to determination of the variation to be the positive integer. The method then proceeds to block 412.

[0058] At block 410, the exposure value of the image capturing unit is updated to a median exposure value, where the median exposure value is less than the first exposure value. In an example, the calibration unit 106 may update the exposure value of the image capturing unit 102 to the median exposure value, in response to determination of the variation to be a negative integer. The method then proceeds to block 412.

[0059] At block 412, an absolute value of variation between the brightness of a second image and the predefined image brightness is determined to be greater than the threshold value. In an example, the calibration unit 106 may determine the absolute value of variation between the brightness of the second image and the predefined image brightness to be greater than the threshold value.

[0060] At block 414, a predictive exposure value for the image capturing unit is determined. The predictive exposure value may be determined using a predictive data model on the first exposure value and the median exposure value. In an example, the calibration unit 106 may determine the predictive exposure value for the image capturing unit 102.

[0061] At block 416, an absolute value of variation between the brightness of a third image captured at the predictive exposure value and the predefined image brightness is determined to be greater than the threshold value. In an example, the calibration unit 106 may determine the absolute value of variation between the brightness of a third image captured at the predictive exposure value and the predefined image brightness may be determined to be greater than the threshold value.

[0062] At block 418, a subsequent median exposure value and a subsequent predictive exposure value is computed, and absolute values of variation of brightness of the recaptured images of the object at the subsequent median exposure values and the subsequent predictive exposure values with the threshold value is compared with the threshold value, until the absolute value of variation between brightness of the recaptured image and the predefined image brightness is less than the threshold value. In an example, the calibration unit 106 may determine the subsequent median exposure values and the subsequent predictive exposure values. The calibration unit may further compare absolute values of variation of brightness of the recaptured images of the object at the subsequent median exposure values and the subsequent predictive exposure values with the threshold value, until the absolute value of variation between brightness of the recaptured image and the predefined image brightness is less than the threshold value.

[0063] Although implementations of the present subject matter have been described in language specific to methods and/or structural features, it is to be understood that the present subject matter is not limited to the specific methods or features described. Rather, the methods and specific features are disclosed and explained as example implementations of the present subject matter.

We Claim:

1. A method for calibrating an imaging device, the method comprising:

capturing an image of an object through an image capturing unit of the imaging device, wherein the image capturing unit is set at an exposure value;

determining brightness of the image;

computing variation between the brightness of the image and a predefined image brightness;

determining an absolute value of variation to be greater than a threshold value; and

iteratively,

updating the image capturing unit to an updated exposure value, wherein the updated exposure value is:

less than the exposure value if the variation is a positive integer; and

more than the exposure value if the variation is a negative integer;

recapturing an image of the object based on the updated exposure value; and

comparing an absolute value of variation of brightness of the recaptured image with the threshold value,

until the absolute value of variation between brightness of the recaptured image and the predefined image brightness is less than the threshold value.

2. The method as claimed in claim 1, wherein the exposure value is a median of a range of exposure values available for the image capturing unit.

3. The method as claimed in claim 1, wherein variation is computed by computing a difference of value between the brightness of the image and the predefined image brightness.

4. The method as claimed in claim 1, wherein the image is captured at a predetermined flash light power.

5. The method as claimed in claim 1 further comprising calibrating the image capturing unit based on a final exposure for which the absolute value of variation between the brightness of an image captured at the final camera exposure and the predefined image brightness is less than the threshold value.

6. An imaging device comprising:

an image capturing unit to capture images of an object at different camera exposure values;

an image processing unit to determine brightness of the images captured by the image capturing unit; and

a calibration unit to:

compute an absolute value of variation between the brightness of an image captured by the image capturing unit at a first exposure value and a predefined image brightness; and

update the image capturing unit to an updated exposure value, the updated exposure value being:

less than the first exposure value if the variation is a positive integer; and

if more than the first exposure value if the variation is a negative integer,

wherein an image of the object is recaptured by the image capturing unit based on the updated exposure value, absolute value of variation of brightness of the recaptured image is compared with the threshold value, and the image capturing unit is updated to an updated exposure value based on the comparison, recursively, until the absolute value of variation between the brightness of the recaptured image and the predefined image brightness is less than the threshold value.

7. The imaging device as claimed in claim 6, wherein the calibration unit is to store an exposure value for which the absolute value of variation between the brightness of the recaptured image and the predefined image brightness is less than the threshold value onto a non-volatile memory.

