



(51) International Patent Classification:

A61B 1/06 (2006.01) *A61B 1/045* (2006.01)
A61B 1/00 (2006.01) *A61B 1/303* (2006.01)

(21) International Application Number:

PCT/IB2013/055323

(22) International Filing Date:

28 June 2013 (28.06.2013)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/667,453 3 July 2012 (03.07.2012) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,

DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) Title: SYSTEM AND METHOD FOR GLARE REDUCTION IN IMAGING A PATIENT'S INTERIOR

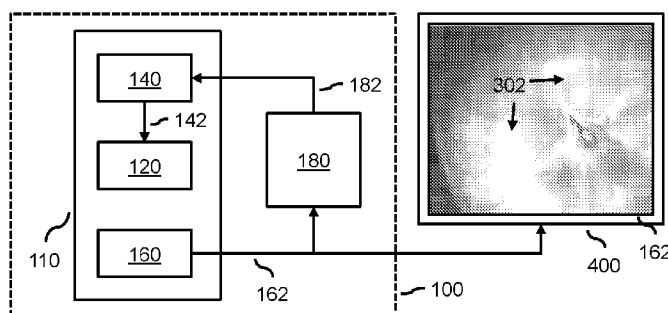


Fig. 1

(57) Abstract: System (100) for imaging a patient's interior, comprising: -a plurality of light sources (120) for illuminating a region of interest in the patient's interior from a plurality of different positions; -a light controller (140) for controlling individual ones of the plurality of light sources (120) to enable illuminating the region of interest with a subset (122-128) of light sources; -an image sensor (160) for acquiring an image (162-168) of the region of interest; and -a processor (180) for i) detecting glare (302-308) in the image, ii) attributing the glare to one or more light sources from the subset of light sources (122-128), and iii) based on said attributing, generating control data (182) for instructing the light controller (140) to adjust the subset of light sources so as to reduce the glare in a subsequent image of the region of interest.

System and method for glare reduction in imaging a patient's interior

FIELD OF THE INVENTION

The invention relates to a system and a method for glare reduction in imaging a patient's interior, to a workstation and imaging system comprising the system, and to a computer program product for causing a processor system to perform the method.

5 Medical diagnosis frequently involves imaging of a patient's interior. For example, in the detection of cervical cancer, a clinician may examine a patient's cervix using a colposcope, i.e., a device which allows the clinician to grade precancerous and early invasive cervical cancer lesions and to identify locations to perform biopsies. A colposcope typically comprises an image sensor to acquire an image of a region of interest in the
10 patient's interior, e.g., the cervix or part thereof. Moreover, a colposcope typically comprises a light source to illuminate the region of interest while acquiring the image. As a result, the clinician is provided with an image of the region of interest being illuminated.

The light source may cause glare to appear in the image. Here, the term glare refers to bright regions appearing within the image which hinder the viewing of the contents
15 of the image, e.g., the region of interest. Such glare may be caused by light being reflected from the patient's interior in a non-diffuse manner. In particular, glare may be caused by the reflection of light from wet, shiny and irregular tissue surfaces within the patient's interior. Such reflections are also referred to as specular reflections, and essentially resemble mirror-like reflections which involve directly reflecting the light instead of serving for illuminating
20 the region of interest, as would occur with diffuse reflections. Glare may obfuscate underlying image details which may be of relevance to the clinician. Disadvantageously, glare may hinder the clinician in obtaining a correct medical diagnosis.

BACKGROUND OF THE INVENTION

US patent 6,088,612 describes an apparatus for glare removal in digital
25 imaging of a cervix. The apparatus includes a digital camera operable to create first and second digital images having substantially the same field of view; lights associated with the camera for illuminating the cervix with light pulses emitted from two locations, and a digital processor. The light pulses are synchronized so the cervix is illuminated with a first pulse for

the creation of the first image and the cervix is illuminated with a second pulse for the creation of the second image. First glare and first non-glare regions are created by the first pulse in the first image, and second glare and second non-glare regions are created by the second pulse in the second image. The processor creates a glare-free digital composite image by replacing the digital elements of the glare region of the first image with the corresponding digital elements from the non-glare region of the second image.

A problem of the aforementioned apparatus is that the glare reduction as applied in the digital imaging of the cervix glare is insufficiently effective.

SUMMARY OF THE INVENTION

It would be advantageous to have a system or method which provides more effective glare reduction when imaging a patient's interior.

To better address this concern, a first aspect of the invention provides a system for imaging a patient's interior, comprising:

- a plurality of light sources for illuminating a region of interest in the patient's interior from a plurality of different positions;
- a light controller for controlling individual ones of the plurality of light sources to enable illuminating the region of interest with a subset of light sources;
- an image sensor for acquiring an image of the region of interest; and
- a processor for i) detecting glare in the image, ii) attributing the glare to one or more light sources from the subset of light sources, and iii) based on said attributing, generating control data for instructing the light controller to adjust the subset of light sources so as to reduce the glare in a subsequent image of the region of interest.

In a further aspect of the invention, a workstation and an imaging apparatus is provided comprising the system set forth.

In a further aspect of the invention, a method is provided for imaging a patient's interior, comprising:

- illuminating a region of interest in the patient's interior from a plurality of different positions using a plurality of light sources;
 - acquiring an image of the region of interest;
- the method further comprising:
- controlling individual ones of the plurality of light sources to enable illuminating the region of interest with a subset of light sources; and

- i) detecting glare in the image, ii) attributing the glare to one or more light sources from the subset of light sources, and iii) based on said attributing, generating control data to adjust the subset of light sources so as to reduce the glare in a subsequent image of the region of interest.

5 In a further aspect of the invention, a computer program product is provided comprising instructions for causing a processor system to perform the method set forth.

The above measures provide a plurality of light sources which are differently positioned with respect to a region of interest so as to illuminate the region of interest from different positions. The term region of interest refers to a portion of the patient's interior
10 which is shown in the image. Said region is a region of interest since it is a subject of the imaging and thus indicates interest from a user of the system. The plurality of light sources illuminates the region of interest so as make the region of interest visible in the image.

The light controller controls each of the plurality of light sources individually. As a result, the light controller can effect an illumination of the region of interest with a set of
15 individual light sources, i.e., a specific selection amongst the plurality of light sources. The region of interest is therefore, when being illuminated by the subset of light sources, not, or not substantially, illuminated by others of the plurality of light sources which are not included in said subset. The subset of light sources are therefore active light sources whereas the others of the plurality of light sources are, at least substantially, non-active light sources.

20 The image sensor acquires an image of the region of interest in that it captures the reflected light from the region of interest and based thereon generates a digital image. The image may or may not be part of an image sequence, i.e., the image sensor may be arranged for providing a real-time view of the region of interest in the patient's interior.

