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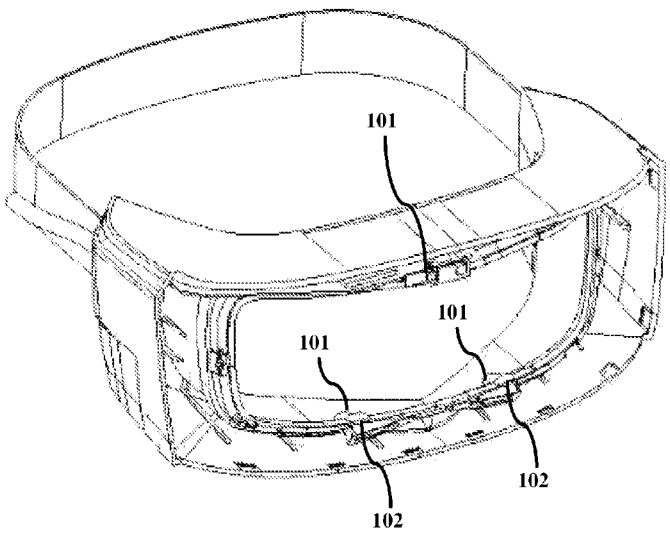
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(54) Title: A SYSTEM AND METHOD FOR TRACKING EYE IN VESTIBULAR EVALUATION

FIG. 1



(57) Abstract: The embodiments herein provide a system and method for an optimal imaging of a pupil for tracking for all gaze positions and all lighting conditions. The system comprises an goggle module with an unobtrusive frame for providing a wide field of view and enables an inferomedial eccentric camera placement. An infra-red band pass filter is provided for cutting-off direct light and reflections from surroundings. An array of linear infrared LEDs are mounted on the frame to provide optimum illumination to the pupil. The goggle module is connected to a computing module for analysis of captured visual data. The system provides no interference with natural line of sight and no restriction of field of vision. The applications of the system include medical applications, defense related, entertainment, exploration and scientific research.

[Continued on next page]

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A SYSTEM AND METHOD FOR TRACKING EYE IN VESTIBULAR EVALUATION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The embodiments herein claim the priority of the Indian Provisional Patent Application with the serial number 201741003806 and entitled, "SYSTEM AND METHOD FOR OPTIMAL IMAGING OF THE PUPIL FOR EYE TRACKING" filed on February 02, 2017 and the contents of which are included entirely as reference herein.

BACKGROUND

Technical Field

[0002] The embodiments herein are generally related to a field of vestibular evaluation. The embodiments herein are particularly related a system and method for tracking an eye in vestibular evaluation. The embodiments herein are more particularly related to a system and method for an optimal imaging of a pupil in an eye for tracking the eye for all gaze positions under all lighting conditions.

Description of the Related Art

[0003] Tracking of human eye movements has been in practice for a long time. Apart from healthcare related applications, tracking of pupil has found applications in the recent past in applications such as human-computer interaction and contextual visual rendering systems. One of the major applications of eye tracking is in the field of videonystagmography, which is a process of testing the vestibular system of a person. The vestibular system provides the sensory information of a person's equilibrium and spatial orientation.

[0004] Current methods of eye tracking, for example for videonystagmography, have limitations in tracking the extreme positions of gaze, especially downward gaze. The upper eyelid interferes with a pupil imaging process when looking downwards, as the camera is

placed straight ahead or looks at a reflected image from a dichroic glass placed in front of the eye. Further, the pupil image is distorted with bright spots interfering with optimal eye tracking in low light or very high ambient light conditions.

[0005] Hence, there is a need for a system and method for an optimal imaging of a pupil in an eye for tracking the eye for all gaze positions. There is also a need for a system and method for an optimal imaging of a pupil in an eye for tracking the eye for all light conditions. Yet there is a need for a system and method for tracking the eye in vestibular evaluation. Yet further, there is a need for a system and method for tracking the eye for all gaze positions in videonystagmography. Yet further, there is a need for a system and method for tracking the eye for all gaze positions in videooculography. Yet further, there is a need for a system and method for tracking the eye in eye tracking based virtual reality.

[0006] The above mentioned shortcomings, disadvantages and problems are addressed herein and which will be understood by reading and studying the following specification.

OBJECTIVES OF THE EMBODIMENTS HEREIN

[0007] The primary object of the embodiments herein is to provide a system and method for imaging of pupil in an eye.

[0008] Another object of the embodiments herein is to provide a system and method for an optimal imaging of a pupil for tracking eye for medical purposes.

[0009] Yet another object of the embodiments herein is to provide a system and method for an optimal imaging of a pupil in an eye for tracking the eye for all gaze positions.

[0010] Yet another object of the embodiments herein is to provide a system and method for an optimal imaging of a pupil in an eye for tracking the eye for all light conditions.

[0011] Yet another object of the embodiments herein is to provide a system and method for an optimal imaging of a pupil in an eye that comprises an infra-red band pass filter for cutting-off direct light and reflections from ambient surroundings.

[0012] Yet another object of the embodiments herein is to provide a system and method for an optimal imaging of a pupil in an eye that enables an inferomedial eccentric camera placement.

[0013] Yet another object of the embodiments herein is to provide a system and method for an optimal imaging of a pupil in an eye that comprises an unobtrusive frame providing a wide field of view.

[0014] Yet another object of the embodiments herein is to provide a system and method for an optimal imaging of a pupil in an eye that comprises an array of a plurality of linear infrared LEDs.

[0015] Yet another object of the embodiments herein is to provide a system and method that enables accurate tracking of the pupil movement even when the patient is wearing prescription glasses.

[0016] Yet another object of the embodiments herein is to provide a system and method that provides binocular examination of the pupil with two eye facing cameras for quality video and eye position data.

[0017] Yet another object of the embodiments herein is to provide a system and method that enables subjecting a patient to a plurality of tests for diagnosing balance disorders.

[0018] Yet another object of the embodiments herein is to provide a system and method that facilitates recording video and graph of any eye movement for diagnosis of balance disorders in the patient.

[0019] Yet another object of the embodiments herein is to provide a system and method that uses one or more cloud based deep learning powered interpretation algorithms for diagnosing balance disorders in a patient.

[0020] Yet another object of the embodiments herein is to provide a system and method that enables automatic pupil location and tracking despite removing and remounting of the goggle module multiple times.

[0021] Yet another object of the embodiments herein is to provide a system and method that enables effective and precise tracking of the pupil despite eye lashes and make-up worn by a patient.

[0022] Yet another object of the embodiments herein is to provide a system for optimal imaging of a pupil that is easy to calibrate and does not requires multiple calibration attempts for the same patient in a single test sitting.

[0023] Yet another object of the embodiments herein is to provide a system and method for tracking the eye in vestibular evaluation.

[0024] Yet another object of the embodiments herein is to provide a system and method for tracking the eye for all gaze positions in videonystagmography.

[0025] Yet another object of the embodiments herein is to provide a system and method for tracking the eye for all gaze positions in videooculography.

[0026] Yet another object of the embodiments herein is to provide a system and method for tracking the eye in eye tracking based virtual reality.

[0027] These and other objects and advantages of the embodiments herein will become readily apparent from the following detailed description taken in conjunction with the accompanying drawings.

SUMMARY

[0028] These and other aspects of the embodiments herein will be better appreciated and understood when considered in conjunction with the following description and the accompanying drawings. It should be understood, however, that the following descriptions, while indicating preferred embodiments and numerous specific details thereof, are given by way of illustration and not of limitation. Many changes and modifications may be made within the scope of the embodiments herein without departing from the spirit thereof, and the embodiments herein include all such modifications.

[0029] The embodiments herein provide a system for an optimal imaging of a pupil for balance assessment of a patient. The system comprises a goggle module comprising an unobtrusive frame. The unobtrusive frame is configured to provide a wide field of view. The unobtrusive frame is further configured for snug fitting user face without any adjustments. The goggle module is configured to provide a complete light sealing to avoid any external interference. The goggle module further comprises one or more cameras coupled with the unobtrusive frame in an inferomedial eccentric manner. The one or more cameras are configured for capturing a plurality of high quality eye images. The system also comprises a computing module run on a hardware processor and communicatively coupled to the goggle module. The computing module is configured for enabling the user to analyze the movement of the pupil for balance assessment of a patient based on the plurality of high quality eye images captured using the goggle module.