8. The imaging device as claimed in claim 6, wherein the first exposure value is a median of a range of exposure values available for the image capturing unit.

9. The imaging device as claimed in claim 6 further comprising a light emitting source to provide light of a predetermined power during capturing of images by the image capturing unit.

10. The imaging device as claimed in claim 6, wherein the calibration unit subtracts the predefined image brightness from the brightness of an image to compute the variation.

11. A method for calibrating an imaging device, the method comprising:

computing variation between brightness of a first image of an object captured by an image capturing unit of the imaging device and a predefined image brightness, wherein the first image is captured at a first exposure value;

determining an absolute value of variation to be greater than a threshold value;

determining a median exposure value, wherein the median exposure value is:

less than the first exposure value if the variation is a positive integer; and

more than the first exposure value if the variation is a negative integer;

determining an absolute value of variation between brightness of a second image captured at the median exposure value and the predefined image brightness to be greater than a threshold value;

determining a predictive exposure value for the image capturing unit using a predictive data model on the first exposure value and the median exposure value;

determining an absolute value of variation between brightness of a third image captured at the predictive exposure value and the predefined image brightness to be greater than the threshold value; and

iteratively,

determining a subsequent median exposure value and a subsequent predictive exposure value and comparing absolute values of variation of brightness of the recaptured images of the object at the subsequent median exposure values and the subsequent predictive exposure values with the threshold value, until the absolute value of variation between brightness of the recaptured image and the predefined image brightness is less than the threshold value.

12. The method as claimed in claim 11, wherein the predictive data model is based on two or more camera exposure values.

13. The method as claimed in claim 11 further comprising calibrating the image capturing unit to a final exposure value where absolute value of variation between the brightness of an image captured at the final camera exposure and the predefined image brightness is less than the threshold value.

14. The method as claimed in claim 13 further comprising storing the final camera exposure value onto a non-volatile memory associated with the image capturing unit.

15. The method as claimed in claim 11, wherein the first exposure value is half of total exposure values available for the image capturing unit.

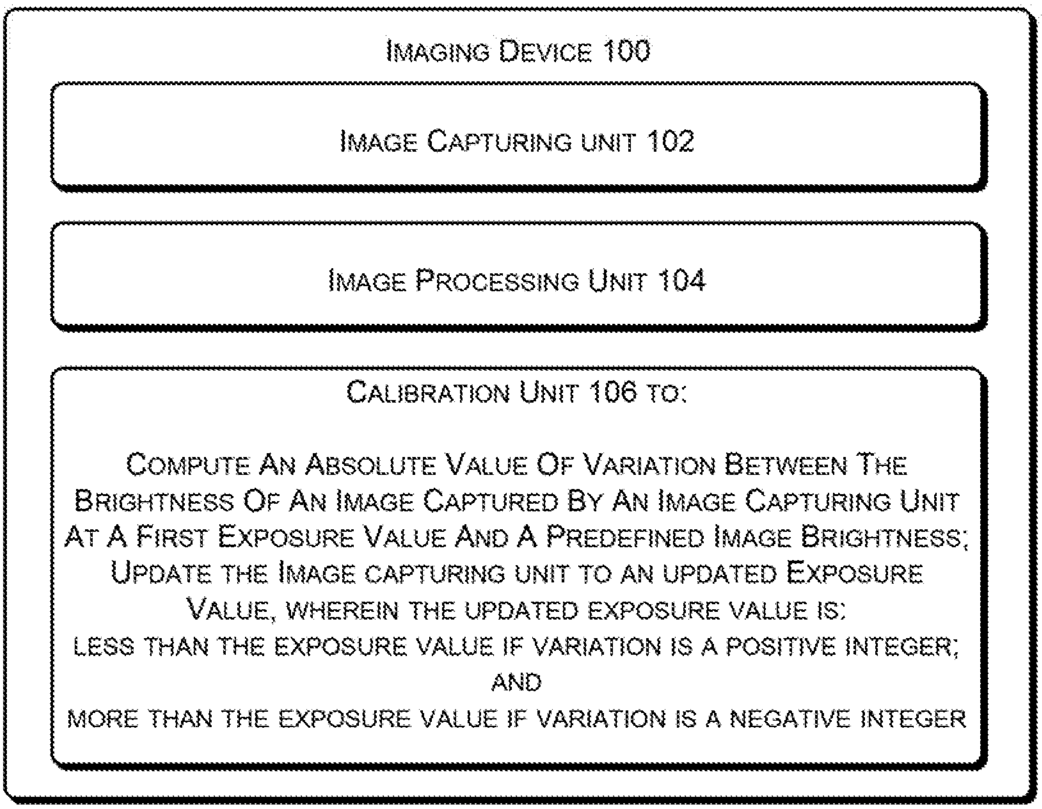
Imaging Device 100
Image Capturing unit 102
Image Processing Unit 104
Calibration Unit 106 to:
Compute An Absolute Value Of Variation Between The Brightness Of An Image Captured By An Image Capturing Unit At A First Exposure Value And A Predefined Image Brightness;
Update the Image capturing unit to an updated Exposure Value, wherein the updated exposure value is:
less than the exposure value if variation is a positive integer;
and
more than the exposure value if variation is a negative integer