The processor analyzes the image to detect glare. If glare is detected, the
25 processor determines how the glare relates to the plurality of light sources, and in particular, identifies which of the subset of light sources, which was used in illuminating the region of interest in the image, caused and/or contributed to the glare in the image. Thus, the glare in the image is attributed to one or more light sources amongst the subset of light sources.

Based on the identified one or more light sources, the processor generates
30 control data for the light controller, with the control data instructing the light controller to adjust the subset of light sources which are used in illuminating the region of interest. Here, the manner of adjustment is determined by the processor, with the light controller effecting the adjustment based on the control data received from the processor. The processor establishes the manner of adjustment so as to reduce the glare. As a result, when a subsequent

image is acquired by the image sensor, the glare is reduced. In general, glare may be reduced due to, e.g., the number and/or intensity of reflections being reduced, reflections being repositioned so as to reduce the perception of glare in the subsequent image, etc.

The above measures have the effect that a feedback mechanism is provided which reduces glare in an image of a region of interest by analyzing the image and, based on a result of the analysis, adjusting the illumination of the region of interest. Advantageously, a clinician is provided with image details which otherwise may have been obfuscated by glare. Advantageously, the likelihood of obtaining an incorrect medical diagnosis is reduced.

Optionally, the processor is arranged for instructing the light controller to adjust the subset of light sources by replacing the one or more light sources from the subset of light sources with one or more other light sources from the plurality of light sources for establishing a new subset of light sources. The subset of light sources is adjusted by removing the one or more light sources to which the glare in the image was attributed to. Hence, said one or more light sources are not used for illuminating the region of interest anymore. Instead, one or more other light sources are used. Effectively, by adjusting the subset of light sources, a new subset of light sources is obtained which may have light sources in common with the previous subset but may equally be a subset which has no light sources in common therewith. Since the one or more other light sources are differently positioned, they cause reflections to occur in different parts of the image. Advantageously, the processor establishes the new subset of light sources so as to reduce the number and/or the intensity of the reflections and/or to reposition the reflections in the subsequent image.

Optionally, the individual ones of the plurality of light sources are adjustable in position and/or orientation, and the processor is arranged for instructing the light controller to adjust the subset of light sources by adjusting the position and/or orientation of the one or more light sources from the subset of light sources. The subset of light sources are adjusted by physically re-positioning or re-orienting the one or more light sources to which the glare in the image was attributed to so as to reduce the glare in a subsequent image. Hence, it is not needed to remove said light sources from the subset of light sources.

Optionally, the light controller is arranged for variably illuminating the region of interest by alternating between different subsets of light sources; the image sensor is arranged for acquiring a sequence of images of the region of interest during said alternating between the different subsets of light sources; the processor is arranged for, based on the sequence of images, generating a composite image in which the glare is reduced; and the processor is arranged for, based on the detecting of glare in the sequence of images,

generating the control data to establish the different subsets of light sources. The glare is thus reduced by temporally alternating between different subsets of light sources so as to spatially shift the reflections throughout the image sequence, which allows the glare to be reduced by generating a composite image based on the image sequence. In addition, the glare is reduced by suitably establishing the different subsets of light sources based on detecting the glare in the sequence of images. Thus, the different subsets of light sources are specifically established by the processor so as to reduce the glare in the composite image of the sequence of images. Advantageously, by combining establishing different subsets of light sources based on glare detected in the sequence of images, and the temporally alternating between the different subsets of light sources, the glare in the composite image is well reduced.

Optionally, the processor is arranged for establishing an illumination duration of each of the different subsets of light sources based on the detecting of glare in the sequence of images. The duration during which each of the different subsets of light sources is used in the illumination of the region of interest is thus established based on the detected in the sequence of images. Advantageously, if by detecting the glare in the sequence of images, it is determined that one of the subset of light sources causes a low amount of glare, the duration of said subset of light sources in the illumination of the region of interest may be increased over another subset of light sources which is determined to cause a high amount of glare. Advantageously, the glare in the composite image is well reduced.

Optionally, the processor is arranged for attributing the glare to the one or more light sources based on a position of the glare in the image. The plurality of light sources typically has a relatively fixed position and/or orientation with respect to the image sensor. The position of the glare in the image is therefore indicative of which of the subset of light sources is most likely to have caused and/or contributed to the glare in the image.

Optionally, the processor is arranged for attributing the glare to the one or more light sources using machine learning, the control data is indicative of the subset of light sources, and the machine learning is based on the position of the glare in the image and the control data. Machine learning is well suited for attributing the glare to the one or more light sources. Advantageously, by basing the machine learning on the position of the glare in the image and control data which indicates which subset of light sources were used in the illumination of the region of interest, the glare contribution of each individual ones of the plurality of light sources can be established, enabling the subset of light sources to be adjusted so as to optimally reduce the glare in a subsequent image of the region of interest.

Optionally, the light controller is arranged for variably illuminating the region of interest by alternating between different subsets of light sources; the image sensor is arranged for acquiring a sequence of images of the region of interest during the alternating between the different subsets of light sources; and the processor is arranged for learning a classifier based on the position of the glare in the sequence of images and the control data. Machine learning is thus used to dynamically adjust the illumination of the region of interest.

Optionally, the plurality of light sources is a plurality of light emitting diodes. Light emitting diodes are well suited as light sources when imaging a patient's interior due to their small size, low power requirements, fast switching on/off speeds, etc.

Optionally, the individual ones of the plurality of light sources are arranged in a circular shape around the image sensor. A circular shape is well suited as this provides significant flexibility in establishing a position of the subset of light sources with respect to the image sensor, which in turn allows the reflection of light to be spatially shifted in the image. Spatially shifting the glare in the image is advantageous since certain portions of the patient's interior may cause less specular reflections, thus causing fewer glare. Similarly, certain portions may be of less relevance to the clinician, which causes the clinician to not to, or to a lesser degree, perceive bright regions in said portions of the image as glare.

Optionally, the subset of light sources is formed by one of the group of: two light sources arranged adjacently in the circular shape, and two light sources arranged oppositely in the circular shape.

Optionally, the system further comprises a scope being one of the group of: a colposcope, a laparoscope and a retinoscope, the scope comprising the plurality of light sources and the image sensor.

It will be appreciated by those skilled in the art that two or more of the above-mentioned embodiments, implementations, and/or aspects of the invention may be combined in any way deemed useful.

Modifications and variations of the workstation, the imaging apparatus, the method, and/or the computer program product, which correspond to the described modifications and variations of the system, can be carried out by a person skilled in the art on the basis of the present description.

