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(71) Applicant: THE JOHNS HOPKINS UNIVERSITY

[US/US]; 3400 N. Charles Street, Baltimore, Maryland 21218 (US).

(72) Inventors: RAJAN, Vikram; 31 Berkley Court, Morgan -

ville, New Jersey 07751 (US). BOLLAND, Michael V.; 11928 Thurloe Dr., Timonium, Maryland 21093 (US).

GADDIPATI, Ravi; 13916 Voyager Parkway, Colorado

Springs, Colorado 80921 (US). JACOBS, Connor; 2914

N. Calvert St., Baltimore, Maryland 21218 (US). KIM,

John Junyeon; 1 East University Pkwy., Apt. 409, Bal-

timore, Maryland 21218 (US). KUZNETSOV, Ivan An-

dreevich; 1833 Wysong Court, Raleigh, North Carolina

27612 (US). LEVENSON, Daniel; 3116 N. Calvert St.,

Baltimore, Maryland 21218 (US). REX, Monica; 11518

Willow Gardens Dr., Windermere, Florida 34786 (US).

TAM, Eric; 3510 N. Charles St., Baltimore, Maryland

21218 (US). WEI, Tony Yihan; 3700 N. Charles St., Apt.

803, Baltimore, Maryland 21218 (US).

(74) Agent: RYAN, Louisa; 100 N. Charles Street, 5th Floor,

Baltimore, Maryland 21201 (US).

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(54) Title: AUTOMATED AND NON-MYDRIATIC FUNDUS-PERIMETRY

CAMERA FOR IRREVERSIBLE EYE DISEASES

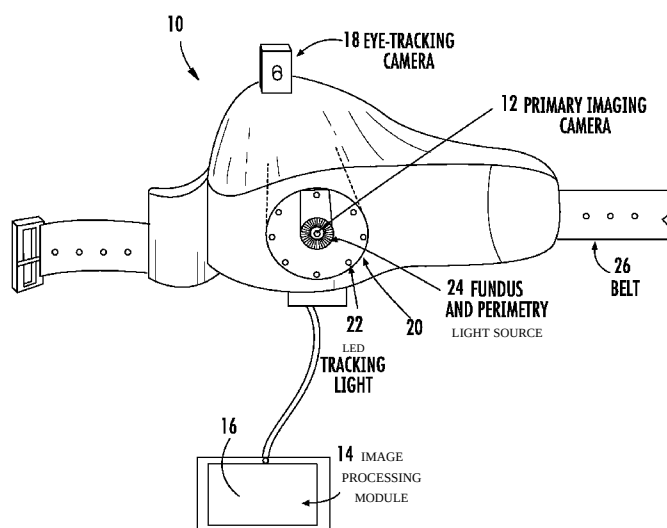


FIG. 1

(57) Abstract: An embodiment in accordance with the present invention provides a system and method for screening for eye diseases, particularly in developing countries. The system includes a primary camera for obtaining images of the eye and retina as well as a secondary camera for tracking eye movement. The system also includes a computing device configured to receive image information from both the primary and secondary cameras. The computing device is loaded with or has access to a non-transitory computer readable medium programmed for image processing to stitch together the image information to provide an operator of the device with detailed information about the patient's eye, and more particularly, the retina and optic nerve. The system is portable and reusable, making it ideal for use in remote and rural areas.



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**AUTOMATED AND NON-MYDRIATIC FUNDUS-PERIMETRY
CAMERA FOR IRREVERSIBLE EYE DISEASES**

CROSS REFERENCE TO RELATED APPLICATION

5 **[0001]** This application claims the benefit of U.S. Provisional Patent Application No. 61/820,302, filed on May 7, 2013, which is incorporated by reference, herein, in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates generally to medical devices. More particularly, the present invention relates to a system and method for testing for eye diseases.

