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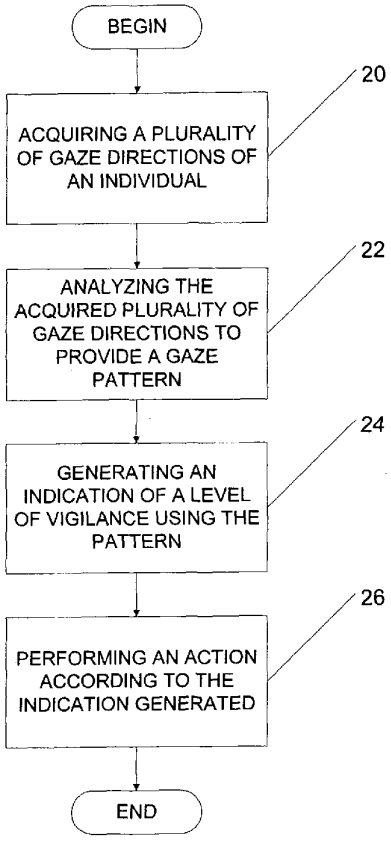
(54) Title: METHOD AND APPARATUS FOR GENERATING AN INDICATION OF A LEVEL OF VIGILANCE OF AN INDIVIDUAL



(57) Abstract: A method and apparatus are disclosed for generating an indication of a level of vigilance of an individual using a gaze acquisition unit providing a gaze data stream of at least one eye of the individual, a processing unit receiving the gaze data stream and determining a level of vigilance.

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METHOD AND APPARATUS FOR GENERATING AN INDICATION OF A LEVEL OF VIGILANCE OF AN INDIVIDUAL

TECHNICAL FIELD

This invention relates to the field of cognitive systems. More precisely, this invention pertains to the field of detecting a level of vigilance of an individual.

BACKGROUND OF THE INVENTION

Despite the advancement of science and technology, humans are still required to achieve complex tasks in which small errors may be very costly. Errors may occur for instance due to fatigue/drowsiness. In the case of a moving vessel such as a truck, the outcome of such errors may be tragic.

It is known to detect drowsiness using various methods. For instance, in the PERCLOS (PERcent eyelid CLOSure) method, a measure of the percentage of eyelid closure over the pupil over time is performed and reflects slow eyelid closures rather than blinks. Unfortunately, such detecting is often of limited interest since, at this point, it is too late to implement an alternative strategy and the situation may already be critical. There is therefore a need for a method and apparatus which enable a prediction of drowsiness.

In another prior art method an EEG (Electroencephalogram) is used to measure signal components over 30Hz which are known to have a correlation with a subject's drowsiness. Unfortunately such method is cumbersome.

There is a need for a method and apparatus that will overcome at least one of the above-identified drawbacks.

SUMMARY OF THE INVENTION

It is an object of the invention to provide a method apparatus for generating an indication of a level of vigilance of an individual.

It is another object of the invention to provide a method and apparatus for alerting an individual in the case of a decrease of a level of vigilance of the individual.

It is another object of the invention to provide a method and apparatus for predicting drowsiness of an individual.

According to a first aspect of the invention, there is provided an apparatus for generating an indication of a level of vigilance of an individual, the apparatus comprising a gaze acquisition unit providing a gaze data stream of at least one eye of the individual, a processing unit receiving the gaze data stream and using the gaze data stream to determine the indication of the level of vigilance and a data providing unit receiving and providing the indication of the level of vigilance.

According to another aspect of the invention, there is provided a method for generating an indication of a level of vigilance of an individual, the method comprising acquiring a plurality of gaze directions of the individual, analyzing the acquired plurality of gaze directions of the individual to determine a gaze pattern and generating an indication of the level of vigilance using the gaze pattern.

According to another aspect of the invention, there is provided a method for predicting drowsiness of an individual, the method comprising acquiring a plurality of gaze directions of the individual, analyzing the acquired plurality of gaze directions of the individual to determine a gaze pattern, generating an indication of the level of vigilance using the gaze pattern and providing an indication of drowsiness of the individual using the indication of said level of vigilance.

BRIEF DESCRIPTION OF THE DRAWINGS

Further features and advantages of the present invention will become apparent from the following detailed description, taken in combination with the appended drawings, in which:

Fig. 1 is a block diagram showing an embodiment of an apparatus which uses an indication of a level of vigilance of an individual;

Fig. 2 is a flowchart showing an embodiment wherein an action is performed according to an indication of a level of vigilance;

Fig. 3 is a flowchart showing how a plurality of gaze directions of an individual is acquired;

Fig. 4 is a flowchart showing how the plurality of gaze directions of the individual is analyzed in order to provide a gaze pattern; and

Fig. 5 is a flowchart showing how an indication of a level of vigilance is generated using the pattern.