The invention is defined in the independent claims. Advantageous embodiments are defined in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described hereinafter. In the drawings,

Fig. 1 shows a system according to the present invention;

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Fig. 2 shows a method according to the present invention;

Fig. 3 shows a computer program product according to the present invention;

Fig. 4 shows a plurality of light sources mounted on a circular carrier and arranged around an image sensor, with a subset of the light sources being activated;

10 Fig. 5a shows an image of a region of interest, the image comprising glare as a result of the region of interest being illuminated by the subset of light sources;

Fig. 5b shows the glare being detected in the image;

Fig. 5c shows a position of the glare being established;

Fig. 6a shows a first image from a sequence of images, said image showing the region of interest being illuminated by a first one of different subsets of light sources;

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Figs. 6b, 6c and 6d show a second, third and fourth image showing the region of interest being illuminated by a second, third and fourth one of the different subsets of light sources, respectively;

Fig. 7 shows a composite image being generated based on the first, second, third and fourth image in which glare is reduced;

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Fig. 8a shows a scope comprising the plurality of light sources and the image sensor, with the plurality of light sources being mounted on a circular carrier; and

Fig. 8b shows the plurality of light sources being re-oriented.

DETAILED DESCRIPTION OF EMBODIMENTS

25 Fig. 1 schematically shows a system 100 for imaging a patient's interior. The system 100 comprises a plurality of light sources 120 for illuminating a region of interest in the patient's interior from a plurality of different positions. The system 100 further comprises a light controller 140 for controlling individual ones of the plurality of light sources 120 to enable illuminating the region of interest with a subset of light sources. For that purpose, the light controller 140 is shown to be electrically connected to the plurality of light sources 120
30 via an electric connection 142. The system 100 further comprises an image sensor 160 for acquiring an image 162 of the region of interest. The system 100 is shown to be connected to a display 400 to enable displaying the image 162 to a user, e.g., a clinician. It is noted,

however, that the system 100 does not need to be connected to a display 400. Rather, the image 162 may be, e.g., transmitted to a different system, stored on a storage medium, etc.

The system 100 further comprises a processor 180 for detecting glare in the image 162. For that purpose, the processor 180 is shown to receive the image 162 from the image sensor 160. The processor 180 is further arranged for attributing the glare to one or more light sources from the subset of light sources, and based on said attributing, generating control data 182 for instructing the light controller 140 to adjust the subset of light sources so as to reduce the glare in a subsequent image of the region of interest.

It can be seen that the combination of image sensor 160, processor 180, light controller 140 and plurality of light sources 120 effectively forms a feedback system in that the plurality of light sources 120 illuminate a region of interest, the image sensor 160 acquires an image 162 of the region of interest, the processor 180 detects glare in the image and, based thereon, generates control data 182 for the light controller 140, and the light controller controls the plurality of light sources 120 based on the control data 182 to reduce the glare in a subsequent image of the region of interest acquired by the image sensor 160.

Fig. 1 schematically shows the plurality of light sources 120, the light controller 140 and the image sensor 160 being arranged within a scope 110. The scope 110 may be used for entry into the patient's interior. The scope 110 may be, e.g., a colposcope, a laparoscope or a retinoscope. However, this is not a limitation. For example, the plurality of light sources 120 and the image sensor 160 may be separate components that are individually positionable with respect to the patient's interior. In addition, the light controller 140 may be an external component, i.e., not used for entry in the patient's interior.

Fig. 2 shows a method 200 for imaging a patient's interior. The method 200 may correspond to an operation of the system 100. However, the method 200 may also be performed in separation of the system 100, e.g., using a different system or device.

The method 200 comprises, in a step titled "ILLUMINATING REGION OF INTEREST USING PLURALITY OF LIGHT SOURCES", illuminating 210 a region of interest in the patient's interior from a plurality of different positions using a plurality of light sources. The method 200 further comprises, in a step titled "ACQUIRING IMAGE OF REGION OF INTEREST", acquiring 220 an image of the region of interest. The method 200 further comprising, in a step titled "CONTROLLING PLURALITY OF LIGHT SOURCES", controlling 260 individual ones of the plurality of light sources to enable illuminating the region of interest with a subset of light sources. The method 200 further comprises, in a step titled "DETECTING GLARE IN IMAGE", detecting 230 glare in the image. The method

200 further comprises, in a step titled “ATTRIBUTING GLARE TO PLURALITY OF LIGHT SOURCES”, attributing 240 the glare to one or more light sources from the subset of light sources. The method 200 further comprises, in a step titled “GENERATING CONTROL DATA”, based on said attributing 240, generating 250 control data to adjust the subset of light sources so as to reduce the glare in a subsequent image of the region of interest. It will be appreciated that the method 200 may be performed in an iterative manner, as indicated in Fig. 2 with the steps of the method 200 forming a circle. However, this is not a limitation, i.e., the method 200 may also be performed non-iteratively.

Fig. 3 shows a computer program product 290 comprising instructions for causing a processor system to perform the method according to the present invention. The computer program product 290 may be comprised on a computer readable medium 280, for example as a series of machine readable physical marks and/or as a series of elements having different electrical, e.g., magnetic, or optical properties or values.

Fig. 4 shows a plurality of light sources 120 being, by way of example, a plurality of light emitting diodes (LEDs). Fig. 4 shows the plurality of light sources 120 head-on, i.e., facing a light-emitting end of the light sources. The plurality of light sources 120 is arranged in a circular shape around the image sensor 160. For supporting the plurality of light sources 120 in the circular shape, the plurality of light sources 120 is shown to be mounted on a circular carrier 130. The circular carrier 130 may be, e.g., a printed circuit board (PCB), which may be further encapsulated so as to allow entry into the patient's interior. Fig. 4 further shows a subset 122 of the plurality of light sources 120 being activated. This is indicated by a star-shaped contour surrounding said light sources 120. Here, the subset of light sources 122 is constituted by two light sources, the two light sources being arranged adjacently in the circular shape, i.e., a right one and a bottom-right one of the plurality of light sources 120 when viewed head-on. The others of the plurality of light sources are not activated, being indicated by the star-shaped contour being absent.

The operation of the system 100 may be further explained in reference to Figs. 5a-5c. Fig. 5a shows an image 162 of a region of interest. For illustration purposes, the region of interest shown in the image 162 is a portion of the exterior of an apple. It is noted, however, that the region of interest typically constitutes a region of interest within a patient's interior, e.g., the cervix or part thereof. The image 162 shows the region of interest being illuminated by the plurality of light sources 120 as shown in Fig. 4. Hence, the subset 122 of two adjacent light sources is used in illuminating the region of interest. As a result of the surface of the apple's exterior being shiny, specular reflections occur which result in bright

regions being visible in the image 162. Said bright regions constitute glare 302 in that they obfuscate image details, i.e., details of the apple which otherwise may be visible.