10 BACKGROUND OF THE INVENTION

[0003] Eye diseases in developing nations commonly cause blindness due to lack of access to suitable treatment and preventative care. Many of the eye diseases that cause blindness in developing nations are preventable and/or treatable to mitigate damage to the patient's sight. While eye camps set up to treat patients with eye disease have been
15 implemented in some developing nations, often, devices needed to test for eye diseases are too expensive for use in these remote and rural areas. Additionally, even if the cost is accounted for these devices might not be portable or might require too much power to be used anywhere but in cities in these developing nations. This leaves those living outside of cities or in remote areas unable to seek treatment without significant travel and a great deal of
20 money. Therefore, these people often forego care, and their eye health deteriorates, even though their conditions are preventable and treatable.

[0004] Accordingly, there is a need in the art for a system and method for screening patients for eye disease in developing countries.

25

SUMMARY OF THE INVENTION

[0005] The foregoing needs are met, to a great extent, by a method for testing for eye diseases including obtaining an image of an eye of the patient using a primary camera. The method also includes tracking movement of the eye using a secondary camera to provide
5 tracking information. Additionally, the method includes processing the image and the tracking information to obtain enhanced image information.

[0006] In accordance with an aspect of the present invention, the method includes blocking entry of ambient light to the eye and an area surrounding the eye. The method includes using a primary camera having infrared capabilities. The method includes prompting
10 the eye to be set at angles relative to the primary imaging camera. Additionally, the method includes defining the image as a number of pixels and assigning each one of the pixels a coordinate. The coordinates are used to aid the co-registration process and allow for image variation. Enhanced image information is constructed using matching of similar areas of pixels on adjacent images. The method also includes determining a quantifiable score for the
15 image using a Fourier transform of the image and using a perimetry test to characterize the visual acuity at the periphery of a visual field of the patient.

[0007] In accordance with another aspect of the present invention, a system for testing for eye diseases, includes a primary camera configured to obtain images of an eye of a patient. The system also includes a secondary camera configured to track movement of the eye of the
20 patient resulting in tracking information. Additionally, the system includes a non-transitory computer readable medium programmed to receive the images and the tracking information and process the images and tracking information into enhanced image information.

[0008] In accordance with yet another aspect of the present invention, the system includes a head mounting device for securing the primary camera and secondary camera to a

head of the patient. The head mount is configured to hold the primary camera in front of the eye of the patient. The system further includes an LED tracking light and a fundus and perimetry light source. The system includes a computing device having a display.

Additionally, the system includes an eyelid holder. A prism can be included to collimate the light. The primary camera further includes infrared capabilities.

BRIEF DESCRIPTION OF THE DRAWING

[0009] The accompanying drawings provide visual representations, which will be used to more fully describe the representative embodiments disclosed herein and can be used by those skilled in the art to better understand them and their inherent advantages. In these drawings, like reference numerals identify corresponding elements and:

[0010] FIG. 1 illustrates a diagram of an eye-tracking camera system according to an embodiment of the present invention.

[0011] FIG. 2 illustrates a front view of the eye-tracking camera system of FIG. 1, as worn by a patient, according to an embodiment of the present invention.

[0012] FIG. 3 illustrates a side view of the eye-tracking camera system of FIG. 1, as worn by a patient, according to an embodiment of the present invention.

DETAILED DESCRIPTION

[0013] The presently disclosed subject matter now will be described more fully hereinafter with reference to the accompanying Drawings, in which some, but not all embodiments of the inventions are shown. Like numbers refer to like elements throughout. The presently disclosed subject matter may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Indeed, many

modifications and other embodiments of the presently disclosed subject matter set forth herein will come to mind to one skilled in the art to which the presently disclosed subject matter pertains having the benefit of the teachings presented in the foregoing descriptions and the associated Drawings. Therefore, it is to be understood that the presently disclosed subject matter is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims.

