(54) **METHOD, COMPUTER PROGRAM PRODUCT, CONTROL UNIT AND HEAD-MOUNTED DISPLAY FOR CONSERVING ENERGY IN AN EYE TRACKING SYSTEM**

VERFAHREN, COMPUTERPROGRAMMPRODUKT, STEUEREINHEIT UND AM KOPF MONTIERTE ANZEIGE ZUR ENERGIEEINSPARUNG IN EINEM AUGENVERFOLGUNGSSYSTEM

PROCÉDÉ, PRODUIT PROGRAMME INFORMATIQUE, UNITÉ DE COMMANDE ET VISIOCASQUE PERMETTANT D'ÉCONOMISER L'ÉNERGIE DANS UN SYSTÈME DE SUIVI DES YEUX

Description

TECHNICAL FIELD

[0001] The invention relates generally to power-efficient eye tracking. In particular, the present invention concerns a method for conserving energy in an eye tracking system that has at least two cameras configured to register eye images of at least one eye of a subject, a control unit configured to implement such a method, and a head-mounted display including the control unit. The invention also relates to a computer program product and a non-volatile data carrier.

BACKGROUND

[0002] To attain high quality and certainty, today's eye trackers usually employ more than one camera to record images of a subject's eyes. Further, each eye is typically illuminated by a plurality of light sources. Of course, this requires a comparatively large amount of energy. Especially in portable devices it is therefore important that the energy resources are not wasted.

[0003] US 2015/0199003 describes a solution for eye gaze detection based upon multiple cameras and/or light sources. The cameras and/or light sources are configured to provide eye gaze detection for a device display at different orientations, at different tilt angles, at different user positions, at different user distances, and so on. The document also shows a controller that selectively controls light source power and camera on/off state to provide images of the eye having sufficient quality for eye gaze detection and/or to conserve power.

[0004] US 2021/0173479 describes a method for detecting an eye event of a user using an eye tracking system, the method comprising capturing a first image of a first eye of a user, capturing an image of a second eye of the user a first period after capturing the first image of the first eye and a second period before capturing a next image of the first eye, capturing a second image of the first eye the second period after capturing the image of the second eye, determining that an eye event has occurred based on a difference between the first and second images of the first eye, and performing at least one action if it is determined that that an eye event has occurred.

[0005] US 2015/0092163 describes an eye tracker comprising at least one illuminator for illuminating an eye, at least two cameras for imaging the eye and a controller is disclosed. The configuration of the reference illuminator(s) and cameras is such that, at least one camera is coaxial with a reference illuminator and at least one camera is non-coaxial with a reference illuminator. On the one hand, the controller is adapted to select one of the cameras to be active with the aim of maximising an image quality metric and avoiding obscuring objects.

[0006] Thus, a solution is known, where cameras and light sources are controlled in such a manner that the eye tracker's overall energy consumption is rendered relatively low. However, there is room for improvements of the efficiency.

SUMMARY

[0007] It is therefore an object of the present invention to offer an improved solution for controlling an eye tracking system in an energy-efficient manner.

[0008] According to one aspect of the invention, this object is achieved by a method for conserving energy in an eye tracking system containing at least two cameras configured to register eye images of at least one eye of a subject. The method is performed in at least one processor and involves obtaining eye images from at least one camera in a subset of the at least two cameras. A first pupil parameter is determined based on a first eye image of the eye images, and a second pupil parameter is determined based on a second eye image of the eye images. The first and second pupil parameters are compared to one another to obtain a test parameter. The test parameter is checked against at least one operation criterion; and in response thereto, a respective operation state is assigned to at least one camera in the subset of the at least two cameras. The operation state involves operating the camera at a high frame rate, if the test parameter indicates that the eye image from the camera fulfills a first operation criterion;

operating the camera at a reduced frame rate being lower than the high frame rate, if the test parameter indicates that the eye image from the camera fulfills a second operation criterion, however not the first operation criterion;

the camera being in a standby mode, if the test parameter indicates that the eye image from the camera fulfills a third operation criterion, however neither the first nor the second operation criterion; or

the camera being powered off, if the test parameter indicates that the eye image from the camera does not fulfil any of the first, second or third operation criteria.

[0009] This method is advantageous because it allows using only the best suited camara(s) at each point in time. Moreover, the cameras may be controlled to exclusively operate at the particular power level needed to attain a specified quality of the eye tracking. Thus, an adequate operation state may be assigned dynamically depending on which image data quality is provided by a particular camera at a particular point in time.

[0010] According to one embodiment of this aspect of the invention, the subset of cameras contains a first camera, and the method involves: obtaining the first eye image captured by the first camera during a first time period; and obtaining the second eye image captured by

the first camera during a second time period after the first time period. The test parameter includes a measure expressing a difference between the first and second eye images. Thus, it is straightforward to determine whether a quality of the image data registered by the first camera increases, decreases or remains essentially stable.

[0011] According to another embodiment of this aspect of the invention, the subset of cameras contains first and second cameras, and the method involves: obtaining the first eye image captured by the first camera during a first time period; and obtaining the second eye image captured by the second camera during the first time period. Here, the test parameter includes a measure expressing a difference between the first and second eye images. Thereby, it is straightforward to determine which camera that produces the best image data, or if both cameras provide essentially the same quality.

[0012] Preferably, the first and second cameras are configured to register the eye images of the same eye, however from different angles. Consequently, at least one of the cameras may produce high image data quality irrespective of the direction in which the subject aims his/her gaze.

[0013] According to yet another embodiment of this aspect of the invention, each of the first and second pupil parameters expresses a respective characteristics of the subject's pupil in terms of a pupil size and/or a pupil position. Namely, these are key characteristics to accomplish reliable eye tracking.

[0014] According to still another embodiment of this aspect of the invention, the pupil size is interpreted to designate a distance from a reference point in the first or second eye image, at which reference point a main optic axis of the camera and a normal of the pupil are parallel to one another, an indication of the pupil being partially occluded, or both. Thus, the pupil size, as such, is an important factor when establishing the image data quality.

[0015] According to still another embodiment of this aspect of the invention, the first and second pupil parameters specify a respective number of glints detected in the first and second eye images respectively. The method further involves assigning the operation state to the at least one camera in the subset of the at least two cameras based on a number of glints detected in the first and second eye images respectively. Namely, in general, detecting more glints is better than detecting fewer glints, especially in the cornea. However, a shape of a pattern formed by the glints, and/ or the shapes of the glints themselves may also be used as quality indicators.

[0016] According to a further embodiment of this aspect of the invention, the eye tracking system includes at least two light sources each of which is configured to project light towards the at least one eye of the subject such that corneal reflection data is generated in the eye images when the projected light is reflected by the eye. Here, the method involves selectively controlling the at least two light sources to be on or off based on the checking of the test parameter relative to the at least one operation criterion. As a result, exclusively those light sources may be activated that cause glints in an eye, which is currently being imaged. Naturally, this is beneficial from an energy-saving point-of-view.

[0017] According to another aspect of the invention, the object is achieved by a computer program product loadable into a non-volatile data carrier communicatively connected to at least one processor in an eye tracking system comprising at least two cameras configured to register eye images of at least one eye of a subject.

[0018] The computer program product contains software configured to, when the computer program product is run on the at least one processor, cause the at least one processor to: obtain eye images from at least one camera in a subset of the at least two cameras; determine a first pupil parameter based on a first eye image of the eye images; determine a second pupil parameter based on a second eye image of said eye images; compare the first and second pupil parameters to one another to obtain a test parameter; check the test parameter against at least one operation criterion; and in response thereto assign a respective operation state to at least one camera in the subset of the at least two cameras, which operation state involves: operating the camera at a high frame rate if the test parameter (PT) indicates that the eye image from the camera fulfills a first operation criterion,

operating the camera at a reduced frame rate being lower than the high frame rate, if the test parameter (PT) indicates that the eye image from the camera fulfills a second operation criterion, however not the first operation criterion;

the camera being in a standby mode, if the test parameter (PT) indicates that the eye image from the camera fulfills a third operation criterion, however neither the first nor the second operation criterion; or

the camera being powered off if the test parameter (PT) indicates that the eye image from the camera does not fulfil any of the first, second or third operation criteria.

[0019] The advantages of this computer program product and non-volatile data carrier are apparent from the discussion above with reference to the proposed method.