[0030] According to an embodiment herein, the goggle module further comprises an array of a plurality of linear infrared LEDs coupled to the unobtrusive frame. The array of a plurality of linear infrared LEDs is configured for providing an optimum illumination to the pupil of the eye when ambient light is low.

[0031] According to an embodiment herein, the goggle module further comprises an infra-red band pass filter coupled to the unobtrusive frame. The infra-red band pass filter is configured for cutting-off direct light and reflections from surroundings when the ambient light is high.

[0032] According to an embodiment herein, the computing module further comprises an image analysis engine configured for analyzing the plurality of high quality eye images captured using one or more cameras. The plurality of high quality eye images are analyzed by an image analysis engine using one or more machine learning algorithms.

[0033] According to an embodiment herein, the computing module further comprises an analytics engine configured for generating one or more reports of the analysis performed using image analysis engine. The one or more reports generated are visually presented to the user using a display device. The generated reports are also downloadable in a PDF or video format on an external storage media.

[0034] According to an embodiment herein, the computing module further comprises an artificial intelligence engine configured for interpreting any neuro-vestibular disorders in the patient based on the captured plurality of high quality eye images.

[0035] According to an embodiment herein, the computing module further comprises an augmented reality engine configured for combining virtual and real time test scenes for accurate balance disorder diagnosis.

[0036] According to an embodiment herein, the system is further configured for subjecting a patient to a plurality of tests for diagnosing balance disorders. The plurality of tests comprise a saccades test, a smooth pursuit test, a caloric reflex test, an optokinetic stimulation test, a nystagmus test, a gaze fixation test, a subjective midpoint test, a pupillometry test, a head impulse test, an open test, a positional test and a subjective visual vertical test.

[0037] According to an embodiment herein, the goggle module is further configured for recording video and graph of any eye movement for diagnosis of balance disorders in the patient.

[0038] According to an embodiment herein, the one or more cameras comprise two eye tracking cameras and one scene camera, and wherein the scene camera is configured for providing additional means for head tracking and auto-calibration.

[0039] According to an embodiment herein, the system is further configured for enabling accurate tracking of the pupil movement even when the patient is wearing prescription glasses.

[0040] According to an embodiment herein, a method for an optimal imaging of a pupil in an eye is provided. The method comprises the steps of fitting a goggle module to a user. The goggle module is communicatively connected to a computing module. The method also comprises setting preferences of image capture in the computing device and initiating image capture process through the goggle module. The method further comprises storing image capture information in the storage database and enabling real-time analysis through the computing module. The method still further comprises ending the image capture process as per user preference and analyzing the captured data. The method still further comprises performing image capture analysis as per user preferences and rendering the analysis to the user on a plurality of devices.

[0041] According to an embodiment herein, the step of analyzing the captured data further comprises analyzing the plurality of captured high quality of eye images using one or more machine learning algorithms through image analysis module.

[0042] According to an embodiment herein, the method further comprises generating one or more reports for the analysis performed using image analysis engine. The one or more reports generated are visually presented to the user using a display device. The generated reports are also downloadable in a PDF or video format on an external storage media.

[0043] According to an embodiment herein, the method further comprises interpreting any neuro-vestibular disorders in the patient based on the captured plurality of high quality eye images using an artificial intelligence engine.

[0044] According to an embodiment herein, the method further comprises combining virtual and real time test scenes for accurate balance disorder diagnosis using an augmented reality engine.

[0045] According to an embodiment herein, the method further comprises subjecting a patient to a plurality of tests for diagnosing balance disorders. The plurality of tests comprise a saccades test, a smooth pursuit test, a caloric reflex test, an optokinetic stimulation test, a nystagmus test, a gaze fixation test, a subjective midpoint test, a pupillometry test, a head impulse test, an open test, a positional test and a subjective visual vertical test.

[0046] According to an embodiment herein, the method further comprises providing optimum illumination to the pupil of the eye when ambient light is low using an array of a plurality of linear infrared LEDs coupled to the unobtrusive frame of the goggle module.

[0047] According to an embodiment herein, the method further comprises cutting-off direct light and reflections from surroundings when the ambient light is high using an infra-red band pass filter coupled to the unobtrusive frame of the goggle module.

[0048] According to an embodiment herein, the method further comprises enabling accurate tracking of the pupil movement even when the patient is wearing prescription glasses.

[0049] The embodiments herein provide a system disclose a system and method for an optimal imaging of a pupil for tracking eye. The embodiments also disclose a system and method for an optimal imaging of a pupil in an eye for tracking the eye for all gaze positions and all light conditions.

[0050] According to an embodiment herein, a system and method for an optimal imaging of a pupil in an eye for tracking the eye is provided. The system comprises an unobtrusive frame providing a wide field of view.

[0051] According to an embodiment herein, a system and method for an optimal imaging of a pupil in an eye for tracking the eye for all gaze positions is provided. The system enables an inferomedial eccentric camera placement and comprises an unobtrusive frame providing a wide field of view.

[0052] According to an embodiment herein, a system and method for an optimal imaging of a pupil in an eye for tracking the eye for all light conditions is provided. The system comprises an infra-red band pass filter for cutting-off direct light and reflections from surroundings when the ambient light is high. The system also comprises an array of a plurality of linear infrared LEDs to provide optimum illumination to the pupil when ambient light is low.

[0053] According to an embodiment herein, the system comprises a goggle module and a computing module. The goggle module and the computing module are communicatively connected to each other through wired or wireless means. The computing module comprises an image analysis module, a storage database, an analytics engine, an artificial intelligence engine, an augmented reality engine, memory and a processor.

[0054] According to an embodiment herein, a method for optimal imaging of the pupil for eye tracking is provided. The method comprises the following steps: a goggle module is fit to a user and goggle module is communicatively connected to a computing

module. The preferences of user in an image capture process are set in the computing device and image capture is initiated through the goggle. The image capture information is stored in the storage database and is analyzed in real-time through the computing module. The image capture process is terminated based on set user preferences and the captured data is analyzed. An image capture analysis is performed based on set user preferences and the analysis is rendered to the user on a plurality of devices.

[0055] The foregoing description of the specific embodiments will so fully reveal the general nature of the embodiments herein that others can, by applying current knowledge, readily modify and/or adapt for various applications such specific embodiments without departing from the generic concept, and, therefore, such adaptations and modifications should and are intended to be comprehended within the meaning and range of equivalents of the disclosed embodiments. It is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation. Therefore, while the embodiments herein have been described in terms of preferred embodiments, those skilled in the art will recognize that the embodiments herein can be practiced with modification within the spirit and scope of the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0056] The other objects, features and advantages will occur to those skilled in the art from the following description of the preferred embodiment and the accompanying drawings in which:

[0057] FIG. 1 illustrates a perspective view of a goggle comprised in the system for optimal imaging of the pupil for eye tracking, according to an embodiment herein.

[0058] FIG. 2 illustrates a rear view of a goggle comprised in the system for optimal imaging of the pupil for eye tracking, according to an embodiment herein.

[0059] FIG. 3 illustrates a front view of a goggle comprised in the system for optimal imaging of the pupil for eye tracking, according to an embodiment herein.

[0060] FIG. 4 illustrates a front view of a goggle with covers and lid in closed condition, in the system for optimal imaging of the pupil for eye tracking, according to an embodiment herein.

[0061] FIG. 5 illustrates a perspective view of a goggle with covers and lid in closed condition in the system for optimal imaging of the pupil for eye tracking, according to an embodiment herein.

[0062] FIG. 6 illustrates a perspective view of a goggle with covers in partially closed condition and one lid in open condition in the system for optimal imaging of the pupil for eye tracking, according to an embodiment herein.

[0063] FIG. 7 illustrates a top view of a goggle in the system for optimal imaging of the pupil for eye tracking, according to an embodiment herein.

[0064] FIG. 8 illustrates a bottom view of a goggle in the system for optimal imaging of the pupil for eye tracking, according to an embodiment herein.

[0065] FIG. 9 illustrates a functional block diagram of a system for optimal imaging of the pupil for eye tracking, according to an embodiment herein.

[0066] FIG. 10 illustrates a flow chart explaining a method for optimal imaging of the pupil for eye tracking, according to an embodiment herein.