Figs. 5b and 5c show a result of the processor 180 detecting the glare 302 in the image 162, and attributing the glare 302 to one or more light sources from the subset of light sources 122 based on a position of the glare 302 in the image 162. The glare 320 may be detected in a number of ways. For example, the image 162 may be considered in RGB color space, i.e., expressed in red, green and blue color components. The green color component of the RGB color space may be used as a so-termed feature space since it provides a high contrast ratio between the glare 302 and the region of interest. Pixels belonging to the glare 302 are typically white in color whereas the background, being the exterior of the apple, is typically red in color. As such, the green color component provides a suitable feature space. It is noted that the green color component typically also provides a suitable feature space for when the image 162 shows a region of interest from a patient's interior, e.g., the cervix, since such region of interests are also typically red or pink in color. A histogram may be generated for the green color component. Herein, a local maximum may be identified. Pixels of the image having a value for the green color component which exceed this local maximum may then be deemed to be part of the glare 302. Fig. 5b shows a resulting glare mask 170, in which the glare is represented by white pixels. The glare mask 170 thus shows the corresponding parts of the image 162 which are deemed to be part of the glare 302.

The position of the glare 302 may also be established using a number of ways. For example, a clustering algorithm may be applied to the glare mask 170 so as to obtain one or more clusters 172, 174 of glare. The positions of said clusters 172, 174 may provide the position of the glare 302. Alternatively or additionally, the image 162 may be divided into segments, e.g., twelve segments 1-12 as shown in Fig. 5c, and within each segment 1-12, a number of glare pixels may be counted, with said number of glare pixels constituting an amount of glare in each respective segment 1-12. In this particular example, it can be seen that the bottom-left segments 7-9 comprise the largest amounts of glare. The position of the glare may therefore be established based on which of the segments 1-12 comprise glare, or comprise an amount of glare which exceeds a predetermined threshold.

The processor 180 may attribute the glare 302 to one or more light sources from the subset of light sources 122 in a number of ways. For example, the processor 180 may, if glare 302 is detected within the image 162, attribute the glare 302 per default to all of the light sources being part of the subset of light sources 122. Based thereon, the processor 180 may establish a new subset of light sources which does not comprise the light sources

from the earlier subset of light sources 122 so as to reduce the glare in a subsequent image. For example, the processor may establish a new subset of light sources 124 as shown in Fig. 6b, which is constituted by two light sources, the two light sources being arranged adjacently in the circular shape, i.e., a top one and a top-right one of the plurality of light sources 120 when viewed head-on. Hence, the right and bottom-right ones of the plurality of light sources 120 are replaced in the new subset of light sources 124 with said top and top-right ones.

The processor 180 may determine or estimate that the new subset of light sources 124 reduces the glare 302 in a subsequent image of the region of interest in a number of ways. For example, the processor 180 may analyze the correspondence between the position of the glare 302 in the image 162 and the positions of the subset of light sources 122 with respect to the image sensor 160. For example, the glare 302 may be detected in a left-hand side of the image 162 whilst the subset of light sources 122 is located on a right-hand side of the image sensor 160 when viewed along its principal optical axis. Such a correspondence may be attributed to a certain shape and/or orientation of the region of interest. Based on said shape and/or orientation, the processor 180 may estimate that the glare 302 may be reduced by using a different subset of light sources. For example, it may be estimated that the region of interest shown in the image 162 is slanted with respect to the image plane of the image sensor 160. As a result, the processor 180 may establish a new subset of light sources 124 of which it is estimated that, based on their relative position to the image sensor 160 and the slant of the region of interest, the specular reflections on the surface of the region of interest are directed away from the image sensor 160.

The processor 180 may also estimate that the new subset of light sources 124 reduces the glare in the subsequent image of the region of interest based on historical data. The historical data may indicate, for different subsets of light sources which were previously used in illuminating the region of interest, which glare occurred in a respective image of the region of interest. The historical data may thus indicate an amount of glare, a position of the glare, etc. As such, the processor 180 may determine that a previously used subset of light sources reduces the glare with respect to the currently used subset of light sources 122. Accordingly, the processor 180 may revert to the previously used subset of light sources, i.e., establish said subset as the new subset of light sources 124. It is noted, however, that due to a re-positioning of the image sensor 160 and/or the plurality of light sources 120 with respect to the region of interest within the patient's interior, such historical data may be particularly useful, i.e., provide good estimates, when it reflects recently used subsets of light sources.

The historical data may be obtained by means of machine learning. In particular, the processor 180 may be arranged for attributing the glare 302 to the one or more light sources using machine learning. For that purpose, the control data 182 may be indicative of the subset of light sources 122, i.e., indicate which light sources were used in illuminating the region of interest in the image 162, and the machine learning may be based on the position of the glare in the image and the control data 182. The historical data may be generated by the light controller 140 being arranged for variably illuminating the region of interest by alternating between different subsets of light sources 122-128, and the image sensor 160 being arranged for acquiring a sequence of images 162-168 of the region of interest during the alternating between the different subsets of light sources 122-128. A result of this is shown in Figs. 6a-6d, where each Figure shows a different subset of light sources 122-128 and an image 162-168 showing the region of interest being illuminated by the respective subset of light sources 122-128, with each image comprising glare 302-308 caused by the respective subset of light sources 122-128. Consequently, Fig. 6a shows a first image 162 and a first subset of light sources 122, Fig. 6b shows a second image 164 and a second subset of light sources 124, Fig. 6c shows a third image 166 and a third subset 126 of light sources, and Fig. 6d shows a fourth image 168 and a fourth subset of light sources 128.

The processor 180 may be arranged for learning a classifier based on the position of the glare 302-308 in the sequence of images 162-168 and the control data 182. Hence, the processor 180 may associate which subset of light sources 122-128 causes which glare 302-308. As a result, the processor may select one of the different subsets 122-128 of light source which is estimated to reduce the glare in a subsequent image of the region of interest. Furthermore, the processor 180 may be arranged for, when the glare increases in a current image, e.g., due to a re-positioning of the image sensor 160 and/or the plurality of light sources 120 with respect to the region of interest, updating the historical data based on the increase in glare. In addition, the processor 180 may select another one of the different subsets of light sources 122-128 which is estimated to cause a lower amount of glare.

For example, in case the first subset of light sources 122 as shown in Fig. 6a constitutes a currently used subset of light sources 122, the fourth subset of light sources 128 as shown in Fig. 6d may be established as the new subset of light sources 128. In this respect, it is noted that although the aforementioned example shows the processor 180 establishing a new subset of light sources 128 in which none of the light sources overlap with the current subset of light sources 122, the processor 180 may also attribute the glare 302 to specific ones of the subset of light sources 122, and establish a new subset of light sources 128 in

which only said specific light sources are removed, i.e., other light sources from the current subset of light sources 122 may still be included in the new subset of light sources 128.