[0020] According to yet another aspect of the invention, the above object is achieved by a control unit for conserving energy in an eye tracking system containing at least two cameras configured to register eye images of at least one eye of a subject. The control unit contains input and output interfaces and a processor. The input interface is configured to obtain eye images from at least one camera in a subset of the at least two cameras. The processor is configured to determine a first pupil parameter based on the first eye image of the eye images; and

determine a second pupil parameter based on the second eye image of the eye images. The processor is further configured to compare the first and second pupil parameters to one another to obtain a test parameter; and check the test parameter against at least one operation criterion. In response to the check, the processor is configured to assign a respective operation state to at least one camera in the subset of the at least two cameras, and forward the respective assigned operation state via the output interface to said at least one camera. The operation state involves operating the camera at a high frame rate, if the test parameter (PT) indicates that the eye image from the camera fulfills a first operation criterion;

operating the camera at a reduced frame rate being lower than the high frame rate, if the test parameter (PT) indicates that the eye image from the camera fulfills a second operation criterion, however not the first operation criterion;

the camera being in a standby mode, if the test parameter (PT) indicates that the eye image from the camera fulfills a third operation criterion, however neither the first nor the second operation criterion; or

the camera being powered off if the test parameter (PT) indicates that the eye image from the camera does not fulfil any of the first, second or third operation criteria.

[0021] The advantages of this control unit are apparent from the discussion above with reference to the proposed method.

[0022] Further advantages, beneficial features and applications of the present invention will be apparent from the following description and the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The invention is now to be explained more closely by means of preferred embodiments, which are disclosed as examples, and with reference to the attached drawings.

Figure 1   shows an arrangement of cameras and light sources that are controllable according to one embodiment of the invention;

Figure 2   shows a block diagram of a control unit according to one embodiment of the invention;

Figures 3a, 3b   show examples of eye images of a subject according to one embodiment of the invention; and

Figure 4   illustrates, by means of a flow diagram, the general method according to the invention.

DETAILED DESCRIPTION

[0024] Figure 1 shows an arrangement of cameras and light sources that are controllable according to one embodiment of the invention. Specifically, Figure 1 exemplifies an arrangement suited to be included in a wearable design, for instance a head-mounted display (HMD) adapted for a virtual reality (VR), an augmented reality (AR) and/or a mixed reality (MR) application.

[0025] In Figure 1, we see the arrangement from a back side in relation to a subject's eyes. Here, a right eyepiece EPR is equipped with a first display DA and a left eyepiece EPL has a second display DB.

[0026] The right eyepiece EPR also contains first and second cameras CA1 and CA2 respectively, which are configured to register eye images of the subject's right eye, and a first set of light sources LA1, LA2, LA3, LA4, LA5, LA6, LA7, LA8, LA9 and LA10 configured to project light towards the subject's right eye such that corneal reflection data is generated in eye images registered by the first and second cameras CA1 and CA2 when the projected light is reflected by the right eye. Analogously, the left eyepiece EPR contains third and fourth cameras CB1 and CB2 respectively, which are configured to register eye images of the subject's left eye, and a second set of light sources LB1, LB2, LB3, LB4, LB5, LB6, LB7, LB8, LB9 and LB10 configured to project light towards the subject's left eye such that corneal reflection data is generated in eye images registered by the third and fourth cameras CA1 and CA2 when the projected light is reflected by the left eye.

[0027] Preferably, as is apparent in Figure 1, the first and second cameras CA1 and CA2 are configured to register the eye images of the right eye, however from different angles; and analogously, the third and fourth cameras CB1 and CB2 are configured to register the eye images of the left eye, however from different angles.

[0028] Figure 2 shows a block diagram of a control unit 200 according to one embodiment of the invention. The control unit 200 is arranged to conserve energy in an eye tracking system including at least two cameras, such as the above-mentioned cameras CA1, CA2, CB1 and CB2, which are configured to register eye images of at least one eye of a subject.

[0029] The control unit 200 contains a processor 220, input and output interfaces 205 and 210 respectively, and a memory unit 230. The input interface 205 is configured to obtain eye images from at least one camera in a subset of the at least two cameras. For example, as illustrated by the examples of eye images in Figures 3a and 3b, the input interface 205 may obtain a first eye image $D_{A1}(T1)$ of a subject's eye, which first eye image $D_{A1}(T1)$ has been captured by the first camera CA1 during a first time period T1, and a second eye image $D_{A2}(T1)$ of the sub-

ject's eye, which second eye image $D_{A2}(T1)$ has been captured by the second camera CA2 during the first time period T1.

[0030] The input interface 205 may obtain a first eye image $D_{A1}(T1)$ of a subject's right eye, which first eye image $D_{A1}(T1)$ has been captured by a first camera CA1 during the first time period T1, and the second eye image $D_{A2}(T1)$ depicts the subject's right eye, which second eye image $D_{A2}(T1)$ has been captured by a second camera CA2 during the first time period T1.

[0031] Alternatively, the input interface 205 may obtain the first eye image $D_{B1}(T1)$ of the subject's left eye, which first eye image $D_{B1}(T1)$ has been captured by a third camera CB1 during the first time period T1, and the second eye image $D_{B2}(T1)$ depicts the subject's left eye, which second eye image $D_{B2}(T1)$ has been captured by a fourth camera CB2 during the first time period T1.

[0032] The processor 220 is configured to determine a first pupil parameter PP_1 based on the first eye image $D_{A1}(T1)$ or $D_{B1}(T1)$, and determine a second pupil parameter PP_2 based on the second eye image $D_{A1}(T2)$ or $D_{B2}(T1)$. The processor 220 is further configured to compare the first and second pupil parameters PP_1 and PP_2 to one another to obtain a test parameter PT. According to one embodiment of the invention, the test parameter PT contains a measure expressing a difference between the first and second eye images $D_{A1}(T1)$ (or $D_{B1}(T1)$) and $D_{A1}(T2)$ (or $D_{B2}(T2)$) respectively.

[0033] Moreover, the processor 220 is configured to check the test parameter PT against at least one operation criterion. For example, if the eye tracking system is performing pupil tracking, the first and second pupil parameters PP_1 and PP_2 may describe respective pupil sizes, respective pupil motions and/or respective directions in which the pupil moves. In this disclosure, the term "pupil size" is understood to designate a total area covered by the pupil in an eye image, e.g. $D_{A1}(T1)$, or $D_{B1}(T1)$, $D_{A1}(T2)$ or $D_{B2}(T2)$. Hence, for example, the "pupil size" is *not* equivalent to a pupil diameter, or a pupil radius.

[0034] The at least one operation criterion may here be as follows. As long as the subject's eye pupil is fully visible in a field of view of the first camera CA1, the second camera CA2 shall be powered off, or at least be placed in a standby mode.

[0035] However, if the processor 220 determines, for example based on a visibility and movement direction of the subject's eye pupil, that the pupil moves toward a field of view of the second camera CA2, the processor 220 assigns such operation states to the first and second cameras CA1 and CA2 that the first camera CA1 is powered off, or at least be placed in the standby mode, and the second camera CA2 is activated. Preferably, during a transition-phase, when the pupil might be fully visible in both the first and second cameras CA1 and CA2, both cameras are active and produce gaze signals, and/or other eye-tracking related signals.

[0036] Generally, according to the invention, the processor 220 is configured to compare the first and second pupil parameters PP_1 and PP_2 to one another to obtain a test parameter, and check the test parameter against an operation criterion. In response thereto, in turn, the control unit 220 is configured to assign a respective operation state to at least one camera in a subset of at least two cameras of the eye tracking system. The respective operation state OP_1, OP_2, OP_3 or OP_4 may involve: operating the camera at a high frame rate, operating the camera at a reduced frame rate being lower than the high frame rate, the camera being in a standby mode, or the camera being powered off.

[0037] The output interface 210 is configured to forward the respective assigned operation state to each camera whose operation state is to be altered, i.e. CA1, CA2, CB1 and/or CB2.

[0038] According to one embodiment of the invention as illustrated by the examples of eye images in Figures 3a and 3b, the control unit 220 obtains a first eye image $D_{A1}(T1)$, for example of the subject's right eye, captured by the first camera CA1 during a first time period T1; and obtains a second eye image $D_{A1}(T2)$ captured by the first camera CA1 during a second time period T2 after the first time period T1. Here, the test parameter PT contains a measure expressing a difference between the first and second eye images $D_{A1}(T1)$ and $D_{A1}(T2)$. For example, the difference may relate to a difference in pupil information between the two images, such as a difference in pupil shape, e.g. the pupil P_1 being more circular in the first eye image $D_{A1}(T1)$ and the pupil P_2 being more oval in the second eye image $D_{A1}(T2)$, and/or the pupil P_1 being at a first position relatively close to being in line with a main optic axis of the first camera CA1 in the first eye image $D_{A1}(T1)$ and the pupil P_2 being at a second position further off from the main optic axis of the first camera CA1 in the second eye image $D_{A1}(T2)$.