[0014] An embodiment in accordance with the present invention provides a system and method for screening for eye diseases, particularly in developing countries. The system includes a primary camera for obtaining images of the eye and retina as well as a secondary camera for tracking eye movement. The system also includes a computing device configured to receive image information from both the primary and secondary cameras. The computing device can take the form of a personal computer, server, imaging device processor, smartphone, tablet, phablet, or any other suitable device known to or conceivable by one of skill in the art. The computing device is loaded with or has access to a non-transitory computer readable medium programmed for image processing to stitch together the image information to provide an operator of the device with detailed information about the patient's eye, and more particularly, the retina and optic nerve. The system is portable and reusable, making it ideal for use in remote and rural areas.

[0015] FIG. 1 illustrates a diagram of an eye-tracking camera system according to an embodiment of the present invention. As illustrated in FIG. 1, the system 10 includes a primary imaging camera 12 configured to transmit images to a computing device 14. The computing device 14 can, not only, display the images as obtained by the primary camera on display 16, but also provides image processing in the form of an image processing software module, or any other suitable means known to or conceivable by one of skill in the art. The system 10 also includes a second, eye-tracking camera 18, also configured to transmit images

to the computing device 14. The computing device 14 includes display 16 to display the image information from the second, eye-tracking camera 18 independently, or can access the non-transitory computer readable medium to process the information to include it in a compiled image or in an image information report. The system 10 can also include light
5 sources 20 in the form of a LED tracking light 22 and a fundus and perimetry light source 24. A belt 26, or other securing device can also be included to hold the cameras 12, 18 of the system to the face of the patient. The belt 26 is also used to keep the cameras 12, 18 close to the face of the patient for instances where outside light needs to be blocked, in order to obtain images.

10 **[0016]** FIG. 2 illustrates a front view of the eye-tracking camera system of FIG. 1, and FIG. 3 illustrates a side view of the eye-tracking camera system of FIG. 1, as worn by a patient, according to an embodiment of the present invention. As illustrated in FIGS. 2 and 3 the eye-tracking camera system is held to an eye of the patient and can be secured using the belt 26. The computing device can be coupled to the cameras using either wired or wireless
15 communication protocols known to or conceivable by one of skill in the art. The computing device can also be used to provide power or auxiliary power to the cameras. The system is configured such that it can be used on either eye of the patient, such that only one system is needed to assess both a left and a right eye of the patient. While a second camera is discussed herein, embodiments that feature only the primary camera to execute all of the aspects of
20 imaging are also possible, and included herein.

[0017] More particularly, for fundus imaging, a complete image is obtained through the capture and combination of several small-size images, using a primary imaging camera, allowing a higher resolution view of the entire optic nerve. The primary imaging camera is capable of lateral movement to maintain line of sight throughout the motion of the patient's
25 eye. A second camera is used to provide rotational awareness of the eye. With a wide field of

view camera (such as the OV8830 from OmniVision) located adjacent to or behind the main imaging camera, the second camera allows tracking of the eye to direct lateral movement of the imaging camera to get a good view of the back of the eye. In addition, the rear camera provides a method to track movements, allowing stabilization in processing spatial tracking
5 in stitching the images together.

[0018] In addition to the method for normal light fundus imaging described herein, the present invention includes a feature that takes advantages of infrared light and pupil dilation without mydriasis. To increase the portion of the retina visible through the pupil without using mydriatic drugs, a method of the present invention initially blocks any entries of
10 normal light to initiate dark adaptation. The pupil has known to reach maximum dilation within 3 to 10 minutes. In order to maintain the dilated pupil during imaging, infrared light will be used to illuminate the eye without triggering the pupillary response, and the primary imaging camera is replaced with an infrared camera that can take images of the fundus.