Alternatively or additionally to using a sequence of images 162-168 to generate historical data, the processor 180 may be arranged for, based on the sequence of images 162-168, generating a composite image 320 in which the glare 302-308 is reduced. Fig. 7 shows an example of such a composite image 320 which is generated based on the sequence of images 162-168 shown in Figs. 6a-6d. It is noted that methods for generating such a composite image are known per se. For example, US patent 6,088,612 describes an apparatus which creates a glare-free digital composite image by replacing the digital elements of the glare region of the first image with the corresponding digital elements from the non-glare region of the second image. Alternatively, the composite image 320 may be created by, e.g., applying a rank order filter to the sequence of images 162-168 on a per-pixel basis. For example, a value pixel of the composite image 320 may be obtained by calculating a median of the values of co-located pixels in the sequence of images 162-168. The composite image 320 may also be created by averaging the sequence of images 162-168, or by weighted averaging, e.g., in which glare-pixels have a lower weight than non-glare pixels. The processor 180 may be arranged for performing image registration, motion compensation or similar techniques to align the region of interest within the sequence of images 162-168. Hence, it is possible to compensate for a re-positioning of the image sensor 160 with respect to the region of interest while obtaining the sequence of images 162-168.

The processor 180 may be further arranged for, based on the detecting of glare 302-308 in the sequence of images 162-168, generating the control data 182 to establish the different subsets 122-128 of light sources. Hence, the processor 180 may select which of the plurality of light sources 120 are included in each of the different subsets of light sources 122-128. For example, the processor 180 may be arranged for establishing the different subsets of light sources 122-128 such that the glare 302-308 does not overlap, i.e., is not spatially co-located, in the sequence of images 162-168. This may facilitate reducing the glare in the composite image 320. Additionally or alternatively, the processor 180 may be arranged for establishing an illumination duration of each of the different subsets of light sources 122-128 based on the detecting of glare 302-308 in the sequence of images 162-168. For example, in the example shown in Figs. 6a-6d, the processor 180 may cycle through the different subsets of light sources 122-128 and may, instead of assigning equal illumination durations to each of the different subsets of light sources 122-128, establish a longest illumination duration for the fourth subset of light sources 128 based on the fourth image 168

showing the least glare 308, and establish a shortest illumination duration for the first subset of light sources 122 based on the first image 162 showing the most glare 302.

In general, the individual ones of the plurality of light sources 120 may be adjustable in position and/or orientation, and the processor 180 may be arranged for
5 instructing the light controller 140 to adjust the subset of light sources 122-128 by adjusting the position and/or orientation of at least the one or more light sources from the subset of light sources. Fig. 8a shows an example of a scope 110 comprising the plurality of light
sources 120 and the image sensor 160. Here, a primary light emission direction of individual ones of the plurality of light sources 120 is indicated with dashed arrows. In this particular
10 example, the individual ones of the plurality of light sources 120 are adjustable in orientation by virtue of being mounted on a circular carrier 130 which is adjustable in orientation with respect to an optical axis of the image sensor 160. Hence, by adjusting the orientation of the circular carrier 130, the orientation of all of the plurality of light sources 120 is adjusted. Fig.
8b shows a result of adjusting the orientation of the circular carrier 130. It can be seen that
15 the primary light emission direction is changed with respect to Fig. 8a. As a result, the glare may shift in a subsequent image of the region of interest. Depending on a shape and/or orientation of the region of interest in the image, the amount of glare may also be reduced, e.g., when the glare shifts from a shiny portion of the region of interest to a matte portion and consequently the reflection changes from specular to diffuse.

20 In general, the processor 180 may be arranged for variably adjusting the power of the individual ones of the plurality of light sources 120 so that when the glare 302 saturates the image 162, as may be determined by analyzing the image 162, said power may be reduced so as to reduce the glare in a subsequent image. Advantageously, a better composite image may be obtained. In case the plurality of light sources 120 is a plurality of
25 LEDs, the surface of the individual ones of the plurality of LEDs maybe convex and/or flat to enable the light being emitted in a diffuse manner. Moreover, the individual ones of the plurality of LEDs may be oriented at a slanting angle which crosses the center of the image 162 so that, when the region of interest is flat and oriented orthogonal to a principal optical axis of the image sensor 160, no or little specular reflections reach the image sensor 160.

30 It will be appreciated that the invention also applies to computer programs, particularly computer programs on or in a carrier, adapted to put the invention into practice. The program may be in the form of a source code, an object code, a code intermediate source and an object code such as in a partially compiled form, or in any other form suitable for use in the implementation of the method according to the invention. It will also be appreciated

that such a program may have many different architectural designs. For example, a program code implementing the functionality of the method or system according to the invention may be sub-divided into one or more sub-routines. Many different ways of distributing the functionality among these sub-routines will be apparent to the skilled person. The sub-routines may be stored together in one executable file to form a self-contained program. Such an executable file may comprise computer-executable instructions, for example, processor instructions and/or interpreter instructions (e.g. Java interpreter instructions). Alternatively, one or more or all of the sub-routines may be stored in at least one external library file and linked with a main program either statically or dynamically, e.g. at run-time. The main program contains at least one call to at least one of the sub-routines. The sub-routines may also comprise function calls to each other. An embodiment relating to a computer program product comprises computer-executable instructions corresponding to each processing step of at least one of the methods set forth herein. These instructions may be sub-divided into sub-routines and/or stored in one or more files that may be linked statically or dynamically.

Another embodiment relating to a computer program product comprises computer-executable instructions corresponding to each means of at least one of the systems and/or products set forth herein. These instructions may be sub-divided into sub-routines and/or stored in one or more files that may be linked statically or dynamically.

The carrier of a computer program may be any entity or device capable of carrying the program. For example, the carrier may include a storage medium, such as a ROM, for example, a CD ROM or a semiconductor ROM, or a magnetic recording medium, for example, a hard disk. Furthermore, the carrier may be a transmissible carrier such as an electric or optical signal, which may be conveyed via electric or optical cable or by radio or other means. When the program is embodied in such a signal, the carrier may be constituted by such a cable or other device or means. Alternatively, the carrier may be an integrated circuit in which the program is embedded, the integrated circuit being adapted to perform, or used in the performance of, the relevant method.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb "comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. The article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. The invention may be implemented by

means of hardware comprising several distinct elements, and by means of a suitably programmed computer. In the device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a

5 combination of these measures cannot be used to advantage.