[0039] Alternatively, the first eye image $D_{B1}(T1)$ may depict the subject's left eye and be captured by the third camera CB1 during the first time period T1; and the second eye image $D_{B1}(T2)$ may depict the subject's left eye and be captured by the third camera CB1 during the second time period T2 after the first time period T1.

[0040] This means that the first and second pupil parameters PP_1 and PP_2 may express a respective characteristics of the subject's pupil in terms of a pupil size and/or a pupil position in the eye image. Here, the test criterion is such that a larger pupil P_1 is favored over a smaller pupil P_2 because the former is interpreted to have been registered by a camera having a more favorable angular relationship to the normal of the pupil P_1.

[0041] The control unit 220 may be configured to interpret the pupil size to designate a distance from a reference point in the eye image where a main optic axis of the camera and a normal of the pupil are parallel to one another. Here, a smaller pupil P_2 is deemed to be more remote from the reference point than a larger pupil P_1. Of course, the pupil's size in a recorded image may also be reduced because the pupil is partially occluded, for example because it is covered by an eyelid, and/or because

the eye's angle toward the camera is very large. The control unit 220 is preferably also configured to interpret a smaller pupil size as a pupil being partially occluded. In any case, the test criterion is such that a closer/less occluded pupil is favored over a more distant/occluded ditto.

[0042] According to one embodiment of the invention, the control unit 220 is specifically configured to determine the pupil position based on a shape of the pupil P_1, P_2. Namely, the smaller the angle is between a main optic axis of the camera and the normal of the pupil, the more circular the pupil will be imaged, and vice versa. Here, the test criterion is such that a more circular pupil P_1 is favored over a less circular ditto.

[0043] Namely, an eye looking more away from the camera is depicted with a pupil shape being more oval, or "thinner", than what an eye looking less away from the camera is depicted. Thus, the overall pupil size will be smaller in the former case than in the latter. Ideally, a subject who is looking straight into the camera will show a maximum pupil size, i.e. that of a pupil P_1 being depicted with a roughly circular shape.

[0044] Typically, in an HMD implementation, the pupil shape at large angles affect the pupil size much more than the actual change in distance between the camera and the pupil.

[0045] It is typically advantageous to first determine the pupil position in the image, and then determine the pupil size and/or shape as a basis for assigning an operation state to a particular camera, such as turning it on or off. In general, it is more difficult to accurately determine gaze data if the angle between the camera's main optic axis and the normal of the pupil P_2 is large. Therefore, a camera having a small angle between the camera's main optic axis and the normal of the pupil P_1 will be favored over a camera having a larger angle between the camera's main optic axis and the normal of the pupil P_2. In other words if the angular difference between an active camera's main optic axis and the normal of the pupil P_2 becomes too large, the strategy is to turn off/reduce the contribution from this camera, and instead turn on/increase the contribution from one or more other cameras depicting the same eye.

[0046] Above, the "pupil position" refers to a two-dimensional coordinate in the respective eye image. Moreover, the distance difference of interest is the distance difference between the pupil positions in the eye images, for example represented by the above-mentioned distance to the reference point in the eye image, where a main optic axis of the camera and a normal of the pupil are parallel to one another.

[0047] However, the distance difference between the pupil to the camera is less interesting. Preferably, namely, the cameras form part of an HMD, which basically remains static relative to the subject's eyes during operation, and therefore also the distances to the cameras are static in relation to the eye. Consequently, in such an HMD environment, each camera may determine an approximate location where the subject is looking only by identifying the pupil position in an eye image.

[0048] For example, the pupil position of the eye in the first eye image $D_{A1}(T1)$ or $D_{B1}(T1)$ may be compared to the pupil position in the second eye image $D_{A1}(T2)$, $D_{A2}(T1)$, $D_{B1}(T2)$ or $D_{B2}(T1)$, captured by the same camera during the second time period T2, or by another camera during the same time period T1.

[0049] Alternatively, the pupil position in the first eye image $D_{A1}(T1)$ or $D_{B1}(T1)$ may be compared to a previously known pupil position, e.g. a reference image when the subject is looking straight into the camera in question CA1 or CB1 respectively.

[0050] As yet an alternative, the pupil position in the first image $D_{A1}(T1)$ or $D_{B1}(T1)$ may be compared to a previously known pupil position of when the subject is looking in another well-defined direction, for instance straight ahead.

[0051] If more than two operation states are employed, it may be advantageous to assign an operation state to a particular camera according to a hierarchical principle in relation to different operation criteria. For example, this may involve operating the camera at the high frame rate, if the test parameter PT indicates that the eye image from the camera fulfills a first operation criterion. If the test parameter PT indicates that the eye image from the camera fulfills a second operation criterion, however not the first operation criterion, the camera may be operated at the reduced frame rate, i.e. below the high frame rate. Further, if the test parameter PT indicates that the eye image from the camera fulfills a third operation criterion, however neither the first nor the second operation criterion, the camera may be placed in the standby mode. Finally, if the test parameter PT indicates that the eye image from the camera does not fulfil any of the first, second or third operation criteria, the camera may be powered off.

[0052] Figures 3a and 3b also illustrate examples of how glints may occur in an eye of a subject according to one embodiment of the invention, for instance as depicted by the first and second cameras CA1 and CA2 respectively.

[0053] In Figure 3a, nine glints are visible in the form of G11, G12, G13, G14, G15, G16, G17, G18 and G19, and in Figure 3b eight glints are visible in the form of G21, G22, G23, G24, G25, G26, G27 and G28. According to one embodiment of the invention, the first and second pupil parameters PP_1 and PP_2 specify the respective number of glints, i.e. here nine and eight respectively, the control unit 220 is configured to assign the operation state, e.g. OP_1, OP_2, OP_3 or OP_4 to the at least one camera in the subset of the at least two cameras, here CA1 or CA2, based on the number of glints detected in the first and second eye images respectively. Here, the test criterion is such that a larger number of detected glints is favored over a smaller ditto. Thus, the first camera CA1 is favored over the second camera CA2.

[0054] According to embodiments of the invention, the

operation state may also be assigned at higher precision and/or on alternative bases. For example, the first and second pupil parameters PP_1 and PP_2 may specifically express a respective number of detected glints in the cornea CR because corneal glints are more useful than for example glints in the sclera. Therefore, the test criterion may here be such that a larger number of corneal glints is favored over a smaller ditto. Again, in the example illustrated in Figures 3a and 3b, this means that the first camera CA1 is favored over the second camera CA2. Thus, a higher number of glints on or in the vicinity of the pupil P_1, P_2 is preferred.

[0055] Alternatively, or additionally, a shape of a pattern formed by the glints, and/or the shapes of the glints themselves may be used as quality indicators. Here, the test criterion may be such that a high similarity between the pattern formed by the glints and the pattern formed by the light sources is favored over a low similarity. Analogously, less distorted the glints relative to the shape of the light sources, are favored over more distorted ditto.

[0056] Returning again to Figure 2, according to one embodiment of the invention, the control unit 200 is configured to selectively control at least one light source in the first set of light sources LA1, LA2, LA3, LA4, LA5, LA6, LA7, LA8, LA9 and LA10; and at least one light source in the second set of light sources LB1, LB2, LB3, LB4, LB5, LAB, LB7, LB8, LB9 and LB10 to be on or off based on the checking of the test parameter PT against the at least one operation criterion. Namely, this may save large amounts of energy, especially since the cameras registering eye images of the eye being illuminated by the light sources in question may be temporarily switched off as described above. For instance, if the light sources are near-IR LED:s, each light source may consume 8mW. Consequently, by powering off a complete set of light sources, in total 8mW x 10 = 80mW can be saved.

[0057] If the eye tracking system is performing gaze tracking and/or tracks eye movements, it is advantageous to track a gaze ray direction, and based thereon, dynamically control a power state of all the light sources per eye, i.e. the first set of light sources LA1, LA2, LA3, LA4, LA5, LA6, LA7, LA8, LA9 and LA10; and the second set of light sources LB1, LB2, LB3, LB4, LB5, LB6, LB7, LB8, LB9 and LB10 respectively.

[0058] Furthermore, knowledge of an eye movement state such as whether the eye is in fixation/saccade state and information about which camera that currently has the eye in its field of view, may be used to control the power state of the light sources in the first and second sets.

[0059] It is generally advantageous if the control unit 200 shown in Figure 2 is configured to effect the above-described procedure in an automatic manner by executing a computer program 235. Therefore, the control unit 200 may include a memory unit 230, i.e. non-volatile data carrier, storing the computer program 235, which, in turn, contains software for a processor 220 in the control unit

200 execute the actions mentioned in this disclosure when the computer program 235 is run on the processor 220.

[0060] In order to sum up, and with reference to the flow diagram in Figure 4, we will now describe the general method according to the invention for conserving energy in an eye tracking system that includes at least two cameras being configured to register eye images of at least one eye.