[0019] For either infrared or normal light image acquisition the method of the present
15 invention includes a patient's eye being prompted to be at set angles relative to a primary imaging camera via an array of fixation points. Hence, ignoring variation of eye fixation from the set point, the sequence of images collected maps out the field of view of the fundus in a predictable way (clockwise illumination of fixation points). The number of images taken are minimized such that there is minimal overlap of points on adjacent images. Another
20 possibility to be determined from the rest of the instrumentation is to collect more adjacent points such that stitching itself is robust enough to form a coherent composite image and has been done for other medical purposes, such as radiography and laryngoscopy. Moreover, due to the consistency of each component image field of view, pixels can be assigned a

coordinate, which can greatly aid the co-registration process and allow for reasonable image variation.

[0020] According to a method of the present invention, the compiled image is reconstructed by matching similar areas of pixels on adjacent images (similar will be quantified as a parameter that can be determined experimentally). Adjacent images are concatenated pixel-wise until all the element images are included in the combined image. Due to motion and other sources of noise, there are spatially-aligned pixels after co-registration that have conflicting values in adjacent images. To resolve this, some basic statistical computation will be performed to give an intermediate value - possibly a simple or weighted average (based on local intensity values).

[0021] The present invention can also include a software component for processing the images obtained using the cameras. The software takes the form of a non-transitory computer readable medium. For the fundus imaging portion the non-transitory computer readable medium is programmed to determine a quantifiable score of the image quality by computing the Fourier transform of the image. The amount of high frequency noise is directly proportional to the blurriness of the image. By creating thresholds for acceptable levels of high frequency noise from the Fourier transform, image quality can be managed. Due to the difficulties in capturing the entire fundus in a single photograph, multiple photographs are taken and stitched together using one image as an anchor image and modifying other photographs to create similar viewing geometries. Through discrete smooth interpolation, differences in intensity values for pixels in the overlapping regions may be compared and averaged to reduce graininess.

[0022] Another feature of a method of the present invention is implementing a perimetry test, which characterizes the visual acuity at the periphery of a patient's visual field. This can be accomplished by directing a point of light onto various sections of the retina. By varying the intensity of the light by a set interval, the present invention can determine a threshold of detection by recording the patient's response to the stimulus in different regions of eye.

Directing the light can be accomplished in many ways: One way would be to create a ring of light and allow only a small wedge through to the retina at a time. By rotating the wedge of passed light, an entire circle of points can be tested around the macula. Another way would be to transmit a small beam of light through two wedge prisms in series. By changing the relative orientation of the prisms, the light can be directed anywhere within a circle described by the angle 4Θ where Θ is the deflection angle of just one prism. By collimating the light, the present invention can be used to reduce the dispersion of the light and limit its location to a much more controlled area of the retina.

[0023] In addition, for stabilization during image acquisition, the following can be added to the system to minimize distortion from head and eyelid movements: A head-mount that holds the imaging device in front of the eye would be able to reduce error generated by the movement of the head. Additionally, to ensure that blinking does not affect our measurement, an eyelid holder would be utilized to restrict movement the eyelid. A head-rest structure with a chin-rest, a forehead rest and a U-shaped rest that restricts lateral head movements would stabilize the movement of the head. An eyelid holder would be utilized to ensure the subject does not blink while the image is being taken.

[0024] It should be noted that the methods described herein can be executed with a program(s) fixed on one or more non-transitory computer readable medium. The non-transitory computer readable medium can be loaded onto a computing device, server, imaging

device processor, smartphone, tablet, phablet, or any other suitable device known to or conceivable by one of skill in the art. It should also be noted that herein the steps of the method described can be carried out using a computer, non-transitory computer readable medium, or alternately a computing device, microprocessor, or other computer type device
5 independent of or incorporated with one or more camera devices. Indeed, any suitable method of calculation known to or conceivable by one of skill in the art could be used.

[0025] A non-transitory computer readable medium is understood to mean any article of manufacture that can be read by a computer. Such non-transitory computer readable media includes, but is not limited to, magnetic media, such as a floppy disk, flexible disk, hard disk,
10 reel-to-reel tape, cartridge tape, cassette tape or cards, optical media such as CD-ROM, writable compact disc, magneto-optical media in disc, tape or card form, and paper media, such as punched cards and paper tape.