[0067] Although the specific features of the present invention are shown in some drawings and not in others. This is done for convenience only as each feature may be combined with any or all of the other features in accordance with the embodiments herein.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0068] In the following detailed description, a reference is made to the accompanying drawings that form a part hereof, and in which the specific embodiments that may be practiced is shown by way of illustration. These embodiments are described in sufficient detail to enable those skilled in the art to practice the embodiments and it is to be understood that the logical, mechanical and other changes may be made without departing from the scope of the embodiments. The following detailed description is therefore not to be taken in a limiting sense.

[0069] The embodiments herein provide a system for an optimal imaging of a pupil for balance assessment of a patient. The system comprises a goggle module comprising an unobtrusive frame. The unobtrusive frame is configured to provide a wide field of view. The unobtrusive frame is further configured for snug fitting user face without any adjustments. The goggle module is configured to provide a complete light sealing to avoid any external interference. The goggle module further comprises one or more cameras coupled with the unobtrusive frame in an inferomedial eccentric manner. The one or more cameras are configured for capturing a plurality of high quality eye images. The system also comprises a computing module run on a hardware processor and communicatively coupled to the goggle module. The computing module is configured for enabling the user to analyze the movement of the pupil for balance assessment of a patient based on the plurality of high quality eye images captured using the goggle module.

[0070] According to an embodiment herein, the goggle module further comprises an array of a plurality of linear infrared LEDs coupled to the unobtrusive frame. The array of a plurality of linear infrared LEDs is configured for providing an optimum illumination to the pupil of the eye when ambient light is low.

[0071] According to an embodiment herein, the goggle module further comprises an infra-red band pass filter coupled to the unobtrusive frame. The infra-red band pass filter is configured for cutting-off direct light and reflections from surroundings when the ambient light is high.

[0072] According to an embodiment herein, the computing module further comprises an image analysis engine configured for analyzing the plurality of high quality eye images captured using one or more cameras. The plurality of high quality eye images are analyzed by an image analysis engine using one or more machine learning algorithms.

[0073] According to an embodiment herein, the computing module further comprises an analytics engine configured for generating one or more reports of the analysis performed using image analysis engine. The one or more reports generated are visually presented to the user using a display device. The generated reports are also downloadable in a PDF or video format on an external storage media.

[0074] According to an embodiment herein, the computing module further comprises an artificial intelligence engine configured for interpreting any neuro-vestibular disorders in the patient based on the captured plurality of high quality eye images.

[0075] According to an embodiment herein, the computing module further comprises an augmented reality engine configured for combining virtual and real time test scenes for accurate balance disorder diagnosis.

[0076] According to an embodiment herein, the system is further configured for subjecting a patient to a plurality of tests for diagnosing balance disorders. The plurality of tests comprise a saccades test, a smooth pursuit test, a caloric reflex test, an optokinetic stimulation test, a nystagmus test, a gaze fixation test, a subjective midpoint test, a pupillometry test, a head impulse test, an open test, a positional test and a subjective visual vertical test.

[0077] According to an embodiment herein, the goggle module is further configured for recording video and graph of any eye movement for diagnosis of balance disorders in the patient.

[0078] According to an embodiment herein, the one or more cameras comprise two eye tracking cameras and one scene camera, and wherein the scene camera is configured for providing additional means for head tracking and auto-calibration.

[0079] According to an embodiment herein, the system is further configured for enabling accurate tracking of the pupil movement even when the patient is wearing prescription glasses.

[0080] According to an embodiment herein, a method for an optimal imaging of a pupil in an eye is provided. The method comprises the steps of fitting a goggle module to a user. The goggle module is communicatively connected to a computing module. The method also comprises setting preferences of image capture in the computing device and initiating image capture process through the goggle module. The method further comprises storing image capture information in the storage database and enabling real-time analysis through the computing module. The method still further comprises ending the image capture process as per user preference and analyzing the captured data. The method still further comprises performing image capture analysis as per user preferences and rendering the analysis to the user on a plurality of devices.

[0081] According to an embodiment herein, the step of analyzing the captured data further comprises analyzing the plurality of captured high quality of eye images using one or more machine learning algorithms through image analysis module.

[0082] According to an embodiment herein, the method further comprises generating one or more reports for the analysis performed using image analysis engine. The one or more reports generated are visually presented to the user using a display device. The generated reports are also downloadable in a PDF or video format on an external storage media.

[0083] According to an embodiment herein, the method further comprises interpreting any neuro-vestibular disorders in the patient based on the captured plurality of high quality eye images using an artificial intelligence engine.

[0084] According to an embodiment herein, the method further comprises combining virtual and real time test scenes for accurate balance disorder diagnosis using an augmented reality engine.

[0085] According to an embodiment herein, the method further comprises subjecting a patient to a plurality of tests for diagnosing balance disorders. The plurality of tests comprise a saccades test, a smooth pursuit test, a caloric reflex test, an optokinetic stimulation test, a nystagmus test, a gaze fixation test, a subjective midpoint test, a pupillometry test, a head impulse test, an open test, a positional test and a subjective visual vertical test.

[0086] According to an embodiment herein, the method further comprises providing optimum illumination to the pupil of the eye when ambient light is low using an array of a plurality of linear infrared LEDs coupled to the unobtrusive frame of the goggle module.

[0087] According to an embodiment herein, the method further comprises cutting-off direct light and reflections from surroundings when the ambient light is high using an infra-red band pass filter coupled to the unobtrusive frame of the goggle module.

[0088] According to an embodiment herein, the method further comprises enabling accurate tracking of the pupil movement even when the patient is wearing prescription glasses.

[0089] The embodiments herein provide a system disclose a system and method for an optimal imaging of a pupil for tracking eye. The embodiments also disclose a system and method for an optimal imaging of a pupil in an eye for tracking the eye for all gaze positions and all light conditions.

[0090] According to an embodiment herein, a system and method for an optimal imaging of a pupil in an eye for tracking the eye is provided. The system comprises an unobtrusive frame providing a wide field of view.

[0091] According to an embodiment herein, a system and method for an optimal imaging of a pupil in an eye for tracking the eye for all gaze positions is provided. The system enables an inferomedial eccentric camera placement and comprises an unobtrusive frame providing a wide field of view.

[0092] According to an embodiment herein, a system and method for an optimal imaging of a pupil in an eye for tracking the eye for all light conditions is provided. The system comprises an infra-red band pass filter for cutting-off direct light and reflections from surroundings when the ambient light is high. The system also comprises an array of a plurality of linear infrared LEDs to provide optimum illumination to the pupil when ambient light is low.

[0093] According to an embodiment herein, the system comprises a goggle module and a computing module. The goggle module and the computing module are communicatively connected to each other through wired or wireless means. The computing module comprises an image analysis module, a storage database, an analytics engine, an artificial intelligence engine, an augmented reality engine, memory and a processor.

[0094] According to an embodiment herein, a method for optimal imaging of the pupil for eye tracking is provided. The method comprises the following steps: a goggle module is fit to a user and goggle module is communicatively connected to a computing

module. The preferences of user in an image capture process are set in the computing device and image capture is initiated through the goggle. The image capture information is stored in the storage database and is analyzed in real-time through the computing module. The image capture process is terminated based on set user preferences and the captured data is analyzed. An image capture analysis is performed based on set user preferences and the analysis is rendered to the user on a plurality of devices.

[0095] **FIG. 1** illustrates an isometric view of a goggle comprised in the system for optimal imaging of the pupil for eye tracking. The goggle comprises a plurality of camera slots 101 and a plurality of infra-red band pass filters 102.

[0096] **FIG. 2** illustrates a rear view of a goggle comprised in the system for optimal imaging of the pupil for eye tracking, according to one embodiment of the present invention.

[0097] **FIG. 3** illustrates a front view of a goggle comprised in the system for optimal imaging of the pupil for eye tracking, according to one embodiment of the present invention.

[0098] **FIG. 4** illustrates a front view of a goggle, with closed covers and lid, comprised in the system for optimal imaging of the pupil for eye tracking, according to one embodiment of the present invention.

[0099] **FIG. 5** illustrates an isometric view of a goggle, with closed covers and lid, comprised in the system for optimal imaging of the pupil for eye tracking, according to one embodiment of the present invention.

[00100] **FIG. 6** illustrates an isometric view of a goggle, with closed covers and one open lid, comprised in the system for optimal imaging of the pupil for eye tracking, according to one embodiment of the present invention.