Figure 1

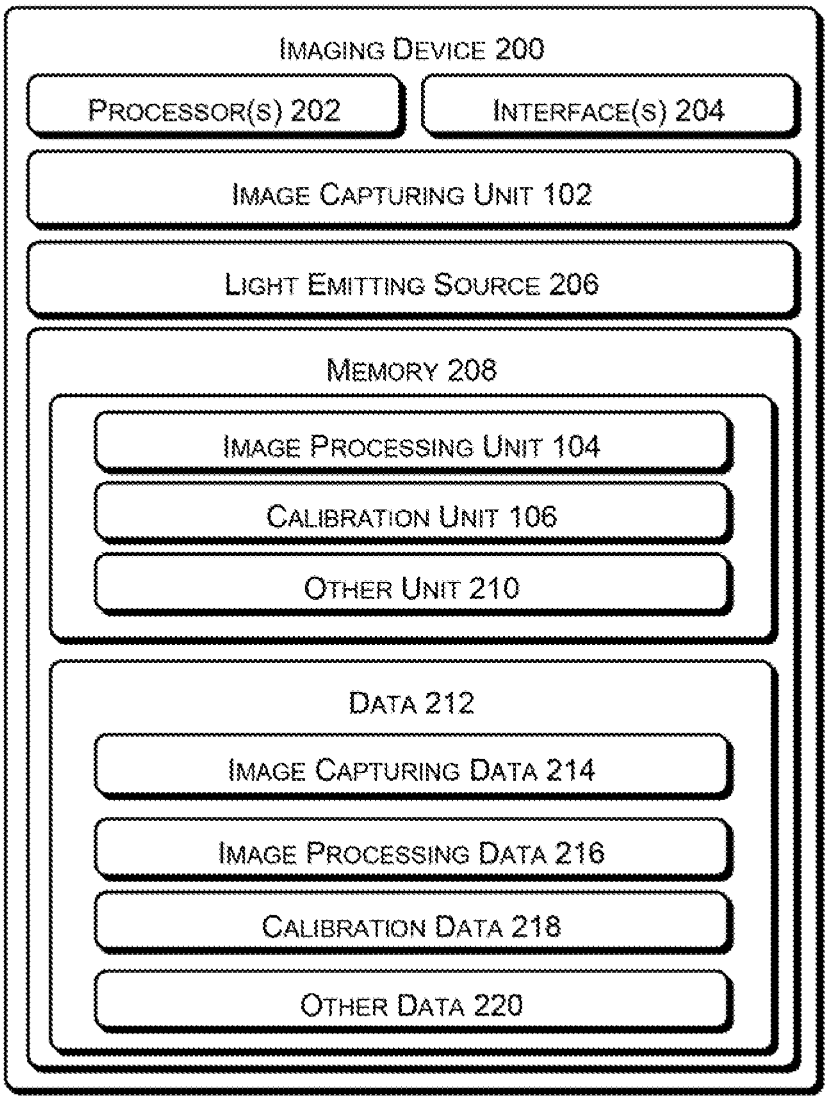
IMAGING DEVICE 200
PROCESSOR(S) 202
INTERFACE(S) 204
IMAGE CAPTURING UNIT 102
LIGHT EMITTING SOURCE 206
MEMORY 208
IMAGE PROCESSING UNIT 104
CALIBRATION UNIT 106
OTHER UNIT 210
DATA 212
IMAGE CAPTURING DATA 214
IMAGE PROCESSING DATA 216
CALIBRATION DATA 218
OTHER DATA 220