CLAIMS:

1. System (100) for imaging a patient's interior, comprising:
 - a plurality of light sources (120) for illuminating a region of interest in the patient's interior from a plurality of different positions;
 - a light controller (140) for controlling individual ones of the plurality of light
 - 5 sources (120) to enable illuminating the region of interest with a subset (122-128) of light sources;
 - an image sensor (160) for acquiring an image (162-168) of the region of interest; and
 - a processor (180) for i) detecting glare (302-308) in the image, ii) attributing
 - 10 the glare to one or more light sources from the subset of light sources (122-128), and iii) based on said attributing, generating control data (182) for instructing the light controller (140) to adjust the subset of light sources so as to reduce the glare in a subsequent image of the region of interest.
- 15 2. System (100) according to claim 1, wherein the processor (180) is arranged for instructing the light controller (140) to adjust the subset of light sources (122-128) by replacing the one or more light sources from the subset of light sources with one or more other light sources from the plurality of light sources for establishing a new subset of light sources.
- 20 3. System according to claim 1, wherein the individual ones of the plurality of light sources (120) are adjustable in position and/or orientation, and wherein the processor (180) is arranged for instructing the light controller (140) to adjust the subset of light sources (122-128) by adjusting the position and/or orientation of at least the one or more light sources
- 25 from the subset of light sources.
4. System (100) according to claim 1, wherein:
 - the light controller (140) is arranged for variably illuminating the region of interest by alternating between different subsets of light sources (122-128);

- the image sensor (160) is arranged for acquiring a sequence of images (162-168) of the region of interest during said alternating between the different subsets of light sources (122-128);

- the processor (180) is arranged for, based on the sequence of images (162-168), generating a composite image (320) in which the glare (302-308) is reduced; and wherein

- the processor (180) is arranged for, based on the detecting of glare (302-308) in the sequence of images (162-168), generating the control data (182) to establish the different subsets of light sources (122-128).

5. System (100) according to claim 4, wherein the processor (180) is arranged for establishing an illumination duration of each of the different subsets of light sources (122-128) based on the detecting of glare (302-308) in the sequence of images (162-168).

6. System (100) according to claim 1, wherein the processor (180) is arranged for attributing the glare (302-308) to the one or more light sources based on a position of the glare in the image (162-168).

7. System (100) according to claim 6, wherein the processor (180) is arranged for attributing the glare (302-308) to the one or more light sources using machine learning, wherein the control data (182) is indicative of the subset of light sources (122-128), and wherein the machine learning is based on the position of the glare in the image and the control data (182).

8. System (100) according to claim 7, wherein

- the light controller (140) is arranged for variably illuminating the region of interest by alternating between different subsets of light sources (122-128);

- the image sensor (160) is arranged for acquiring a sequence of images (162-168) of the region of interest during the alternating between the different subsets of light sources (122-128); and wherein

- the processor (180) is arranged for learning a classifier based on the position of the glare (302-308) in the sequence of images and the control data (182).

9. System (100) according to claim 1, wherein the plurality of light sources (120) is a plurality of light emitting diodes.

10. System (100) according to claim 1, wherein the individual ones of the plurality of light sources (120) are arranged in a circular shape (130) around the image sensor (160).

11. System (100) according to claim 10, wherein the subset of light sources (122-128) is formed by one of the group of: two light sources arranged adjacently in the circular shape (130), and two light sources arranged oppositely in the circular shape.

12. System (100) according to claim 1, further comprising a scope (110) being one of the group of: a colposcope, a laparoscope and a retinoscope, the scope comprising the plurality of light sources (120) and the image sensor (160).

13. Workstation or imaging system comprising the system according to claim 1.

14. A method (200) for imaging a patient's interior, comprising:

- illuminating (210) a region of interest in the patient's interior from a plurality of different positions using a plurality of light sources;

- acquiring (220) an image of the region of interest;
the method further comprising:

- controlling (260) individual ones of the plurality of light sources to enable illuminating the region of interest with a subset of light sources; and

- i) detecting (230) glare in the image, ii) attributing (240) the glare to one or more light sources from the subset of light sources, and iii) based on said attributing, generating (250) control data to adjust the subset of light sources so as to reduce the glare in a subsequent image of the region of interest.

15. A computer program product (290) comprising instructions for causing a processor system to perform the method according to claim 14.

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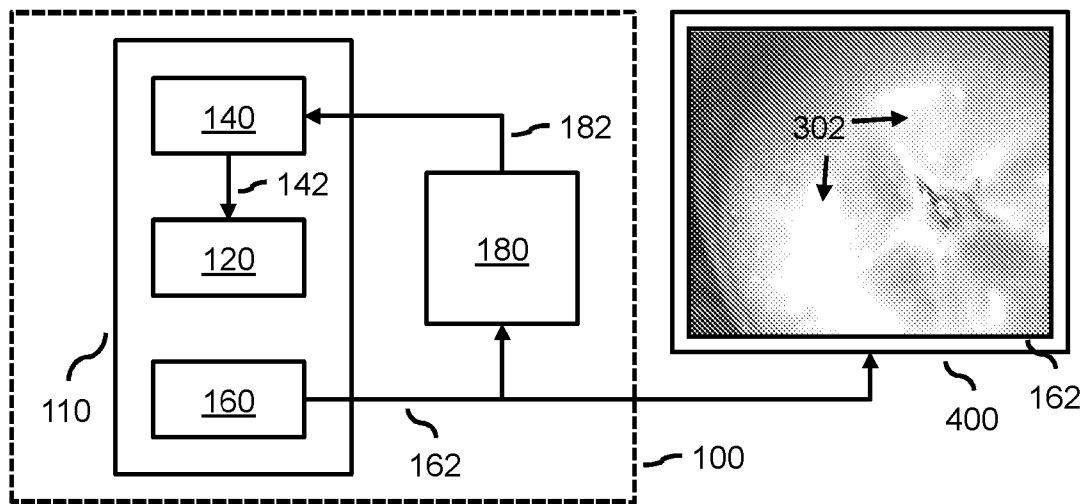