[0061] In a first step 410, eye images are obtained from at least one camera in a subset of the at least two cameras of the eye tracking system.

[0062] In subsequent steps 420 and 430, first and second pupil parameters PP_1 and PP_2 are determined based on first and second eye images respectively.

[0063] Thereafter, in a step 440, the first and second pupil parameters are compared to one another to obtain a test parameter; and in a following step 450, the test parameter is checked against at least one operation criterion.

[0064] In response to this checking, a step 460 assigns a respective operation state to the at least one camera in the subset of said at least two cameras. The operation state may involve: operating the camera at a high frame rate, operating the camera at a reduced frame rate being lower than the high frame rate, the camera being in a standby mode, or the camera being powered off. Naturally, the assigning of the respective operation state may involve turning a camera on to operate at the high frame rate or the reduced frame rate if the camera in question is turned off when entering step 460.

[0065] Subsequently the procedure loops back to step 410.

[0066] All of the process steps, as well as any subsequence of steps, described with reference to Figure 4 above may be controlled by means of at least one programmed processor. Moreover, although the embodiments of the invention described above with reference to the drawings comprise processor and processes performed in at least one processor, the invention thus also extends to computer programs, particularly computer programs on or in a carrier, adapted for putting the invention into practice. The program may be in the form of source code, object code, a code intermediate source and object code such as in partially compiled form, or in any other form suitable for use in the implementation of the process according to the invention. The program may either be a part of an operating system, or be a separate application. The carrier may be any entity or device capable of carrying the program. For example, the carrier may comprise a storage medium, such as a Flash memory, a ROM (Read Only Memory), for example a DVD (Digital Video/Versatile Disk), a CD (Compact Disc) or a semiconductor ROM, an EPROM (Erasable Programmable Read-Only Memory), an EEPROM (Electrically Erasable Programmable Read-Only Memory), or a magnetic recording medium, for example a floppy disc or hard disc. Further, the carrier may be a transmissible carrier

such as an electrical or optical signal which may be conveyed via electrical or optical cable or by radio or by other means. When the program is embodied in a signal which may be conveyed directly by a cable or other device or means, the carrier may be constituted by such cable or device or means. Alternatively, the carrier may be an integrated circuit in which the program is embedded, the integrated circuit being adapted for performing, or for use in the performance of, the relevant processes.

[0067] Variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims.

[0068] The term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components. The term does not preclude the presence or addition of one or more additional elements, features, integers, steps or components or groups thereof. The indefinite article "a" or "an" does not exclude a plurality. In the claims, the word "or" is not to be interpreted as an exclusive or (sometimes referred to as "XOR"). On the contrary, expressions such as "A or B" covers all the cases "A and not B", "B and not A" and "A and B", unless otherwise indicated. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

[0069] It is also to be noted that features from the various embodiments described herein may freely be combined, unless it is explicitly stated that such a combination would be unsuitable.

[0070] The invention is not restricted to the described embodiments in the figures but may be varied freely within the scope of the claims.

Claims

1. A method for conserving energy in an eye tracking system comprising at least two cameras (CA1, CA2, CB1, CB2) configured to register eye images of at least one eye of a subject, which method is performed in at least one processor (220) and comprises:

   obtaining eye images from at least one camera in a subset of the at least two cameras (CA1, CA2, CB1, CB2);
   determining a first pupil parameter (PP_1) based on a first eye image ($D_{A1}(T1)$, $D_{B1}(T1)$) of said eye images;
   determining a second pupil parameter (PP_2) based on a second eye image ($D_{A1}(T2)$, $D_{A2}(T1)$, $D_{B1}(T2)$, $D_{B2}(T1)$) of said eye images;
   comparing the first and second pupil parameters

   (PP_1, PP_2) to one another to obtain a test parameter (PT);
   checking the test parameter (PT) against at least one operation criterion; and in response thereto assigning a respective operation state (OP_1, OP_2, OP_3, OP_4) to at least one camera in the subset of the at least two cameras (CA1, CA2, CB1, CB2), **characterized in that** the respective operation state involves one of:

   operating the camera at a high frame rate, if the test parameter (PT) indicates that the eye image from the camera fulfills a first operation criterion;
   operating the camera at a reduced frame rate being lower than the high frame rate, if the test parameter (PT) indicates that the eye image from the camera fulfills a second operation criterion, however not the first operation criterion;
   the camera being in a standby mode, if the test parameter (PT) indicates that the eye image from the camera fulfills a third operation criterion, however neither the first nor the second operation criterion; and
   the camera being powered off, if the test parameter (PT) indicates that the eye image from the camera does not fulfil any of the first, second or third operation criteria.

2. The method according to claim 1, wherein the subset contains a first camera (CA1), and the method comprises:

   obtaining the first eye image ($D_{A1}(T1)$) captured by the first camera (CA1) during a first time period; and
   obtaining the second eye image ($D_{A1}(T2)$) captured by the first camera (CA1) during a second time period after the first time period; and

   wherein the test parameter (PT) comprises a measure expressing a difference between the first and second eye images ($D_{A1}(T1)$), ($D_{A1}(T2)$).

3. The method according to any one of the claims 1 or 2, wherein the subset contains first and second cameras (CA1, CA2), and the method comprises:

   obtaining the first eye image ($D_{A1}(T1)$) captured by the first camera (CA1(T1)) during a first time period; and
   obtaining the second eye image ($D_{A2}(T1)$) captured by the second camera (CA2(T1)) during the first time period; and wherein the test parameter (PT) comprises a measure expressing a difference between the first and second eye images ($D_{A1}(T1)$), ($D_{A2}(T1)$).

4. The method according to claim 3, wherein the first and second cameras (CA1, CA2; CB1, CB2) are configured to register the eye images of the same eye from different angles.

5. The method according to any one of the preceding claims, wherein each of the first and second pupil parameters (PP_1, PP_2) expresses a respective characteristics of the subject's pupil (P_1, P_2) in terms of at least one of: a pupil size and a pupil position.

6. The method according to any one of the preceding claims, comprising:
   assigning the respective operation state (OP_1, OP_2, OP_3, OP_4) to the at least one camera in the subset of the at least two cameras (CA1, CA2, CB1, CB2) based on a shape of the pupil (P_1, P_2).

7. The method according to any one of the claims 5 or 6, comprising interpreting the pupil size to designate at least one of:

   a distance from a reference point in the first or second eye image ($D_{A1}(T1)$, $D_{B1}(T1)$, ($D_{A1}(T2)$, $D_{A2}(T1)$, $D_{B1}(T2)$, $D_{B2}(T1)$)) where a main optic axis of the camera and a normal of the pupil (P_1, P_2) are parallel to one another, and
   an indication of the pupil being partially occluded.

8. The method according to any one of the preceding claims, wherein the first and second pupil parameters (PP_1, PP_2) specify a respective number of glints (G11, G12, G13, G14, G15, G16, G17, G18, G19; G21, G22, G23, G24, G25, G26, G27, G28) detected in the first and second eye images respectively, and the method comprises:
   assigning the operation state (OP_1, OP_2, OP_3, OP_4) for the at least one camera in the subset of the at least two cameras (CA1, CA2, CB1, CB2) based on a number of glints detected in the first and second eye images respectively.

9. The method according to any one of the preceding claims, wherein the eye tracking system further comprises at least two light sources (LA1, LA2, LA3, LA4, LA5, LA6, LA7, LA8, LA9, LA10; LB1, LB2, LB3, LB4, LB5, LAB, LB7, LB8, LB9, LB10) each of which is configured to project light towards the at least one eye of the subject such that corneal reflection data is generated in the eye images when the projected light is reflected by the eye, and the method comprises:
   selectively controlling the at least two light sources (LB1, LA2, LA3, LA4, LA5, LA6, LA7, LA8, LA9, LA10; LB1, LB2, LB3, LB4, LB5, LAB, LB7, LB8, LB9, LB10) to be on or off based on the checking of the test parameter (PT) against the at least one operation criterion.