Figure 2

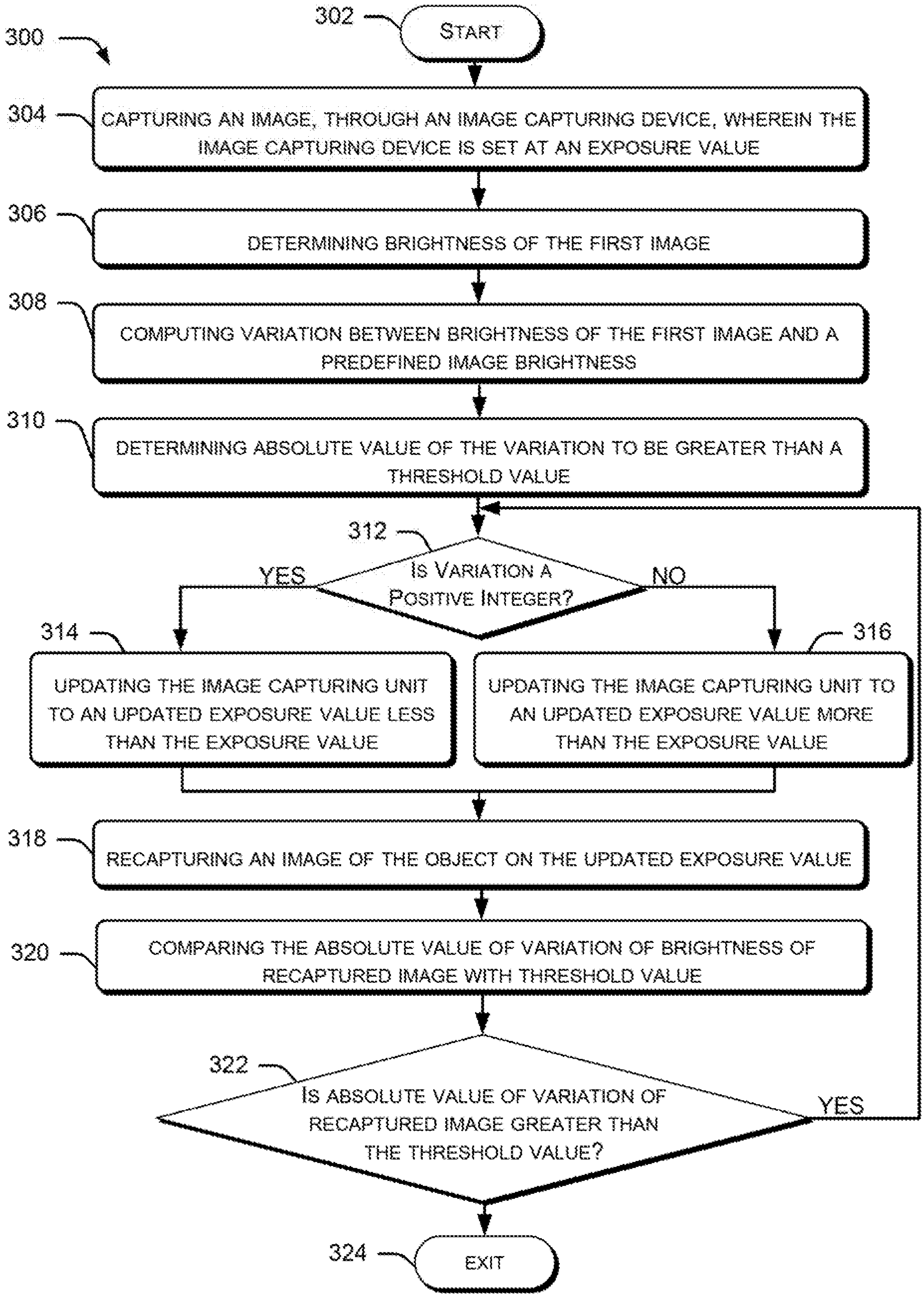
300
302
START
304
CAPTURING AN IMAGE, THROUGH AN IMAGE CAPTURING DEVICE, WHEREIN THE IMAGE CAPTURING DEVICE IS SET AT AN EXPOSURE VALUE
306
DETERMINING BRIGHTNESS OF THE FIRST IMAGE
308
COMPUTING VARIATION BETWEEN BRIGHTNESS OF THE FIRST IMAGE AND A PREDEFINED IMAGE BRIGHTNESS
310
DETERMINING ABSOLUTE VALUE OF THE VARIATION TO BE GREATER THAN A THRESHOLD VALUE
312
IS VARIATION A POSITIVE INTEGER?
YES
NO
314
UPDATING THE IMAGE CAPTURING UNIT TO AN UPDATED EXPOSURE VALUE LESS THAN THE EXPOSURE VALUE
316
UPDATING THE IMAGE CAPTURING UNIT TO AN UPDATED EXPOSURE VALUE MORE THAN THE EXPOSURE VALUE
318
RECAPTURING AN IMAGE OF THE OBJECT ON THE UPDATED EXPOSURE VALUE
320
COMPARING THE ABSOLUTE VALUE OF VARIATION OF BRIGHTNESS OF RECAPTURED IMAGE WITH THRESHOLD VALUE
322
IS ABSOLUTE VALUE OF VARIATION OF RECAPTURED IMAGE GREATER THAN THE THRESHOLD VALUE?
YES
324
EXIT