[00101] **FIG. 7** illustrates a top view of a goggle comprised in the system for optimal imaging of the pupil for eye tracking, according to one embodiment of the present invention.

[00102] **FIG. 8** illustrates a bottom view of a goggle comprised in the system for optimal imaging of the pupil for eye tracking, according to one embodiment of the present invention.

[00103] **FIG. 9** illustrates a functional block diagram of a system for optimal imaging of the pupil for eye tracking, according to one embodiment of the present invention. The system comprises a goggle module 100 and a computing module 902. The goggle module 100 and the computing module 902 are communicatively connected to each other through wired or wireless means. The computing module 902 comprises an image analysis module 902a, a storage database 902b, an analytics engine 902c, an artificial intelligence engine 902d, an augmented reality engine 902e, memory 902f and a processor 902g.

[00104] According to an embodiment herein, the goggle module 100 comprises an unobtrusive frame configured for providing a wide field of view. The unobtrusive frame is further configured for snug fitting user face without any adjustments. The goggle module 100 is configured for providing complete light sealing in order to avoid any external interference. The goggle module 100 further comprises one or more cameras coupled with the unobtrusive frame in an inferomedial eccentric manner. The one or more cameras are configured for capturing a plurality of high quality eye images. The goggle module 100 further comprises an array of a plurality of linear infrared LEDs coupled to the unobtrusive frame. The array of a plurality of linear infrared LEDs is configured for providing optimum illumination to the pupil of the eye when ambient light is low. The goggle module 100 further comprises an infra-red band pass filter coupled to the unobtrusive frame. The infra-red band pass filter is configured for cutting-off direct light and reflections from surroundings when the ambient light is high.

[00105] According to an embodiment herein, the computing module 902 is configured for enabling the user to analyze the movement of the pupil for balance assessment of a patient based on the plurality of high quality eye images captured using the goggle module 100. The image analysis engine 902a is configured for analyzing the plurality of high quality eye images captured using one or more cameras. The plurality of high quality eye images are analyzed by the image analysis engine 902a using one or more machine learning algorithms. The analytics engine 902c is configured for generating one or more reports for the analysis performed using image analysis engine. The one or more reports generated are visually presented to the user using a display device (not shown). The generated reports are also downloadable in a PDF or video format on an external storage media.

[00106] According to an embodiment herein, the user is also allowed to add comments related to every displayed graph by clicking below the comments section. The user is also provided with an option of either printing all the pages or select specific pages to print. For selecting specific pages to print, first the print all button is unmarked and then user proceeds to the select the pages to print by clicking on them. The user accesses the videos and PDFs by clicking on file explorer button available on the report module. The videos and PDFs are also accessed from the patient management module by clicking on the file explorer button next to the visit date and time button.

[00107] According to an embodiment herein, the artificial intelligence engine 902d is configured for interpreting any neuro-vestibular disorders in the patient based on the captured plurality of high quality eye images. The augmented reality engine 902e is configured for combining virtual and real time test scenes for accurate balance disorder diagnosis.

[00108] According to an embodiment herein, the system is further configured for subjecting a patient to a plurality of tests for diagnosing balance disorders, and wherein the plurality of tests comprise a saccades test, a smooth pursuit test, a caloric reflex test, an optokinetic stimulation test, a nystagmus test, a gaze fixation test, a subjective midpoint test, a pupillometry test, a head impulse test, an open test, a positional test, a subjective visual vertical test and the like. In the saccades test, the patient is instructed to refixate on the target once it appears on a new area in the screen and to keep looking at it until the target disappears. Movement of the eyes in anticipation of a target appearing in a new area is avoided. The results provided include velocity, precision and latency.

[00109] According to an embodiment herein, for smooth pursuit test horizontal and vertical stimulation modes are made available. The results provided include forward gain and backward gain for each eye. In case of horizontal stimulation, the rightward eye movement is considered for forward gain calculation and leftward eye movement is considered for backward gain calculation. For vertical stimulation, the upward eye movement is considered for forward gain calculation and downward eye movement is considered for backward gain calculation. The patient is instructed to follow the target as smoothly as possible. This helps to tell the patient to "allow your eyes" to follow the target as it smoothly travels to and fro across the screen.

[00110] According to an embodiment herein, in case of calorics test, the standard bithermal caloric test, ice cold response, initial spontaneous nystagmus is recorded. The caloric test is performed with fixation eliminated i.e. right and left eye flap covered. The stimulation duration for the standard bithermal caloric test using water is 30 seconds for each stimulation modality. A total of 250 ml of water is irrigated over 30 seconds. A voice command guides the user to the time of starting and ending the irrigation. The begin stimulation command is given after 10 seconds of starting the recording. The end stimulation

command is given after 40 seconds of starting the recording. A total recording duration of two minutes and thirty seconds is recommended for each modality.

[00111] In this example embodiment, the calculation of results is automatic. However, it is strongly recommended that the user verifies the input parameters for the calculations by manually perusing the graph. 'Delete marker' option is used to remove 'points' that in the users judgment do not represent valid points on the graph for calculation. 'Add marker' option is used to insert points on the graph which in the user's judgment represent valid points on the graph for calculation.

[00112] In this example embodiment, the caloric test is performed with both eye flaps covered and the patient is instructed to keep the eyes open throughout. Immediately after the slow phase velocity has peaked and has started to wane, the user is prompted by a voice command to open the eye flaps. The eye flaps are opened and the patient is instructed to fixate on a point on the ceiling. After five seconds, another voice command is prompted to user to reapply the eye flaps. Recording of the graph is continued for the total duration of two and half minutes from the beginning of irrigation.

[00113] Further, the input parameter used for calculation of results is 'slow phase velocity.' The mean of five consecutive beats at the peak slow phase velocity is used for calculation of total response, unilateral weakness and directional preponderance. For fixation index, mean of five consecutive beats during fixation is compared with the mean of five consecutive beats before fixation.

[00114] According to an embodiment herein, for optokinetic test alternating white and black bars are used for optokinetic stimulation. The stimulation modes available are left to right 20 degrees per second, right to left 20 degrees per second, top to bottom 20 degrees per second, bottom to top 20 degrees per second, left to right 40 degrees per second, right to left 40 degrees per second, the subject is instructed to stare at the screen. The subject is

instructed NOT to follow any bar. The result provided is gain. The gain is calculated as a ratio of slow phase eye movement velocity to stimulation bar movement velocity.

[00115] According to an embodiment herein, for nystagmus test the nystagmus is recorded separately under the subtests such as spontaneous in light, spontaneous in dark, high frequency head shake, hyperventilation, valsalva glottis, valsalva mouth and nose, tullio, fistula. The results provided include slow phase velocity, amplitude, direction and frequency.

[00116] According to an embodiment herein, for gaze fixation test the gaze movement and stability is tested in the centre, left, up, right and down directions. If any gaze evoked nystagmus is detected, the slow phase velocity, amplitude, direction and frequency in each direction of gaze is separately provided. In addition, the graph represents the movement of the eye to study the trajectory and conjugacy of eye movements.

[00117] According to an embodiment herein, for the positional tests and maneuvers the subtests available include Dix Hallpike, Epley, Semont, Gufoni, Barbecue roll, Straight head hanging, Yacovino, McClure Pagnini and Head positions (yaw, pitch and roll). This test module allows the user to record each position of the test separately. The right arrow on the keyboard is used to advance to the next step of the test while recording. There is NO need to stop the test recording to proceed to next step. The results provided are slow phase velocity, amplitude, direction and frequency.

[00118] According to an embodiment herein, for the subjective midpoint test the stimulation modes available are background moving left to right, background moving right to left and blank background. The patient uses 2 and 4 buttons on the joystick to move the bar on the screen to the middle. Alternatively, the right and left arrows on the keyboard are used. The result is provided as distance offset from the midline.

[00119] According to an embodiment herein, in case of subjective visual vertical test, the stimulation modes available are background moving clockwise, background moving anticlockwise and blank background. The patient uses 1 and 3 buttons on the joystick to move the bar on the screen to the middle. Alternatively, the up and down arrows on the keyboard are used. The result is provided as degrees of deviation from the vertical.

[00120] According to an embodiment herein, for open test the user is allowed to record video and graph of any eye movement that do not fall under the previously described tests.