10. A computer program product (235) loadable into a non-volatile data carrier (230) communicatively connected to at least one processor (220) in an eye tracking system comprising at least two cameras configured to register eye images of at least one eye of a subject, the computer program product (235) comprising software configured to, when the computer program product (235) is run on the at least one processor (220), cause the at least one processor to:

   obtain eye images from at least one camera in a subset of the at least two cameras (CA1, CA2; CB1, CB2);
   determine a first pupil parameter (PP_1) based on a first eye image ($D_{A1}(T1)$, $D_{B1}(T1)$) of said eye images;
   determine a second pupil parameter (PP_2) based on a second eye image ($D_{A1}(T2)$, $D_{A2}(T1)$, $D_{B1}(T2)$, $D_{B2}(T1)$) of said eye images;
   compare the first and second pupil parameters (PP_1, PP_2) to one another to obtain a test parameter (PT);
   checking the test parameter (PT) against at least one operation criterion; and in response thereto assign an operation state (OP_1, OP_2, OP_3, OP_4) for at least one camera in the subset of the at least two cameras (CA1, CA2, CB1, CB2), **characterized in that** the respective operation state involves one of:

   operating the camera at a high frame rate, if the test parameter (PT) indicates that the eye image from the camera fulfills a first operation criterion;
   operating the camera at a reduced frame rate being lower than the high frame rate, if the test parameter (PT) indicates that the eye image from the camera fulfills a second operation criterion, however not the first operation criterion;
   the camera being in a standby mode, if the test parameter (PT) indicates that the eye image from the camera fulfills a third operation criterion, however neither the first nor the second operation criterion; and
   the camera being powered off, if the test parameter (PT) indicates that the eye image from the camera does not fulfil any of the first, second or third operation criteria.

11. A non-volatile data carrier (230) containing the computer program product (235) of claim 10.

12. A control unit (200) for conserving energy in an eye tracking system comprising at least two cameras (CA1, CA2, CB1, CB2) configured to register eye images of at least one eye of a subject, the control

unit (200) comprising:

an input interface (205) configured to obtain eye images from at least one camera in a subset of the at least two cameras;
a processor (220) to:

determine a first pupil parameter (PP_1) based on a first eye image $(D_{A1}(T1), D_{B1}(T1))$ of said eye images;
determine a second pupil parameter (PP_2) based on a second eye image $(D_{A1}(T2), D_{A2}(T1), D_{B1}(T2), D_{B2}(T1))$ of said eye images;
compare the first and second pupil parameters (PP_1, PP_2) to one another to obtain a test parameter (PT);
checking the test parameter (PT) against at least one operation criterion; and in response thereto
assign a respective operation state (OP_1, OP_2, OP_3, OP_4) to at least one camera in the subset of the at least two cameras (CA1, CA2, CB1, CB2), **characterized in that** the respective operation state involves one of:

operating the camera at a high frame rate, if the test parameter (PT) indicates that the eye image from the camera fulfills a first operation criterion;
operating the camera at a reduced frame rate being lower than the high frame rate, if the test parameter (PT) indicates that the eye image from the camera fulfills a second operation criterion, however not the first operation criterion;
the camera being in a standby mode, if the test parameter (PT) indicates that the eye image from the camera fulfills a third operation criterion, however neither the first nor the second operation criterion; and
the camera being powered off, if the test parameter (PT) indicates that the eye image from the camera does not fulfil any of the first, second or third operation criteria; and an output interface (210) configured to forward the respective assigned operation state to the at least one camera.

13. A head-mounted display (HMD) comprising:

at least two cameras (CA1, CA2, CB1, CB2) configured to register eye images of at least one eye of a subject, and
the control unit according to claim 12.

Patentansprüche

1. Verfahren zum Einsparen von Energie in einem Augenverfolgungssystem, umfassend mindestens zwei Kameras (CA1, CA2, CB1, CB2), die konfiguriert sind, um Augenbilder von mindestens einem Auge eines Subjekts zu registrieren, wobei das Verfahren in mindestens einem Prozessor (220) durchgeführt wird und umfasst:

Erhalten von Augenbildern von mindestens einer Kamera in einer Teilmenge der mindestens zwei Kameras (CA1, CA2, CB1, CB2);
Bestimmen eines ersten Pupillenparameters (PP_1) basierend auf einem ersten Augenbild $(D_{A1}(T1), D_{B1}(T1))$ der Augenbilder;
Bestimmen eines zweiten Pupillenparameters (PP_2) basierend auf einem zweiten Augenbild $(D_{A1}(T2), D_{A2}(T1), D_{B1}(T2), D_{B2}(T1))$ der Augenbilder;
Vergleichen des ersten und des zweiten Pupillenparameters (PP_1, PP_2) miteinander, um einen Testparameter (PT) zu erhalten;
Überprüfen des Testparameters (PT) anhand von mindestens einem Betriebskriterium; und als Reaktion darauf
Zuweisen eines entsprechenden Betriebszustands (OP_1, OP_2, OP_3, OP_4) zu mindestens einer Kamera in der Teilmenge der mindestens zwei Kameras (CA1, CA2, CB1, CB2), **dadurch gekennzeichnet, dass** der jeweilige Betriebszustand eines beinhaltet von:

Betreiben der Kamera mit einer hohen Bildfrequenz, falls der Testparameter (PT) anzeigt, dass das Augenbild von der Kamera ein erstes Betriebskriterium erfüllt;
Betreiben der Kamera mit einer reduzierten Bildfrequenz, die niedriger als die hohe Bildfrequenz ist, falls der Testparameter (PT) anzeigt, dass das Augenbild von der Kamera ein zweites Betriebskriterium, jedoch nicht das erste Betriebskriterium, erfüllt;
wobei sich die Kamera in einem Standby-Modus befindet, falls der Testparameter (PT) anzeigt, dass das Augenbild von der Kamera ein drittes Betriebskriterium, jedoch weder das erste noch das zweite Betriebskriterium, erfüllt; und
die Kamera ausgeschaltet wird, falls der Testparameter (PT) anzeigt, dass das Augenbild von der Kamera keines des ersten, des zweiten oder des dritten Betriebskriteriums erfüllt.

2. Verfahren nach Anspruch 1, wobei die Teilmenge eine erste Kamera (CA1) enthält, und das Verfahren

umfasst:

Erhalten des ersten Augenbilds (D_{A1}(T1)), das durch die erste Kamera (CA1) während eines ersten Zeitraums erfasst wird; und

Erhalten des zweiten Augenbilds (D_{A1}(T2)), das durch die erste Kamera (CA1) während eines zweiten Zeitraums nach dem ersten Zeitraum erfasst wird; und

wobei der Testparameter (PT) ein Maß umfasst, das einen Unterschied zwischen dem ersten und dem zweiten Augenbild (D_{A1}(T1), (D_{A1}(T2)) AUSDRÜCKT.

3. Verfahren nach einem der Ansprüche 1 oder 2, wobei die Teilmenge eine erste und eine zweite Kamera (CA1; CA2) enthält und das Verfahren umfasst:

Erhalten des ersten Augenbilds (D_{A1}(T1)), das durch die erste Kamera (CA1 (T1)) während eines ersten Zeitraums erfasst wird; und

Erhalten des zweiten Augenbilds (D_{A2}(T1)), das durch die zweite Kamera (CA2(T1)) während des ersten Zeitraums erfasst wird; und

wobei der Testparameter (PT) ein Maß umfasst, das einen Unterschied zwischen dem ersten und dem zweiten Augenbild (D_{A1}(T1), (D_{A2}(T1)) AUSDRÜCKT.

4. Verfahren nach Anspruch 3, wobei die erste und die zweite Kamera (CA1, CA2; CB1, CB2) konfiguriert sind, um die Augenbilder des gleichen Auges aus unterschiedlichen Winkeln zu registrieren.

5. Verfahren nach einem der vorstehenden Ansprüche, wobei jeder des ersten und des zweiten Pupillenparameters (PP_1, PP_2) eine jeweilige Eigenschaft der Pupille (P_1, P_2) des Subjekts hinsichtlich mindestens einem ausdrückt von: einer Pupillengröße und einer Pupillenposition.

6. Verfahren nach einem der vorstehenden Ansprüche, umfassend:
Zuweisen des jeweiligen Betriebszustands (OP_1, OP_2, OP_3, OP_4) an die mindestens eine Kamera in der Teilmenge der mindestens zwei Kameras (CA1, CA2, CB1, CB2) basierend auf einer Form der Pupille (P_1, P_2).

7. Verfahren nach einem der Ansprüche 5 oder 6, umfassend ein Interpretieren der Pupillengröße, um mindestens eines zu kennzeichnen von:

einem Abstand von einem Referenzpunkt in dem ersten oder dem zweiten Augenbild (D_{A1}(T1), D_{B1}(T1), (D_{A1}(T2), D_{A2}(T1), D_{B1}(T2), D_{B2}(T1)), wobei eine optische Hauptachse der Ka-

mera und eine Normale der Pupille (P_1, P_2) parallel zueinander sind, und

einer Anzeige, dass die Pupille teilweise abgedeckt ist.