Figure 3

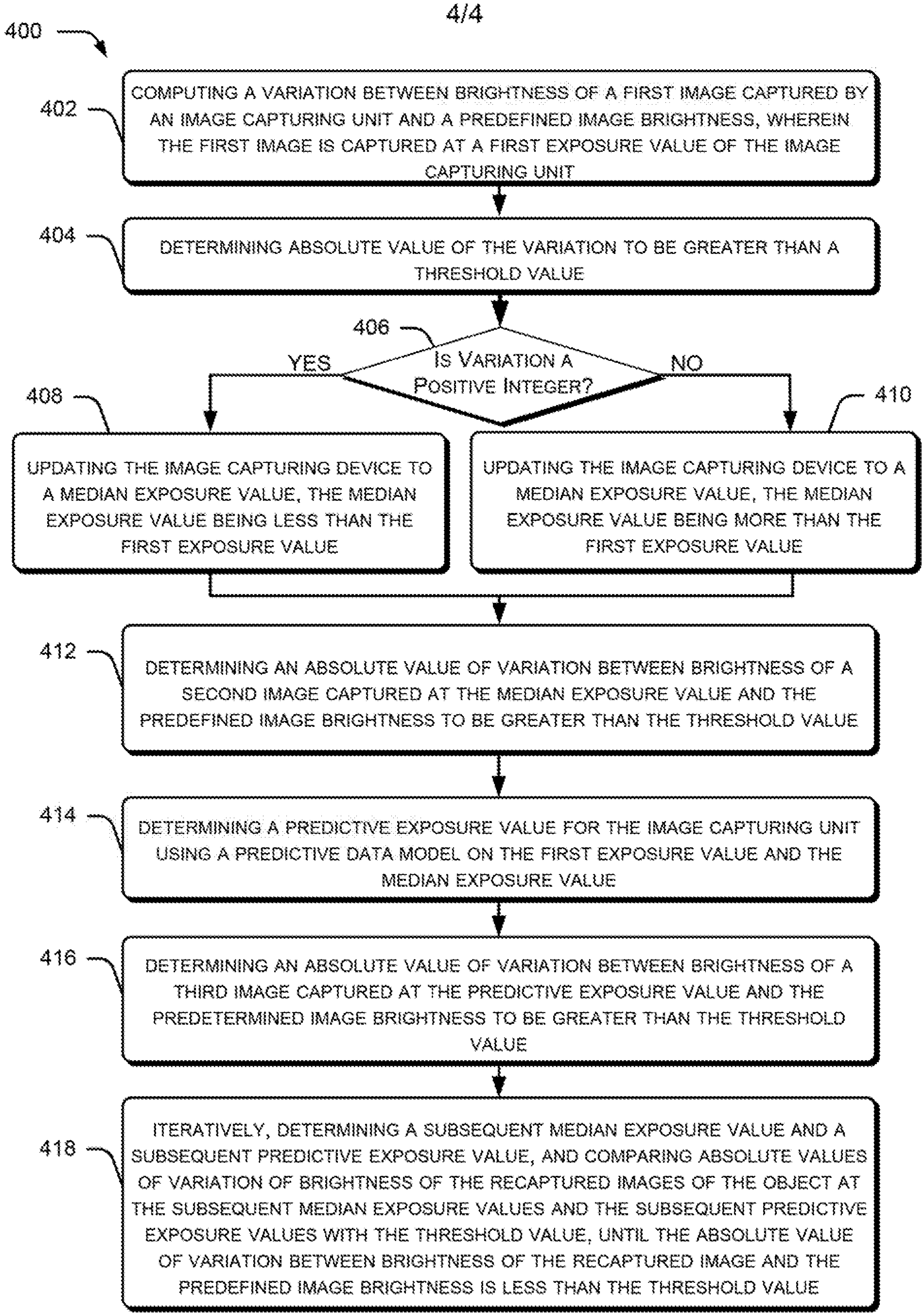
400
402
COMPUTING A VARIATION BETWEEN BRIGHTNESS OF A FIRST IMAGE CAPTURED BY AN IMAGE CAPTURING UNIT AND A PREDEFINED IMAGE BRIGHTNESS, WHEREIN THE FIRST IMAGE IS CAPTURED AT A FIRST EXPOSURE VALUE OF THE IMAGE CAPTURING UNIT
404
DETERMINING ABSOLUTE VALUE OF THE VARIATION TO BE GREATER THAN A THRESHOLD VALUE
406
IS VARIATION A POSITIVE INTEGER?
YES
NO
408
UPDATING THE IMAGE CAPTURING DEVICE TO A MEDIAN EXPOSURE VALUE, THE MEDIAN EXPOSURE VALUE BEING LESS THAN THE FIRST EXPOSURE VALUE
410
UPDATING THE IMAGE CAPTURING DEVICE TO A MEDIAN EXPOSURE VALUE, THE MEDIAN EXPOSURE VALUE BEING MORE THAN THE FIRST EXPOSURE VALUE
412
DETERMINING AN ABSOLUTE VALUE OF VARIATION BETWEEN BRIGHTNESS OF A SECOND IMAGE CAPTURED AT THE MEDIAN EXPOSURE VALUE AND THE PREDEFINED IMAGE BRIGHTNESS TO BE GREATER THAN THE THRESHOLD VALUE
414
DETERMINING A PREDICTIVE EXPOSURE VALUE FOR THE IMAGE CAPTURING UNIT USING A PREDICTIVE DATA MODEL ON THE FIRST EXPOSURE VALUE AND THE MEDIAN EXPOSURE VALUE
416
DETERMINING AN ABSOLUTE VALUE OF VARIATION BETWEEN BRIGHTNESS OF A THIRD IMAGE CAPTURED AT THE PREDICTIVE EXPOSURE VALUE AND THE PREDETERMINED IMAGE BRIGHTNESS TO BE GREATER THAN THE THRESHOLD VALUE
418