[00121] According to an embodiment herein, the calculations related to all the tests are done automatically. Except for calorics test, the calculations are based on the area of graph currently under display in the screen. The user selects the area that best represents the correct eye trace for the test under consideration. The selection is made by holding the left mouse button down and dragging rightward until the area of interest is covered. At any point, the whole graph is made to appear by clicking on the reset button. The graph displays the points selected by the software for the calculations. The user needs to verify if the selected points represent the true points. The user is allowed to change the points selected for calculations using the delete marker and add marker buttons. At any point, the delete or add marker function of the mouse are disabled by clicking on the select button.

[00122] **FIG. 10** illustrates a method for optimal imaging of the pupil for eye tracking, according to one embodiment of the present invention. The method comprises the following steps: a goggle module is fit to a user and goggle module is communicatively connected to a computing module (1001); preferences of image capture are set in the computing device and image capture is initiated through the goggle (1002); image capture information is stored in the storage database and real-time analysis through the computing module is enabled (1003); image capture process ends as per user preference and the

captured data is analyzed (1004); and, image capture analysis is performed as per user preferences and the analysis is rendered to the user on a plurality of devices (1005).

[00123] Therefore, the embodiments herein disclose a system and method for an optimal imaging of a pupil for tracking eye. The embodiments also disclose a system and method for an optimal imaging of a pupil in an eye for tracking the eye for all gaze positions and all light conditions. The system comprises an unobtrusive frame providing a wide field of view. The system enables an inferomedial eccentric camera placement. The system comprises an infra-red band pass filter for cutting-off direct light and reflections from surroundings when the ambient light is high. The system also comprises an array of a plurality of linear infrared LEDs to provide optimum illumination to the pupil when ambient light is low. The system provides no interference with natural line of sight and no restriction of field of vision. The system enables an accurate eye tracking in a variety of ambient light conditions and provides a robust eye image in all positions of gaze. The applications of the system include medical applications, defense related, entertainment, exploration and scientific research.

[00124] Thus, the system is used for vestibular evaluation. The system facilitates diagnose, document and interpretation support for various neuro vestibular disorders by recording and analyzing the movement of the pupil. The overall solution comprises of eye tracking goggles, multi interface unit and software modules as well as cloud based storage and interpretation support. The eye tracking goggles captures the pupil image and sends the same to the desktop/laptop computer for image processing and graphical representation. The system is meant to be used by trained clinicians like ENT specialists, Neuro vestibular specialists, Neurologists and Audiologists.

[00125] The foregoing description of the specific embodiments will so fully reveal the general nature of the embodiments herein that others can, by applying current knowledge, readily modify and/or adapt for various applications such specific embodiments without departing from the generic concept, and, therefore, such adaptations and modifications should and are intended to be comprehended within the meaning and range of equivalents of the disclosed embodiments. It is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation. Therefore, while the embodiments herein have been described in terms of preferred embodiments, those skilled in the art will recognize that the embodiments herein can be practiced with modification within the spirit and scope of the appended claims.

[00126] Although the embodiments herein are described with various specific embodiments, it will be obvious for a person skilled in the art to practice the invention with modifications. However, all such modifications are deemed to be within the scope of the claims.

[00127] It is also to be understood that the following claims are intended to cover all of the generic and specific features of the embodiments described herein and all the statements of the scope of the embodiments which as a matter of language might be the to fall there between.

CLAIMS

What is claimed is:

1. A system for an optimal imaging of a pupil for balance assessment of a patient, the system comprises:

a goggle module comprising an unobtrusive frame, and wherein the unobtrusive frame is configured for providing a wide field of view, and wherein the unobtrusive frame is further configured for snug fitting user face without any adjustments, and wherein the goggle module is configured for providing complete light sealing in order to avoid any external interference;

one or more cameras coupled with the unobtrusive frame in an inferomedialeccentric manner, and wherein the one or more cameras are configured for capturing a plurality of high quality eye images; and

a computing module run on a hardware processor and communicatively coupled to the goggle module, and wherein the computing module is configured for enabling the user to analyze the movement of the pupil for balance assessment of a patient based on the plurality of high quality eye images captured using the goggle module;

an array of a plurality of linear infrared LEDs coupled to the unobtrusive frame, and wherein the array of a plurality of linear infrared LEDs is configured for providing optimum illumination to the pupil of the eye when ambient light is low;

wherein the plurality of cameras are arranged in a lower frame and the plurality of LEDs are arranged at preset distances to emit light in preset angles.

2. The system according to claim 1, wherein the goggle module further comprises an infra-red band pass filter coupled to the unobtrusive frame, and wherein the infra-red

band pass filter is configured for cutting-off direct light and reflections from surroundings when the ambient light is high.

3. The system according to claim 1, wherein the computing module further comprises an image analysis engine, and wherein the image analysis engine is configured for analyzing the plurality of high quality eye images captured using one or more cameras, and wherein the plurality of high quality eye images are analyzed by the image analysis engine using one or more machine learning algorithms.

4. The system according to claim 1, wherein the computing module further comprises an analytics engine, and wherein the analytics engine is configured for generating one or more reports for the analysis performed using image analysis engine, and wherein the one or more reports generated are visually presented to the user using a display device, and wherein the generated reports are also downloadable in a PDF or video format on an external storage media.

5. The system according to claim 1, wherein the computing module further comprises an artificial intelligence engine, and wherein the artificial intelligence engine is configured for interpreting any neuro-vestibular disorders in the patient based on the analysis of the plurality of captured high quality eye images.

6. The system according to claim 1, wherein the computing module further comprises an augmented reality engine, and wherein the augmented reality engine is configured for combining virtual and real time test scenes for an accurate balance disorder diagnosis.

7. The system according to claim 1, wherein the system is further configured for subjecting a patient to a plurality of tests for diagnosing balance disorders, and

wherein the plurality of tests comprise a saccades test, a smooth pursuit test, a caloric reflex test, an optokinetic stimulation test, a nystagmus test, a gaze fixation test, a subjective midpoint test, a pupillometry test, a head impulse test, an open test, a positional test and a subjective visual vertical test.

8. The system according to claim 1, wherein the goggle module is further configured for recording video and graph of any eye movement for diagnosis of balance disorders in the patient.

9. The system according to claim 1, wherein the one or more cameras comprise two eye tracking cameras and one scene camera, and wherein the scene camera is configured for providing additional means for head tracking and auto-calibration.

10. The system according to claim 1, wherein the system is further configured for enabling accurate tracking of the pupil movement even when the patient is wearing prescription glasses.

11. A computer implemented method comprising instructions stored on a non-transitory computer readable storage medium and run on a computing device provided with a hardware processor and memory for an optimal imaging of a pupil in an eye, the method comprising the steps of:

fitting a goggle module to a user, and wherein the goggle module is communicatively connected to a computing module;

setting preferences of image capture in the computing device and initiating image capture process through the goggle module;

storing image capture information in the storage database and enabling real-time analysis through the computing module;

ending the image capture process as per user preference and analyzing the captured data; and

performing image capture analysis as per user preferences and rendering the analysis to the user on a plurality of devices;

wherein the plurality of cameras are arranged in a lower frame and the plurality of LEDs are arranged at preset distances to emit light in preset angles.

12. The method according to claim 11, wherein the step of analyzing the captured data further comprises analyzing the plurality of captured high quality of eye images using one or more machine learning algorithms through image analysis module.

13. The method according to claim 11, wherein the method further comprises generating one or more reports for the analysis performed using image analysis engine, and wherein the one or more reports generated are visually presented to the user using a display device, and wherein the generated reports are also downloadable in a PDF or video format on an external storage media.

14. The method according to claim 11, wherein the method further comprises interpreting any neuro-vestibular disorders in the patient based on the captured plurality of high quality eye images using an artificial intelligence engine.

15. The method according to claim 11, wherein the method further comprises combining virtual and real time test scenes for accurate balance disorder diagnosis using an augmented reality engine.

16. The method according to claim 11, wherein the method further comprises subjecting a patient to a plurality of tests for diagnosing balance disorders, and wherein the plurality of tests comprise a saccades test, a smooth pursuit test, a caloric reflex test,

an optokinetic stimulation test, a nystagmus test, a gaze fixation test, a subjective midpoint test, a pupillometry test, a head impulse test, an open test, a positional test and a subjective visual vertical test.