8. Verfahren nach einem der vorstehenden Ansprüche, wobei der erste und der zweite Pupillenparameter (PP_1, PP_2) eine jeweilige Anzahl von Glanzpunkten (G11, G12, G13, G14, G15, G16, G17, G18, G19; G21, G22, G23, G24, G25, G26, G27, G28) spezifizieren, die in dem ersten beziehungsweise dem zweiten Augenbild erkannt werden, und das Verfahren umfasst:
Zuweisen des Betriebszustands (OP_1, OP_2, OP_3, OP_4) für die mindestens eine Kamera in der Teilmenge der mindestens zwei Kameras (CA1, CA2, CB1, CB2) basierend auf einer Anzahl von Glanzpunkten, die in dem ersten beziehungsweise dem zweiten Augenbild erkannt werden.

9. Verfahren nach einem der vorstehenden Ansprüche, wobei das Augenverfolgungssystem ferner mindestens zwei Lichtquellen (LA1, LA2, LA3, LA4, LA5, LA6, LA7, LA8, LA9, LA10; LB1, LB2, LB3, LB4, LB5, LAB, LB7, LB8, LB9, LB10) umfasst, von denen jede konfiguriert ist, um Licht in Richtung des mindestens einen Auges des Subjekts derart zu projizieren, dass Hornhautreflexionsdaten in den Augenbildern erzeugt werden, wenn das projizierte Licht durch das Auge reflektiert wird, und das Verfahren umfasst:
selektives Steuern der mindestens zwei Lichtquellen (LB1, LA2, LA3, LA4, LA5, LA6, LA7, LA8, LA9, LA10; LB1, LB2, LB3, LB4, LB5, LAB, LB7, LB8, LB9, LB10), um an oder aus zu sein, basierend auf der Überprüfung des Testparameters (PT) anhand des mindestens einen Betriebskriteriums.

10. Computerprogrammprodukt (235), das in einen nichtflüchtigen Datenträger (230) geladen werden kann, der mit mindestens einem Prozessor (220) in einem Augenverfolgungssystem kommunikativ verbunden ist, umfassend mindestens zwei Kameras, die konfiguriert sind, um Augenbilder von mindestens einem Auge eines Subjekts zu registrieren, das Computerprogrammprodukt (235) umfassend Software, die konfiguriert ist, um, wenn das Computerprogrammprodukt (235) auf dem mindestens einen Prozessor (220) laufen gelassen wird, den mindestens einen Prozessor veranlasst zum:

Erhalten von Augenbildern von mindestens einer Kamera in einer Teilmenge der mindestens zwei Kameras (CA1, CA2; CB1, CB2);
Bestimmen eines ersten Pupillenparameters (PP_1) basierend auf einem ersten Augenbild (D_{A1}(T1), D_{B1}(T1)) der Augenbilder;
Bestimmen eines zweiten Pupillenparameters

(PP₂) basierend auf einem zweiten Augenbild ($D_{A1}(T2)$, $D_{A2}(T1)$, $D_{B1}(T2)$, $D_{B2}(T1)$) der Augenbilder;

Vergleichen des ersten und des zweiten Pupillenparameters (PP_1, PP_2) miteinander, um einen Testparameter (PT) zu erhalten;

Überprüfen des Testparameters (PT) anhand von mindestens einem Betriebskriterium; und als Reaktion darauf

Zuweisen eines Betriebszustands (OP_1, OP_2, OP_3, OP_4) für mindestens eine Kamera in der Teilmenge der mindestens zwei Kameras (CA1, CA2, CB1, CB2), **dadurch gekennzeichnet, dass** der jeweilige Betriebszustand eines beinhaltet von:

Betreiben der Kamera mit einer hohen Bildfrequenz, falls der Testparameter (PT) anzeigt, dass das Augenbild von der Kamera ein erstes Betriebskriterium erfüllt;

Betreiben der Kamera mit einer reduzierten Bildfrequenz, die niedriger als die hohe Bildfrequenz ist, falls der Testparameter (PT) anzeigt, dass das Augenbild von der Kamera ein zweites Betriebskriterium, jedoch nicht das erste Betriebskriterium, erfüllt;

wobei sich die Kamera in einem Standby-Modus befindet, falls der Testparameter (PT) anzeigt, dass das Augenbild von der Kamera ein drittes Betriebskriterium, jedoch weder das erste noch das zweite Betriebskriterium, erfüllt; und

die Kamera ausgeschaltet wird, falls der Testparameter (PT) anzeigt, dass das Augenbild von der Kamera keines des ersten, des zweiten oder des dritten Betriebskriteriums, erfüllt.

11. Nicht flüchtiger Datenträger (230), der das Computerprogrammprodukt (235) nach Anspruch 10 enthält.

12. Steuereinheit (200) zum Einsparen von Energie in einem Augenverfolgungssystem, umfassend mindestens zwei Kameras (CA1, CA2, CB1, CB2), die konfiguriert sind, um Augenbilder von mindestens einem Auge eines Subjekts zu registrieren, die Steuereinheit (200) umfassend:

eine Eingabeschnittstelle (205), die konfiguriert ist, um Augenbilder von mindestens einer Kamera in einer Teilmenge der mindestens zwei Kameras zu erhalten;

einen Prozessor (220) zum:

Bestimmen eines ersten Pupillenparameters (PP_1) basierend auf einem ersten Augenbild ($D_{A1}(T1)$, $D_{B1}(T1)$) der Augenbilder;

Bestimmen eines zweiten Pupillenparameters (PP_2) basierend auf einem zweiten Augenbild ($D_{A1}(T2)$, $D_{A2}(T1)$, $D_{B1}(T2)$, $D_{B2}(T1)$) der Augenbilder;

Vergleichen des ersten und des zweiten Pupillenparameters (PP_1, PP_2) miteinander, um einen Testparameter (PT) zu erhalten;

Überprüfen des Testparameters (PT) anhand von mindestens einem Betriebskriterium; und als Reaktion darauf

Zuweisen einen entsprechenden Betriebszustand (OP_1, OP_2, OP_3, OP_4) zu mindestens einer Kamera in der Teilmenge der mindestens zwei Kameras (CA1, CA2, CB1, CB2), **dadurch gekennzeichnet, dass** der jeweilige Betriebszustand eines beinhaltet von:

Betreiben der Kamera mit einer hohen Bildfrequenz, falls der Testparameter (PT) anzeigt, dass das Augenbild von der Kamera ein erstes Betriebskriterium erfüllt;

Betreiben der Kamera mit einer reduzierten Bildfrequenz, die niedriger als die hohe Bildfrequenz ist, falls der Testparameter (PT) anzeigt, dass das Augenbild von der Kamera ein zweites Betriebskriterium, jedoch nicht das erste Betriebskriterium, erfüllt;

wobei sich die Kamera in einem Standby-Modus befindet, falls der Testparameter (PT) anzeigt, dass das Augenbild von der Kamera ein drittes Betriebskriterium, jedoch weder das erste noch das zweite Betriebskriterium, erfüllt; und

die Kamera ausgeschaltet wird, falls der Testparameter (PT) anzeigt, dass das Augenbild von der Kamera keines des ersten, des zweiten oder des dritten Betriebskriteriums erfüllt; und

eine Ausgabeschnittstelle (210), die konfiguriert ist, um den jeweils zugewiesenen Betriebszustand an die mindestens eine Kamera weiterzuleiten.

13. Helmdisplay (HMD), umfassend:

mindestens zwei Kameras (CA1, CA2, CB1, CB2), die konfiguriert sind, um Augenbilder von mindestens einem Auge eines Subjekts zu registrieren, und

die Steuereinheit nach Anspruch 12.

Revendications

1. Procédé permettant d'économiser de l'énergie dans un système de suivi d'œil comprenant au moins deux caméras (CA1, CA2, CB1, CB2) configurées pour enregistrer des images d'œil d'au moins un œil d'un sujet, ce procédé étant mis en œuvre dans au moins un processeur (220) et comprenant :

   l'obtention d'images d'œil en provenance d'au moins une caméra dans un sous-ensemble des au moins deux caméras (CA1, CA2, CB1, CB2) ;
   la détermination d'un premier paramètre de pupille (PP_1) en fonction d'une première image d'œil ($D_{A1}(T1)$, $D_{B1}(T1)$) desdites images d'œil ;
   la détermination d'un second paramètre de pupille (PP_2) en fonction d'une seconde image d'œil ($D_{A1}(T2)$, $D_{A2}(T1)$, $D_{B1}(T2)$, $D_{B2}(T1)$) desdites images d'œil ;
   la comparaison des premier et second paramètres de pupille (PP_1, PP_2) l'un à l'autre pour obtenir un paramètre de test (PT) ;
   la vérification du paramètre de test (PT) vis-à-vis d'au moins un critère de fonctionnement ; et en réponse à celui-ci
   l'attribution d'un état de fonctionnement respectif (OP_1, OP_2, OP_3, OP_4) à au moins une caméra dans le sous-ensemble des au moins deux caméras (CA1, CA2, CB1, CB2), **caractérisé en ce que** l'état de fonctionnement respectif implique l'un parmi :

      le fonctionnement de la caméra à un débit de trame élevé, si le paramètre de test (PT) indique que l'image d'œil en provenance de la caméra respecte un premier critère de fonctionnement ;
      le fonctionnement de la caméra à un débit de trame réduit étant inférieur au débit de trame élevé, si le paramètre de test (PT) indique que l'image d'œil en provenance de la caméra respecte un deuxième critère de fonctionnement, mais pas le premier critère de fonctionnement ;
      la caméra étant dans un mode d'attente, si le paramètre de test (PT) indique que l'image d'œil en provenance de la caméra respecte un troisième critère de fonctionnement, mais pas le premier ni le deuxième critère de fonctionnement ; et
      la caméra étant mise hors tension, si le paramètre de test (PT) indique que l'image d'œil en provenance de la caméra ne respecte aucun des premier, deuxième ou troisième critères de fonctionnement.