[0026] The many features and advantages of the invention are apparent from the detailed specification, and thus, it is intended by the appended claims to cover all such features and
15 advantages of the invention which fall within the true spirit and scope of the invention.

Further, since numerous modifications and variations will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.

What is claimed is:

1. A method for testing for eye diseases comprising:

obtaining an image of an eye of the patient using a primary camera;

tracking movement of the eye using a secondary camera to provide tracking

5 information; and

processing the image and the tracking information to obtain enhanced image

information.

2. The method of claim 1 further comprising blocking entry of ambient light to the eye

10 and an area surrounding the eye.

3. The method of claim 1 using the primary camera comprising infrared capabilities.

4. The method of claim 1 further comprising prompting the eye to be set at angles

15 relative to the primary imaging camera.

5. The method of claim 1 further comprising defining the image as a number of pixels.

6. The method of claim 5 further comprising assigning each one of the pixels a

20 coordinate.

7. The method of claim 6 further comprising using the coordinates to aid the co-registration process and allow for image variation.

8. The method of claim 1 further comprising constructing the enhanced image
5 information using matching of similar areas of pixels on adjacent images.

9. The method of claim 1 further comprising determining a quantifiable score for the image using a Fourier transform of the image.

10 10. The method of claim 1 further comprising using a perimetry test to characterize the visual acuity at the periphery of a visual field of the patient.

11. A system for testing for eye diseases, comprising:

a primary camera configured to obtain images of an eye of a patient;

15 a secondary camera configured to track movement of the eye of the patient resulting in tracking information; and,

a non-transitory computer readable medium programmed to receive the images and the tracking information and process the images and tracking information into enhanced image information.

12. The system of claim 1 further comprising a head mounting device for securing the primary camera and secondary camera to a head of the patient.

13. The system of claim 11 further comprising an LED tracking light.

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14. The system of claim 11 further comprising a fundus and perimetry light source.

15. The system of claim 11 further comprising a computing device.

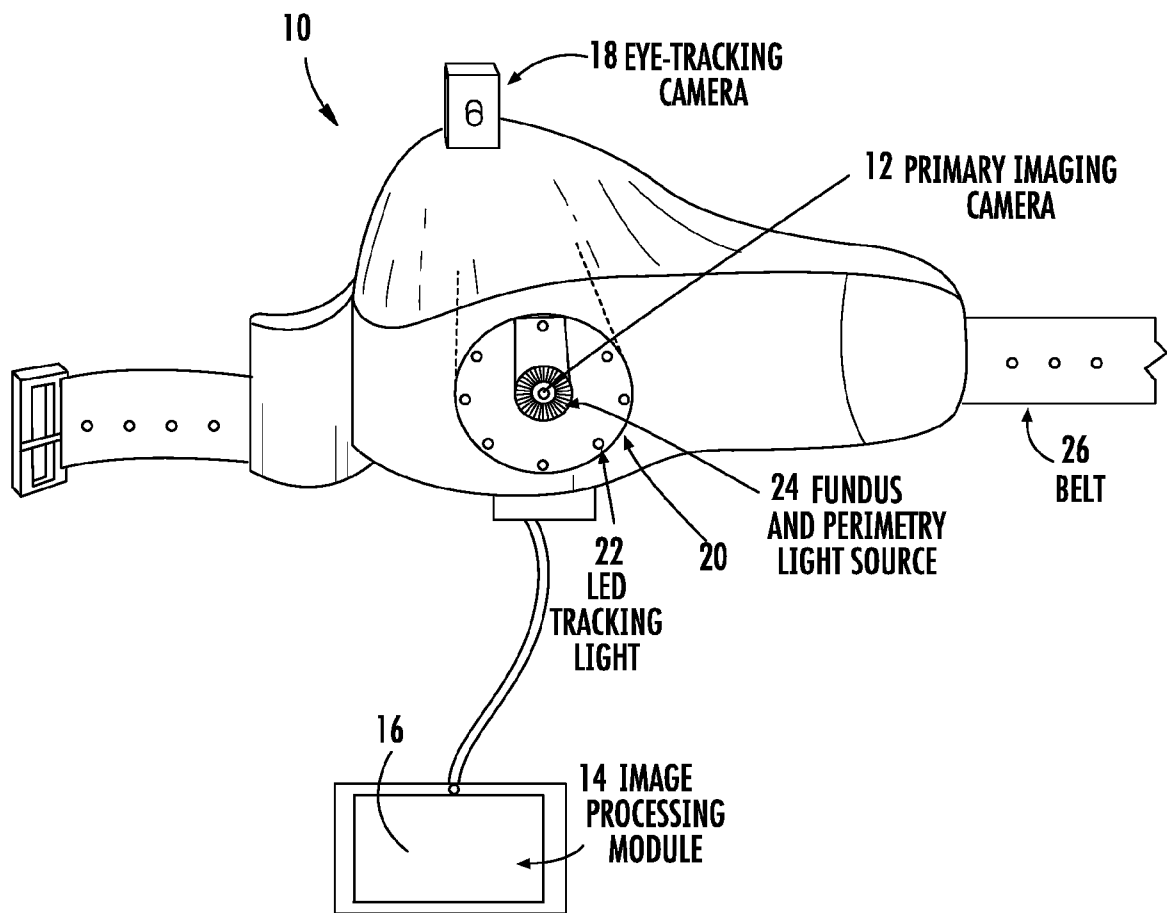
10 16. The system of claim 15 wherein the computing device further comprises a display.