17. The method according to claim 11, wherein the method further comprises providing optimum illumination to the pupil of the eye when ambient light is low using an array of a plurality of linear infrared LEDs coupled to the unobtrusive frame of the goggle module.

18. The method according to claim 11, wherein the method further comprises cutting-off direct light and reflections from surroundings when the ambient light is high using an infra-red band pass filter coupled to the unobtrusive frame of the goggle module.

19. The method according to claim 11, wherein the method further comprises enabling accurate tracking of the pupil movement even when the patient is wearing prescription glasses.

100

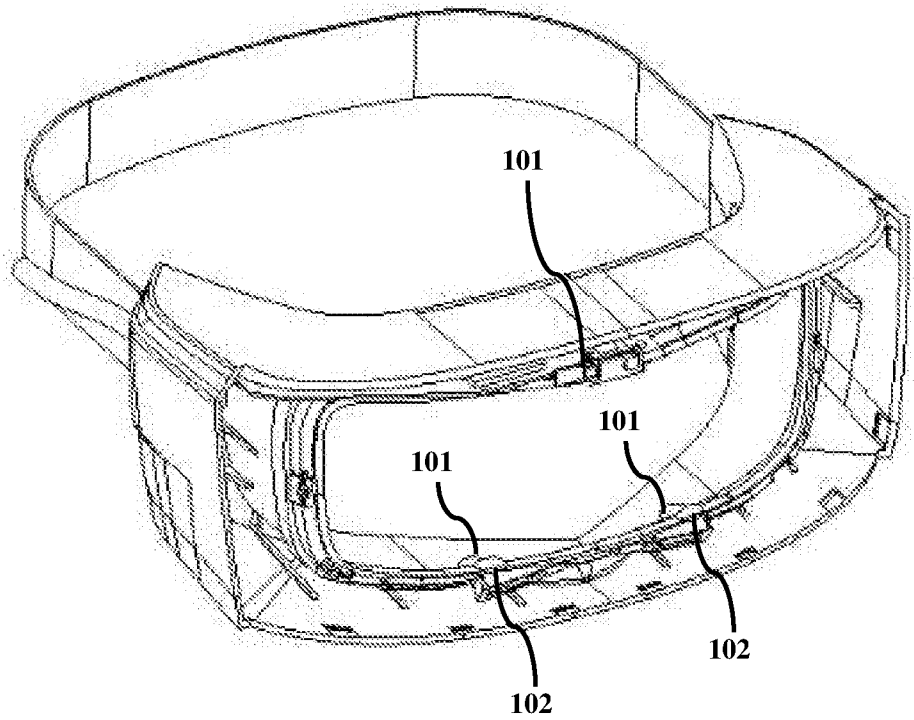


FIG. 1

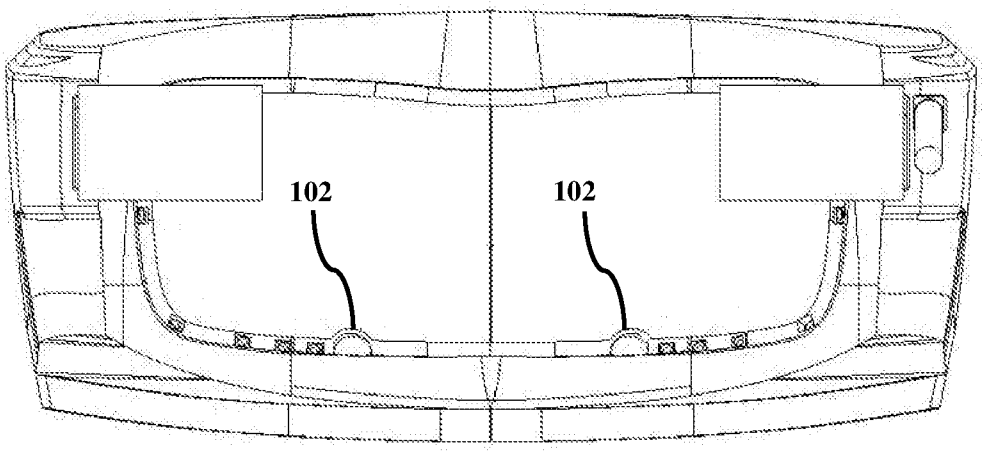


FIG. 2

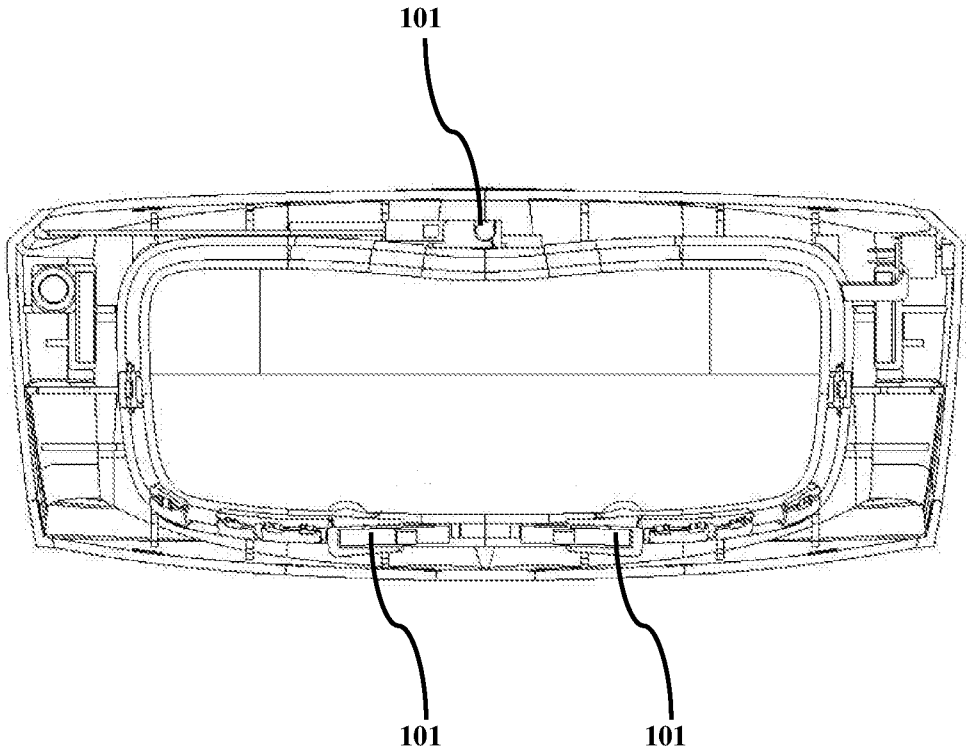


FIG. 3

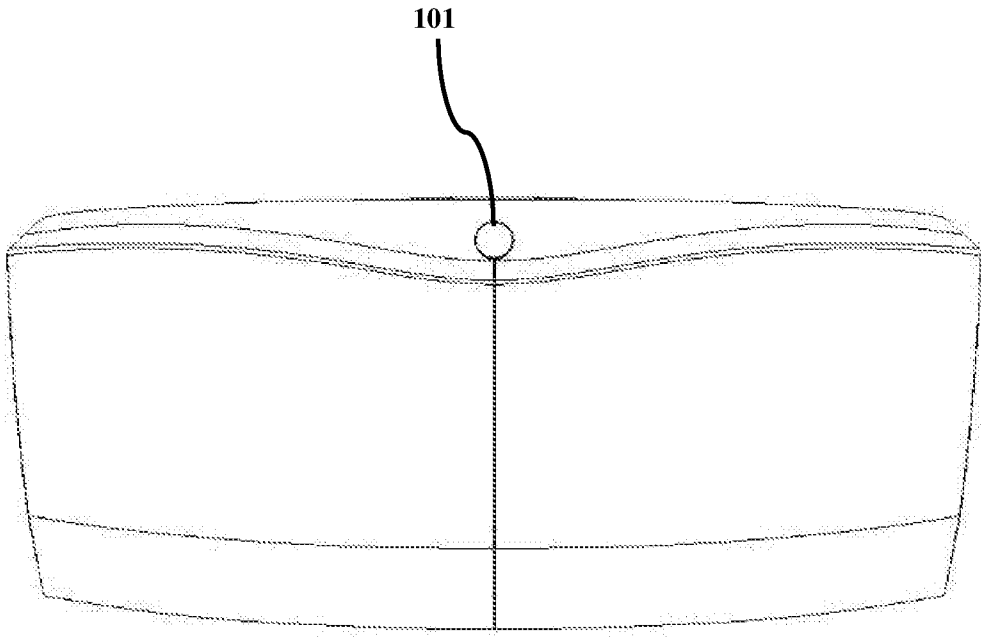


FIG. 4

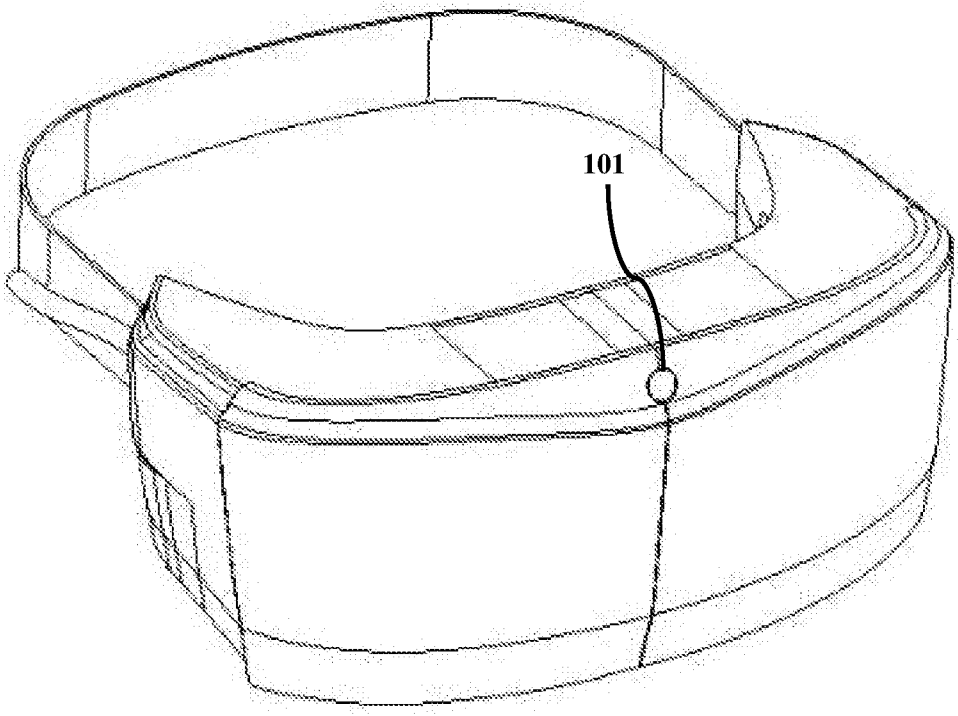


FIG. 5