ITERATIVELY, DETERMINING A SUBSEQUENT MEDIAN EXPOSURE VALUE AND A SUBSEQUENT PREDICTIVE EXPOSURE VALUE, AND COMPARING ABSOLUTE VALUES OF VARIATION OF BRIGHTNESS OF THE RECAPTURED IMAGES OF THE OBJECT AT THE SUBSEQUENT MEDIAN EXPOSURE VALUES AND THE SUBSEQUENT PREDICTIVE EXPOSURE VALUES WITH THE THRESHOLD VALUE, UNTIL THE ABSOLUTE VALUE OF VARIATION BETWEEN BRIGHTNESS OF THE RECAPTURED IMAGE AND THE PREDEFINED IMAGE BRIGHTNESS IS LESS THAN THE THRESHOLD VALUE

Figure 4

INTERNATIONAL SEARCH REPORT	International application No. PCT/US 2019/017359

A. CLASSIFICATION OF SUBJECT MATTER

G06T7/80*(2017.01)*

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)

G06T 1/00, 7/80, H04N 5/225, 5/235

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)

PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, DWPI, EAPATIS, PATENTSCOPE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	US 8736685 B1 (ANRITSU COMPANY) 27.05.2014, abstract, fig.8,9,13, col.6 line 35- col.7 line 17, col.9 lines 26-28, 42-46	1, 6-7 2-5, 8-10 11-15
Y	US 9479705 B2 (HTC CORPORATION) 25.10.2016, abstract, col.7 lines.1-10, fig.3	2-5, 8-10
A	US 2010/0149357 A1 (HON HAI PREC IND CO LTD) 17.06.2010	1-15
A	EP 1924966 A2 (RUBNER JOSEPH) 28.05.2008	1-15

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document 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	Date of mailing of the international search report
23 October 2019 (23.10.2019)	31 October 2019 (31.10.2019)

Name and mailing address of the ISA/RU:	Authorized officer
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