2. Procédé selon la revendication 1, dans lequel le sous-ensemble contient une première caméra (CA1), et le procédé comprend :

   l'obtention de la première image d'œil ($D_{A1}(T1)$) capturée par la première caméra (CA1) pendant un premier laps de temps ; et
   l'obtention de la seconde image d'œil ($D_{A1}(T2)$) capturée par la première caméra (CA1) pendant un second laps de temps après le premier laps de temps ; et
   dans lequel le paramètre de test (PT) comprend une mesure exprimant une différence entre les première et seconde images d'œil ($D_{A1}(T1)$), ($D_{A1}(T2)$).

3. Procédé selon l'une quelconque des revendications 1 ou 2, dans lequel le sous-ensemble contient des première et seconde caméras (CA1, CA2), et le procédé comprend :

   l'obtention de la première image d'œil ($D_{A1}(T1)$) capturée par la première caméra (CA1(T1)) pendant un premier laps de temps ; et
   l'obtention de la seconde image d'œil ($D_{A2}(T1)$) capturée par la seconde caméra (CA2(T1)) pendant le premier laps de temps ; et
   dans lequel le paramètre de test (PT) comprend une mesure exprimant une différence entre les première et seconde images d'œil ($D_{A1}(T1)$), ($D_{A2}(T1)$).

4. Procédé selon la revendication 3, dans lequel les première et seconde caméras (CA1, CA2 ; CB1, CB2) sont configurées pour enregistrer les images d'œil du même œil à partir d'angles différents.

5. Procédé selon l'une quelconque des revendications précédentes, dans lequel chacun des premier et second paramètres de pupille (PP_1, PP_2) exprime des caractéristiques respectives de la pupille (P_1, P_2) du sujet en termes d'au moins l'un parmi : une taille de pupille et une position de pupille.

6. Procédé selon l'une quelconque des revendications précédentes, comprenant :
   l'attribution de l'état de fonctionnement respectif (OP_1, OP_2, OP_3, OP_4) à l'au moins une caméra dans le sous-ensemble des au moins deux caméras (CA1, CA2, CB1, CB2) en fonction d'une forme de la pupille (P_1, P_2).

7. Procédé selon l'une quelconque des revendications 5 ou 6, comprenant l'interprétation de la taille de pupille pour désigner au moins l'une parmi :

   une distance par rapport à un point de référence dans la première ou seconde image d'œil ($D_{A1}(T1)$, $D_{B1}(T1)$, ($D_{A1}(T2)$, $D_{A2}(T1)$, $D_{B1}(T2)$, $D_{B2}(T1)$) où un axe optique principal de la caméra et

une normale de la pupille (P_1, P_2) sont parallèles l'un à l'autre, et

une indication de la pupille étant partiellement fermée.

8. Procédé selon l'une quelconque des revendications précédentes, dans lequel les premier et second paramètres de pupille (PP_1, PP_2) spécifient un nombre respectif de reflets (G11, G12, G13, G14, G15, G16, G17, G18, G19 ; G21, G22, G23, G24, G25, G26, G27, G28) détectés dans les première et seconde images d'œil respectivement, et le procédé comprend :

l'attribution de l'état de fonctionnement (OP_1, OP_2, OP_3, OP_4) pour l'au moins une caméra dans le sous-ensemble des au moins deux caméras (CA1, CA2, CB1, CB2) en fonction d'un nombre de reflets détectés dans les première et seconde images d'œil respectivement.

9. Procédé selon l'une quelconque des revendications précédentes, dans lequel le système de suivi d'œil comprend en outre au moins deux sources de lumière (LA1, LA2, LA3, LA4, LA5, LA6, LA7, LA8, LA9, LA10 ; LB1, LB2, LB3, LB4, LB5, LAB, LB7, LB8, LB9, LB10) dont chacune est configurée pour projeter de la lumière en direction de l'au moins un œil du sujet de telle sorte que des données de réflexion cornéenne sont générées dans les images d'œil lorsque la lumière projetée est réfléchie par l'œil, et le procédé comprend :

la commande sélective des au moins deux sources de lumière (LB1, LA2, LA3, LA4, LA5, LA6, LA7, LA8, LA9, LA10 ; LB1, LB2, LB3, LB4, LB5, LAB, LB7, LB8, LB9, LB10) pour qu'elles soient allumées ou éteintes en fonction de la vérification du paramètre de test (PT) vis-à-vis de l'au moins un critère de fonctionnement.

10. Produit programme informatique (235) pouvant être chargé dans un support de données non volatil (230) connecté par communications à au moins un processeur (220) dans un système de suivi d'œil comprenant au moins deux caméras configurées pour enregistrer des images d'œil d'au moins un œil d'un sujet, le produit programme d'ordinateur (235) comprenant un logiciel configuré, lorsque le produit programme informatique (235) est exécuté sur l'au moins un processeur (220), pour amener l'au moins un processeur à :

obtenir des images d'œil en provenance d'au moins une caméra dans un sous-ensemble des au moins deux caméras (CA1, CA2, CB1, CB2) ;
déterminer un premier paramètre de pupille (PP_1) en fonction d'une première image d'œil ($D_{A1}(T1)$, $D_{B1}(T1)$) desdites images d'œil ;
déterminer un second paramètre de pupille

(PP_2) en fonction d'une seconde image d'œil ($D_{A1}(T2)$, $D_{A2}(T1)$, $D_{B1}(T2)$, $D_{B2}(T1)$) desdites images d'œil ;
comparer les premier et second paramètres de pupille (PP_1, PP_2) l'un à l'autre pour obtenir un paramètre de test (PT) ;
la vérification du paramètre de test (PT) vis-à-vis d'au moins un critère de fonctionnement ; et en réponse à celui-ci
attribuer un état de fonctionnement (OP_1, OP_2, OP_3, OP_4) pour au moins une caméra dans le sous-ensemble des au moins deux caméras (CA1, CA2, CB1, CB2), **caractérisé en ce que** l'état de fonctionnement respectif implique l'un parmi :

le fonctionnement de la caméra à un débit de trame élevé, si le paramètre de test (PT) indique que l'image d'œil en provenance de la caméra respecte un premier critère de fonctionnement ;
le fonctionnement de la caméra à un débit de trame réduit étant inférieur au débit de trame élevé, si le paramètre de test (PT) indique que l'image d'œil en provenance de la caméra respecte un deuxième critère de fonctionnement, mais pas le premier critère de fonctionnement ;
la caméra étant dans un mode d'attente, si le paramètre de test (PT) indique que l'image d'œil en provenance de la caméra respecte un troisième critère de fonctionnement, mais pas le premier ni le deuxième critère de fonctionnement ; et
la caméra étant mise hors tension, si le paramètre de test (PT) indique que l'image d'œil en provenance de la caméra ne respecte aucun des premier, deuxième ou troisième critères de fonctionnement.