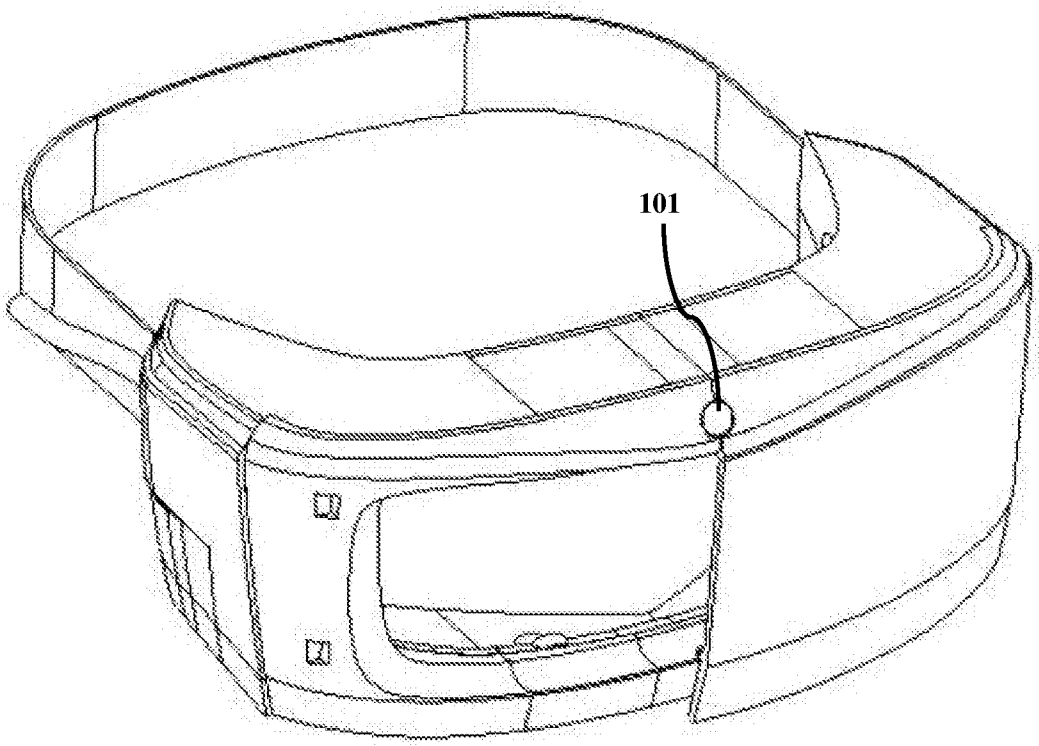


FIG. 6

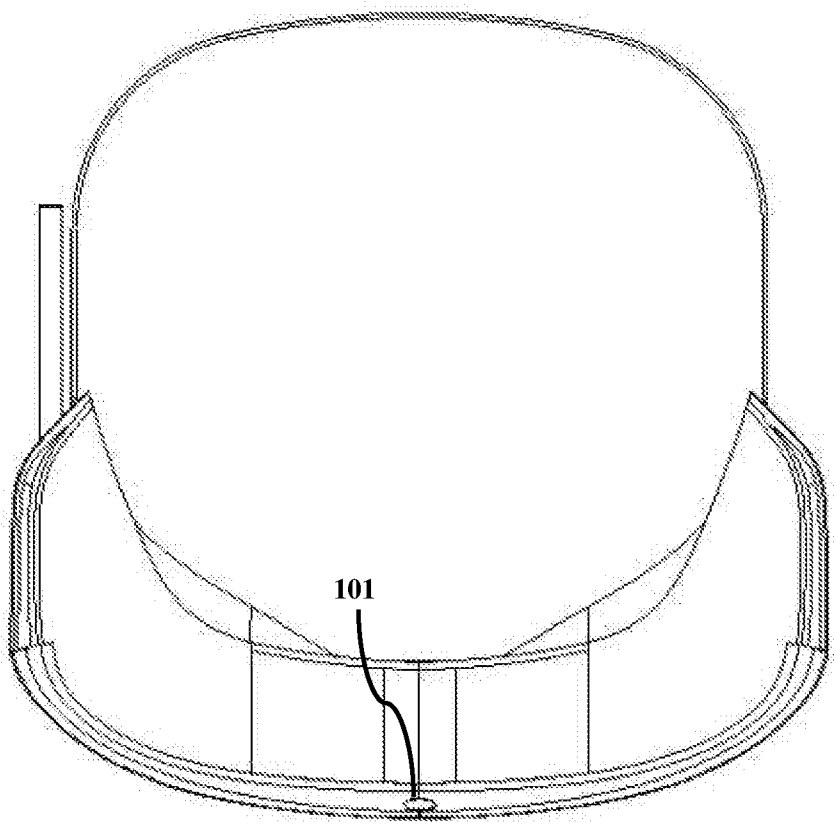


FIG. 7

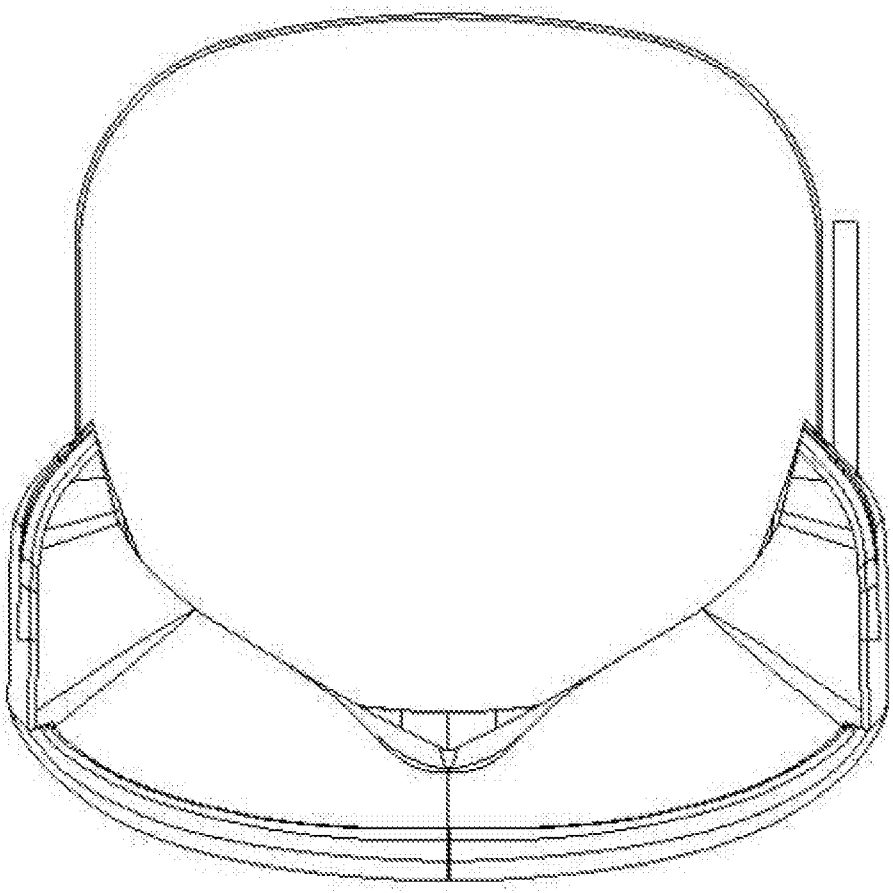


FIG. 8

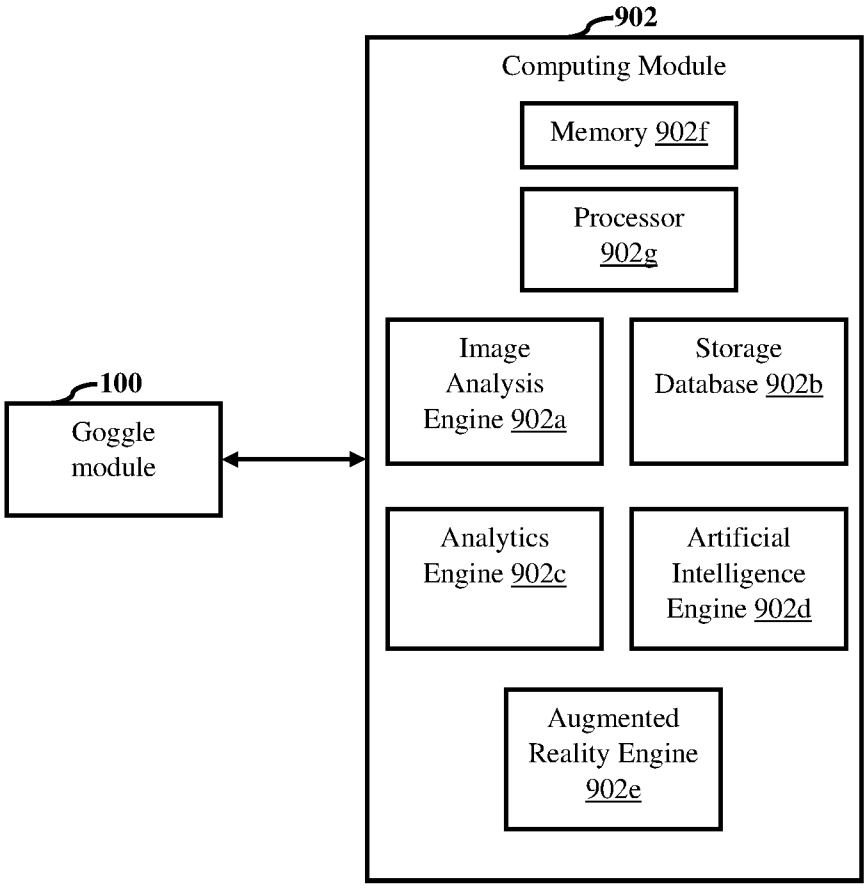

902
Computing Module
Memory 902f
Processor 902g
Image Analysis Engine 902a
Storage Database 902b
Analytics Engine 902c
Artificial Intelligence Engine 902d
Augmented Reality Engine 902e
100
Goggle module

FIG. 9

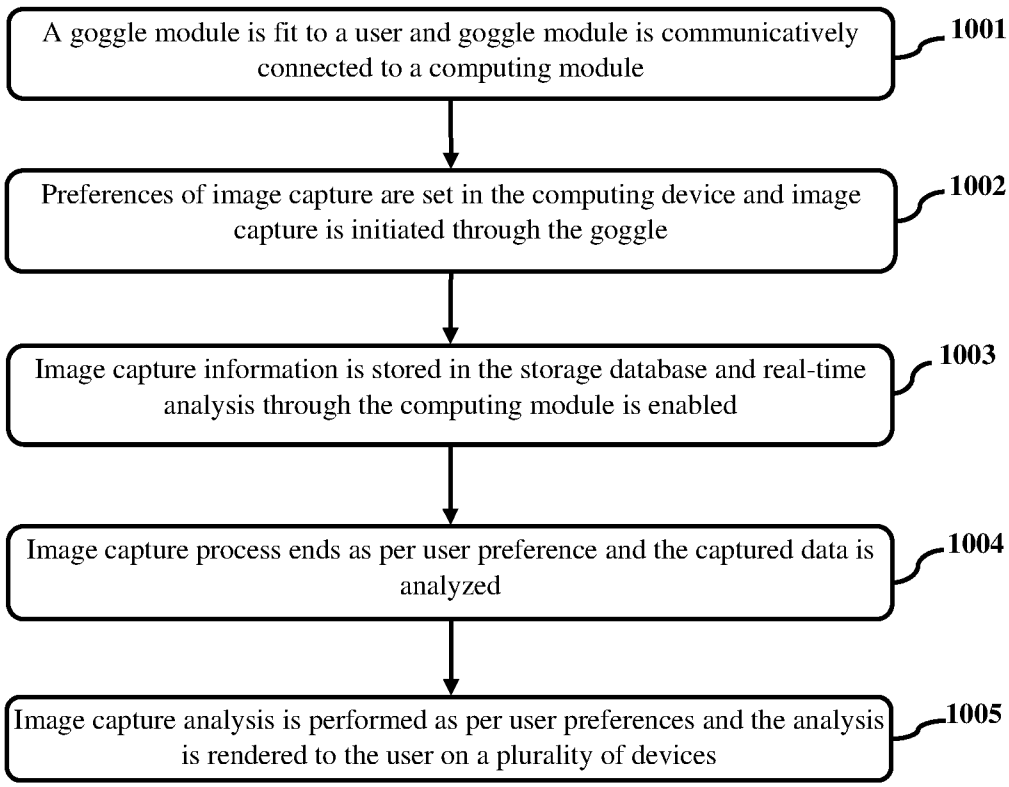

A goggle module is fit to a user and goggle module is communicatively connected to a computing module
1001
Preferences of image capture are set in the computing device and image capture is initiated through the goggle
1002
Image capture information is stored in the storage database and real-time analysis through the computing module is enabled
1003
Image capture process ends as per user preference and the captured data is analyzed
1004
Image capture analysis is performed as per user preferences and the analysis is rendered to the user on a plurality of devices
1005

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN2018/050052

A. CLASSIFICATION OF SUBJECT MATTER
A61B3/113,G06F3/01 Version=2018.01

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)

A61B, G06F

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)

TotalPatent One, IPO Internal Database
Keywords: Imaging, balance assessment, goggle, camera, computation

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 20160007849 A1 (IARMOURHOLDINGS INC.), 14 January 2016 (14.01.2016) Description, Claims 2-3	1, 3-4, 6-13, 15-17 & 19
Y	Description	2, 5, 14 & 18
Y	US 20160132726 A1 (UMOOVE SERVICES Ltd), 12 May 2016 (12.05.2016) Description	2, 5, 14 & 18

☐ 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
27-04-2018	27-04-2018
Name and mailing address of the ISA/ Indian Patent Office Plot No.32, Sector 14,Dwarka,New Delhi-110075 Facsimile No.	Authorized officer Pritish Ranjan Pal Telephone No. +91-1125300200