Fig. 1

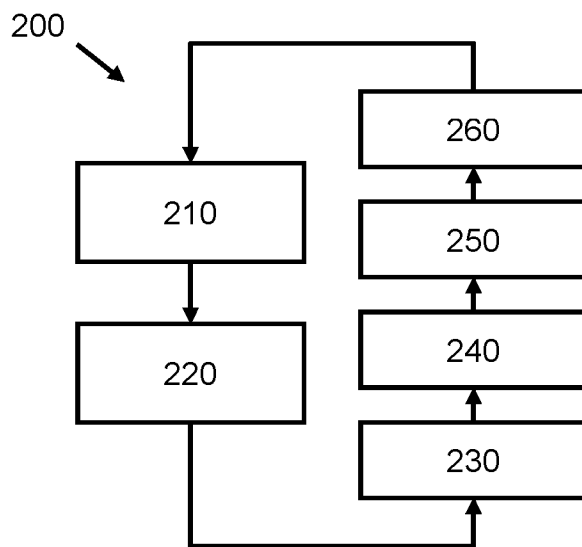


Fig. 2

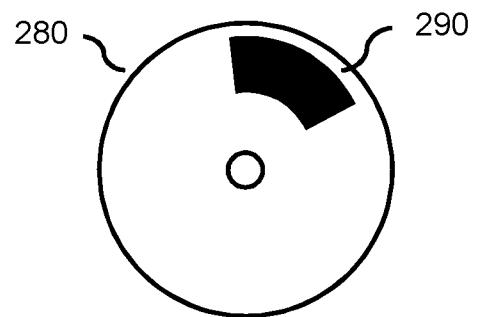


Fig. 3

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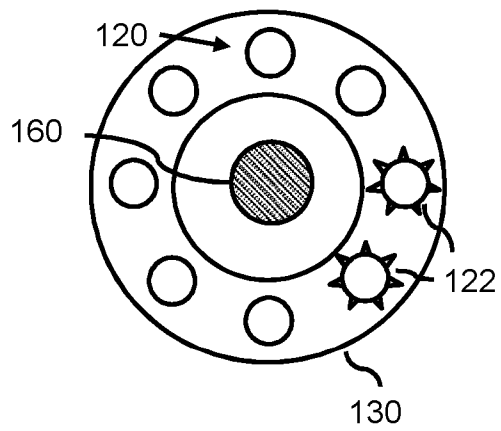


Fig. 4

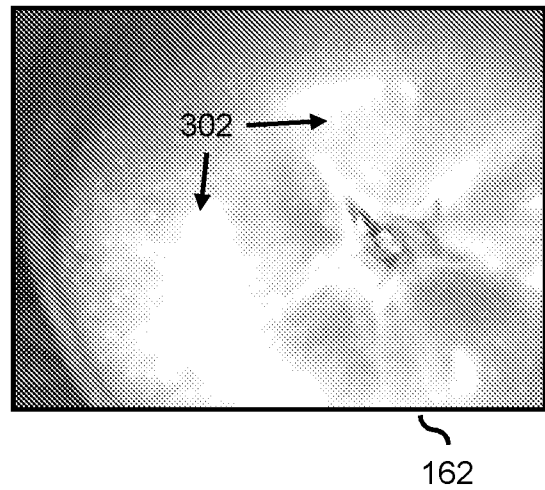


Fig. 5a

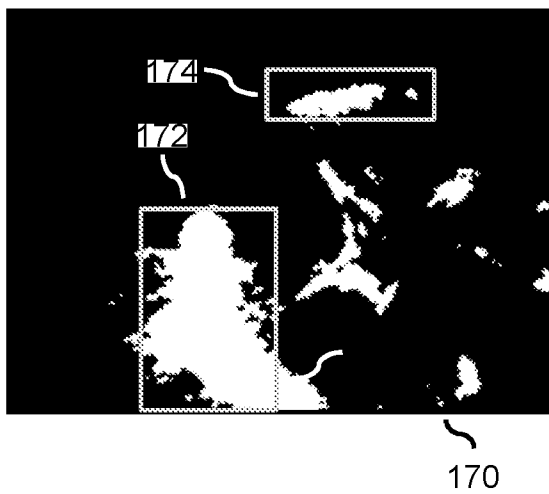


Fig. 5b

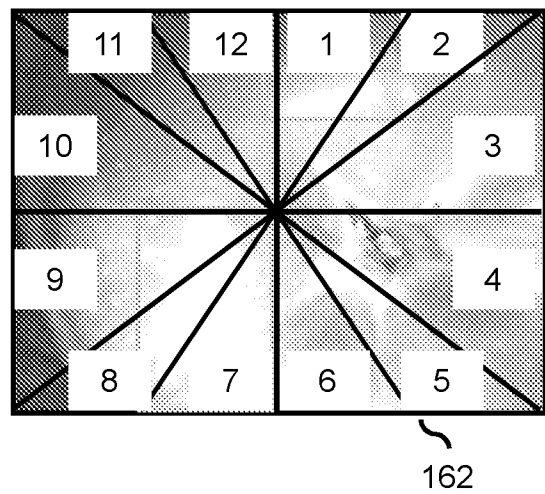


Fig. 5c

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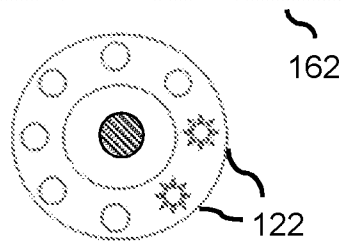
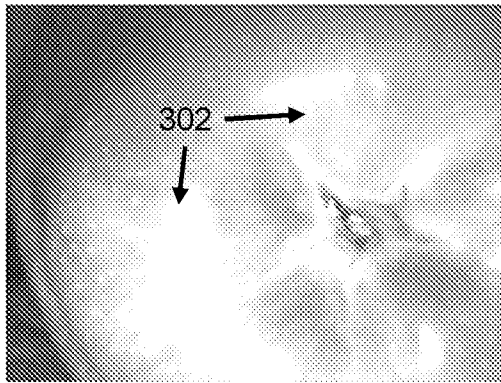


Fig. 6a

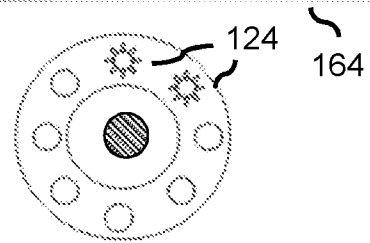
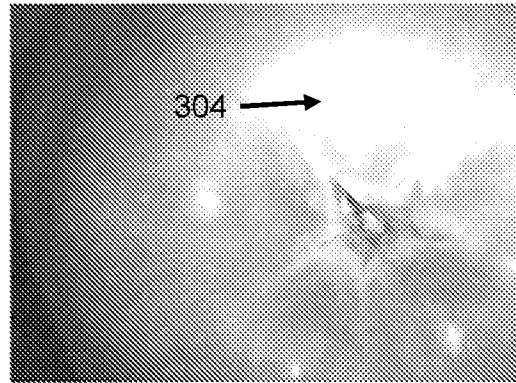


Fig. 6b

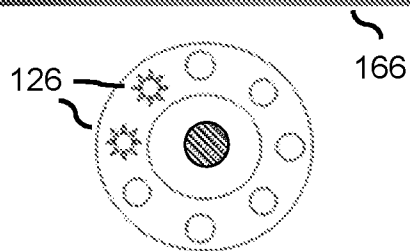
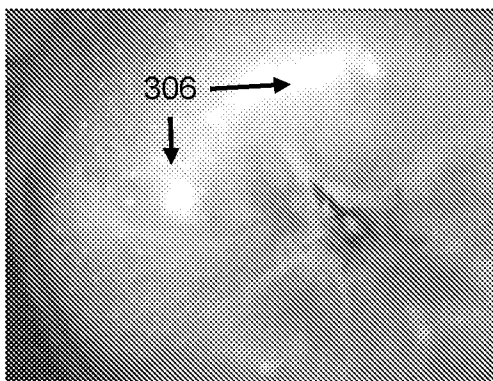