11. Support de données non volatil (230) contenant le produit programme informatique (235) selon la revendication 10.

12. Unité de commande (200) permettant d'économiser de l'énergie dans un système de suivi d'œil comprenant au moins deux caméras (CA1, CA2, CB1, CB2) configurées pour enregistrer des images d'œil d'au moins un œil d'un sujet, l'unité de commande (200) comprenant :

une interface d'entrée (205) configurée pour obtenir des images d'œil en provenance d'au moins une caméra dans un sous-ensemble des au moins deux caméras ;
un processeur (220) pour :

déterminer un premier paramètre de pupille

(PP$_1$) en fonction d'une première image d'œil (D$_{A1}$(T1), D$_{B1}$(T1)) desdites images d'œil ;

déterminer un second paramètre de pupille (PP$_2$) en fonction d'une seconde image d'œil (D$_{A1}$(T2), D$_{A2}$(T1), D$_{B1}$(T2), D$_{B2}$(T1)) desdites images d'œil ;

comparer les premier et second paramètres de pupille (PP$_1$, PP$_2$) l'un à l'autre pour obtenir un paramètre de test (PT) ;

la vérification du paramètre de test (PT) vis-à-vis d'au moins un critère de fonctionnement ; et en réponse à celui-ci

attribuer un état de fonctionnement respectif (OP$_1$, OP$_2$, OP$_3$, OP$_4$) à au moins une caméra dans le sous-ensemble des au moins deux caméras (CA1, CA2, CB1, CB2), **caractérisé en ce que** l'état de fonctionnement respectif implique l'un parmi :

le fonctionnement de la caméra à un débit de trame élevé, si le paramètre de test (PT) indique que l'image d'œil en provenance de la caméra respecte un premier critère de fonctionnement ;

le fonctionnement de la caméra à un débit de trame réduit étant inférieur au débit de trame élevé, si le paramètre de test (PT) indique que l'image d'œil en provenance de la caméra respecte un deuxième critère de fonctionnement, mais pas le premier critère de fonctionnement ;

la caméra étant dans un mode d'attente, si le paramètre de test (PT) indique que l'image d'œil en provenance de la caméra respecte un troisième critère de fonctionnement, mais pas le premier ni le deuxième critère de fonctionnement ; et

la caméra étant mise hors tension, si le paramètre de test (PT) indique que l'image d'œil en provenance de la caméra ne respecte aucun des premier, deuxième ou troisième critères de fonctionnement ; et

une interface de sortie (210) configurée pour acheminer l'état de fonctionnement attribué respectif à l'au moins une caméra.

13. Visiocasque (HMD) comprenant :

au moins deux caméras (CA1, CA2, CB1, CB2) configurées pour enregistrer des images d'œil d'au moins un œil d'un sujet, et

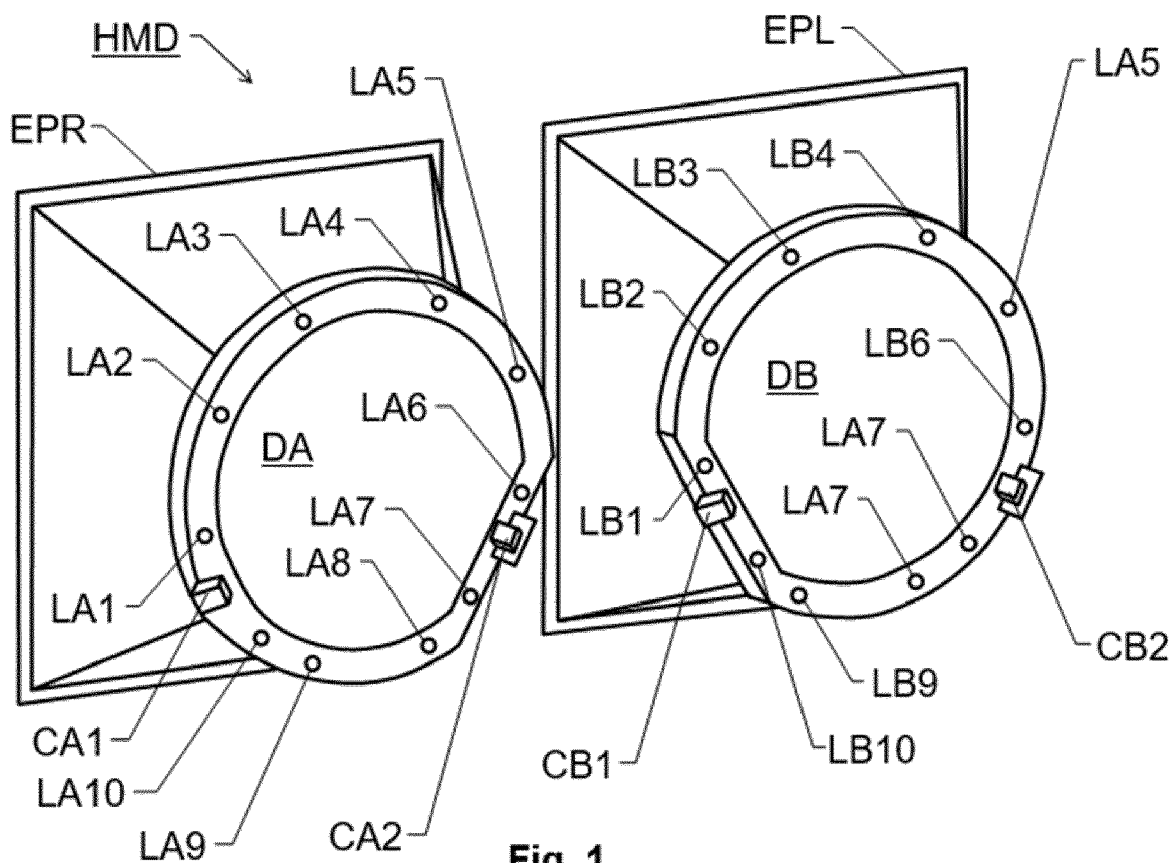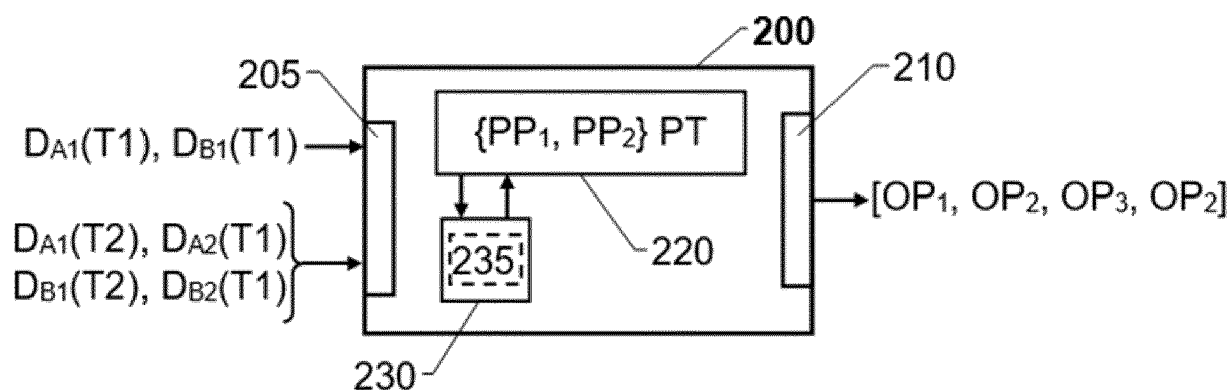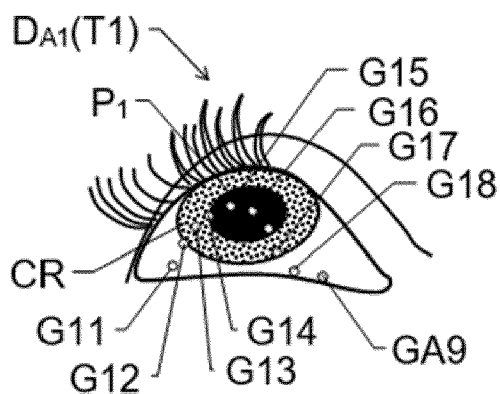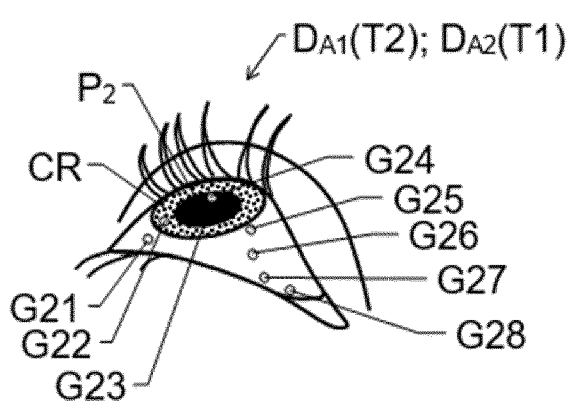l'unité de commande selon la revendication 12.

Fig. 1

Fig. 2

Fig. 3a

Fig. 3b

START

Obtain eye images — 410

Determine 1st pupil parameter based on a 1st image — 420

Determine 2nd pupil parameter based on a 2nd image — 430

Compare 1st and 2nd pupil parameters to obtain a test parameter — 440

Check the test parameter against at least one operation criterion — 450

Assign operation state for ≥ 1 camera in response to the test parameter relative to at least one operation criterion — 460

Fig. 4

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US 20150199003 A **[0003]**
- US 20210173479 A **[0004]**
- US 20150092163 A **[0005]**