17. The system of claim 11 further comprising an eyelid holder.

18. The system of claim 12 further comprising the head mount being configured to hold
15 the primary camera in front of the eye of the patient.

19. The system of claim 11 further comprising a prism to collimate the light.

20. The system of claim 11 wherein the primary camera further comprises infrared capabilities.

**FIG. 1**

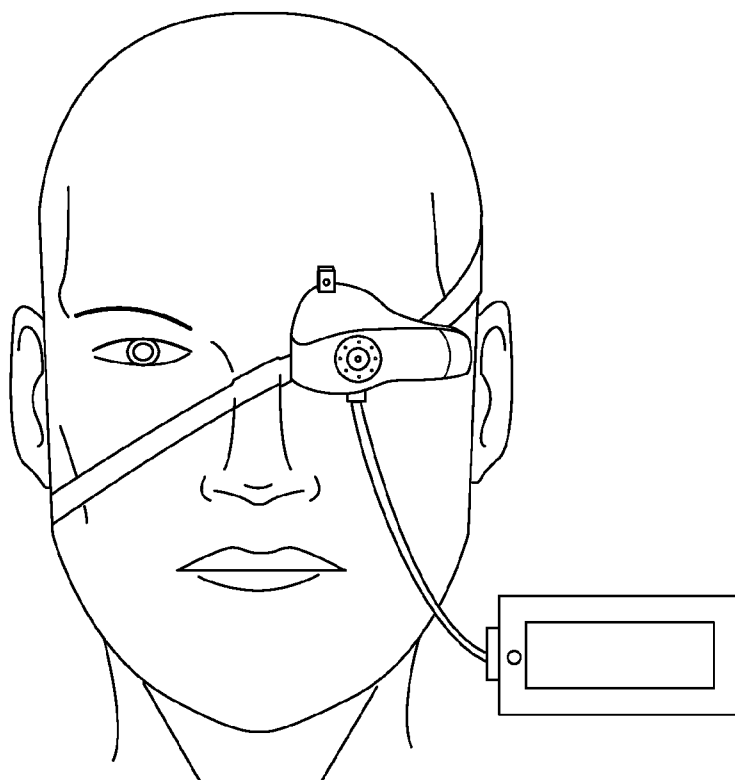


FIG. 2

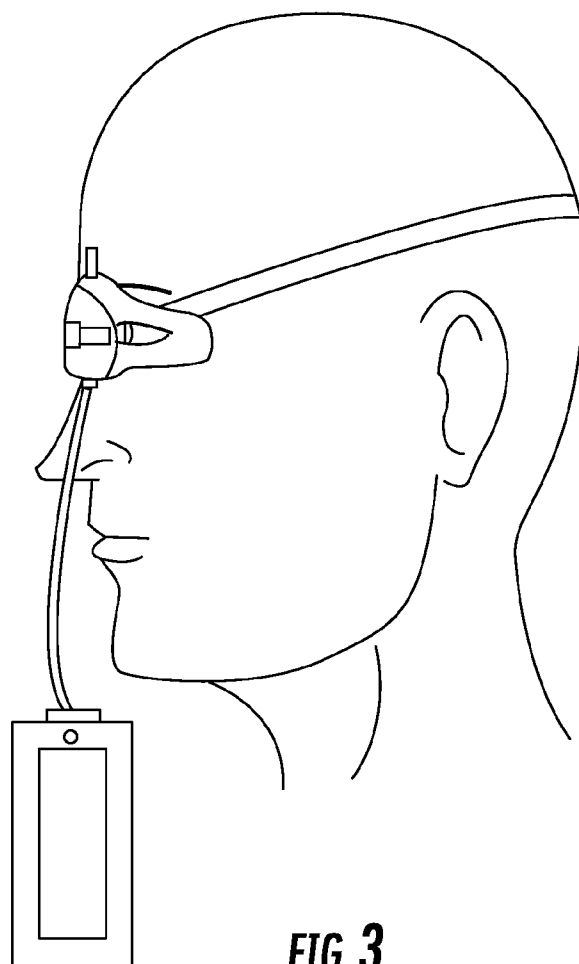


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/037075**A. CLASSIFICATION OF SUBJECT MATTER****A61B 3/10(2006.01)i, A61B 3/113(2006.01)i, A61B 3/14(2006.01)i**

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 3/10; G03B 17/00; A61B 5/117; G06K 9/00; G06T 1/00; A61B 3/14; A61B 3/113

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: eye, test, camera, tracking

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 10-137219 A (OKI ELECTRIC IND. CO., LTD.) 26 May 1998 See abstract, paragraphs [0014]- [0019], claim 1 and figures 1-6.	11-20
Y	US 2010-0097573 A1 (STEVEN ROGER VERDOONER et al.) 22 April 2010 See abstract, paragraphs [0026]- [0053], claim 1 and figures 2-4.	11-20
A	CN 202235300 U (BEIJING AISHENG SCIENCE AND TRADE CO., LTD.) 30 May 2012 See abstract, paragraphs [0027]- [0032] and figures 1-5.	11-20
A	US 2004-0252277 A1 (THOMAS ADAM CHMIELEWSKI et al.) 16 December 2004 See abstract, paragraphs [0022]- [0028], claim 1 and figures 1-3.	11-20
A	US 6094499 A (HIROSHI NAKAJIMA et al.) 25 July 2000 See abstract, column 11, lines 1-29 and claim 1.	11-20

II 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

05 September 2014 (05.09.2014)

Date of mailing of the international search report

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Name and mailing address of the ISA/KR

International Application Division
Korean Intellectual Property Office
189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City, 302-701,
Republic of Korea

Facsimile No. +82-42-472-7140

Authorized officer

KTM, Tae Hoon

Telephone No. +82-42-481-8407



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/037075

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos. : 1-10
because they relate to subject matter not required to be searched by this Authority, namely:
Claims 1-10 pertain to a method of treatment of the human body by surgery or by therapy/diagnostic methods and thus relate to a subject matter which this International Searching Authority is not required, under PCT Article 17(2)(a)(i) and PCT Rule 39.1(iv), to search.
2. ☐ Claims Nos. :
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically :
3. ☐ Claims Nos. :
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos. :

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/037075

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