Fig. 6c

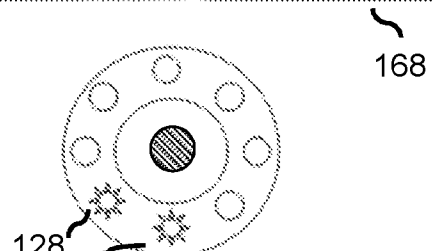
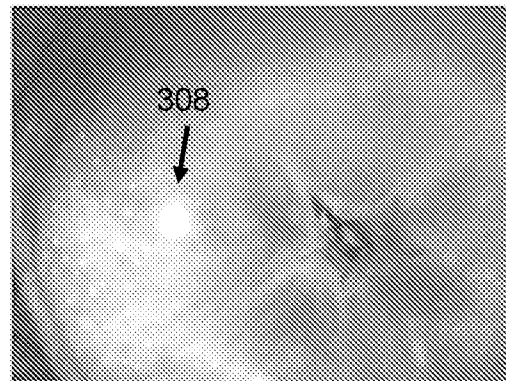


Fig. 6d

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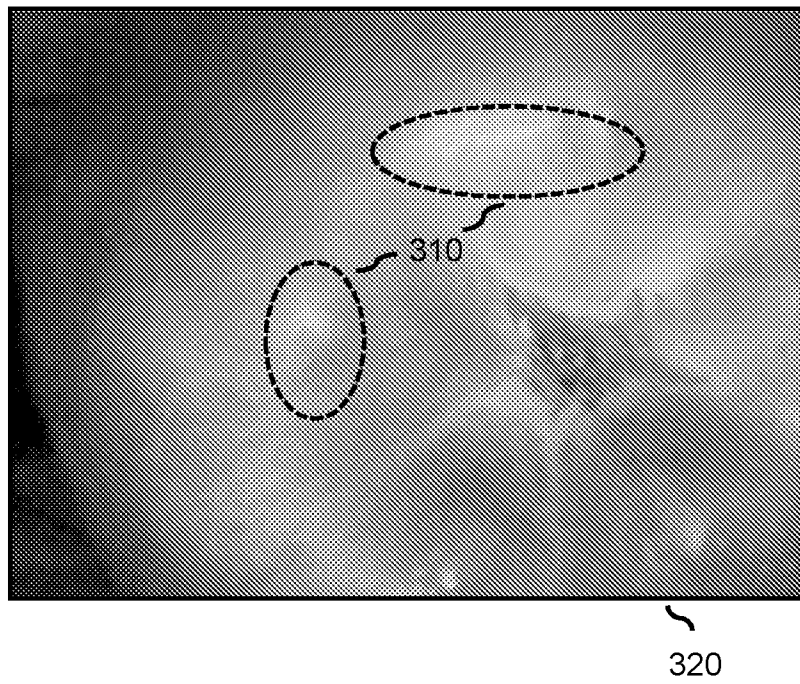


Fig. 7

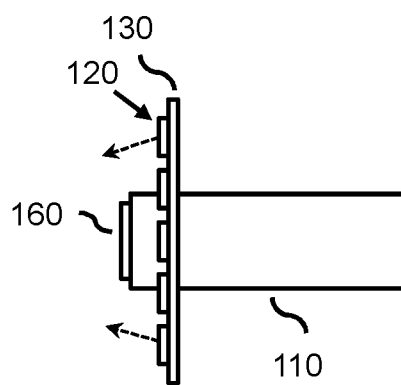


Fig. 8a

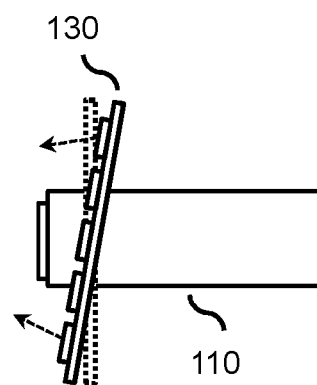


Fig. 8b

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2013/055323

A. CLASSIFICATION OF SUBJECT MATTER INV. A61B1/06 A61B1/00 A61B1/045 ADD. A61B1/303		
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) A61B G06T		
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) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/214156 A1 (SCHOMACKER KEVIN T [US] ET AL) 28 October 2004 (2004-10-28)	1,2,4-6, 10-15
Y	paragraphs [0070] - [0121] figures 1-5	3,9

Y	US 2012/147165 A1 (YOSHINO KOICHIRO [JP] ET AL) 14 June 2012 (2012-06-14)	3,9
A	paragraphs [0135] - [0150] figures 17-22	1,2,4-8, 10-15

A	US 6 088 612 A (BLAIR KERRY L [US]) 11 July 2000 (2000-07-11) cited in the application column 10, line 29 - column 11, line 40	1-15

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☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent 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	
29 October 2013	07/11/2013	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Gärtner, Andreas	

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2013/055323

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/026785 A1 (SOTO-THOMPSON MARCELO ESTEBAN [US] ET AL) 4 February 2010 (2010-02-04) paragraph [0008] -----	1-15
A	US 6 503 195 B1 (KELLER KURTIS P [US] ET AL) 7 January 2003 (2003-01-07) column 12, lines 19-43 figure 4 -----	1-15
A	LANGE H: "Automatic glare removal in reflectance imagery of the uterine cervix", PROCEEDINGS OF SPIE, SPIE - INTERNATIONAL SOCIETY FOR OPTICAL ENGINEERING, BELLINGHAM, WA, US, vol. 5747, no. 1, 12 February 2005 (2005-02-12), pages 2183-2192, XP002693387, ISSN: 1605-7422, DOI: 10.1117/12.596012 the whole document -----	1-15
A	US 2009/030276 A1 (SAADAT VAHID [US] ET AL) 29 January 2009 (2009-01-29) paragraphs [0019], [0062], [0070] figures 9, 15 -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2013/055323

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2004214156	A1	28-10-2004	AU 2003251796 A1 23-01-2004
			CA 2491699 A1 15-01-2004
			EP 1535033 A1 01-06-2005
			US 2004007674 A1 15-01-2004
			US 2004214156 A1 28-10-2004
			WO 2004005869 A1 15-01-2004
US 2012147165	A1	14-06-2012	JP 2012125293 A 05-07-2012
			US 2012147165 A1 14-06-2012
US 6088612	A	11-07-2000	NONE
US 2010026785	A1	04-02-2010	CN 102215732 A 12-10-2011
			EP 2309913 A1 20-04-2011
			JP 2012508034 A 05-04-2012
			US 2010026785 A1 04-02-2010
			WO 2010014072 A1 04-02-2010
US 6503195	B1	07-01-2003	NONE
US 2009030276	A1	29-01-2009	NONE