It will be noted that throughout the appended drawings, like features are identified by like reference numerals.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The definition of drowsiness, also referred to as sleepiness, may be found in Santamaria and Chiappa "The EEG of Drowsiness in Normal Adults" Journal of Clinical Neurophysiology", 4, 4, 1987, pp327-379. Sleepiness is also referred to as "level 0.5" by Wright in "Vigilance on the civil flight deck: Incidence of sleepiness and sleep during long-haul flights and associated changes in physiological parameters" Ergonomics, 44, 1, 82 (25p). While each of the two last references discloses a definition of sleepiness, it should be understood that the definition of "sleepiness" should not be limited to these definitions and the skilled addressee will appreciate that other definitions of sleepiness may be found in the pertinent literature. This description is intended to encompass all such definitions.

Now referring to Fig. 1, there is shown an embodiment of an apparatus 8 which uses an indication of a level of vigilance of an individual.

The apparatus 8 comprises an image acquisition unit 10 which is an embodiment of a gaze acquisition unit, a processing unit 12, a data providing unit 14, a user interface 16 and a memory unit 18.

The image acquisition unit 10 is adapted to provide an image data stream signal which is an embodiment of a gaze data stream. The image data stream signal comprises a plurality of timely-spaced images of an individual. More precisely, the timely-spaced images comprise at least the

eyes of the individual. It has been contemplated that the timely-spaced images may comprise images of only one of the eyes of the individual. It will be appreciated that preferably the image acquisition unit 10 is a digital black and white image acquisition unit further having infra-red sensors in order to detect the eyes of the individual by day or night. The image acquisition unit 10 preferably provides a resulting image which results from the subtraction of a bright image from a dark image.

The processing unit 12 is adapted to provide an indication of a level of vigilance of the individual using the image data stream signal provided by the image acquisition unit 10 and further using a data signal to retrieve provided by the memory unit 18. The processing unit 12 is further adapted to provide a data signal to store to the memory unit 18. The processing unit 12 is selected from the group consisting of field programmable gate arrays (FPGA), processors, microcontrollers, dedicated circuits or the like.

The data providing unit 14 receives the indication of a level of vigilance and provides a detection signal to provide to the user interface 16.

The user interface 16 is adapted to provide a signal to an individual (or to another entity as discussed below) according to the detection signal to provide to the user interface 16. The signal may be a sensorial data which is selected from a group consisting of visual signals, acoustic signals, stimulation signals and motion signals. The user interface 16 may therefore comprise for instance a sound providing unit, a display unit, a motion providing unit, a cell phone, etc. The skilled addressee

will appreciate that existing user interfaces providing information to the individual such as LCD screen display in car, car navigation console, etc may be advantageously used in order to provide the signal to the individual.

The memory unit 18 is adapted for storing a data signal to store and further to provide the data signal to retrieve as explained below.

Referring to Fig. 2, there is shown how an action is performed according to a generated indication of a level of vigilance.

According to step 20, a plurality of gaze directions of the individual is acquired. The plurality of gaze directions is acquired using the image acquisition unit 10.

Now referring to Fig. 3, there is shown how the plurality of gaze directions of the individual is acquired.

According to step 30, an image is acquired with an indication of a temporal location. The image is acquired using the image acquisition unit 10. As explained above, the image acquired is preferably the resulting image from a subtraction of a bright image (in which the pupil of an eye will be white) of the individual from a dark image of the individual (in which the pupil of the eye of the individual will be black). The skilled addressee will appreciate that this is of great advantage in order to locate the pupil of the eye.

According to step 32, the position of the eyes, relative to the individual's head is detected in the acquired image. The position of the eyes of the individual is

detected by the processing unit 12. More precisely, the position of the eyes is detected using a Kalman algorithm for detecting the pupil of the eye as disclosed in "Lips and face real time tracker", Conference on computer vision and pattern recognition, by Olivier, Pentland and Berard in Puerto Rico, June 1997, pp 123-129. It should be appreciated that upon detection of the position of the eyes, an X coordinate and a Y coordinate are associated to each eye for identifying uniquely the position of each eye.

According to step 34, the position of the eyes is provided with the corresponding indication of a temporal location. The position of the eyes is provided in a memory not shown in Figure 1.

Referring back to Fig. 2 and according to step 22, the acquired plurality of gaze directions of the individual is analyzed to provide a gaze pattern.

Now referring to Fig. 4, there is shown how the acquired plurality of gaze directions of the individual is analyzed.

According to step 40, the position of the eyes in the image is provided with the time indication.

According to step 42, an eye fixation position is determined using the position of the eyes and the time indication. The eye fixation position is determined using the processing unit 12.

According to step 44, a moving frequency between two eye positions is determined using the processing unit 12.

According to step 46, a gaze pattern is created using the determined eye fixation and the determined moving frequency.

Referring back to Fig. 2 and according to step 24, an indication of a level of vigilance is generated using the created gaze pattern.

Now referring to Fig. 5, there is shown how the indication of a level of vigilance is generated using the created pattern.

According to step 50, the created pattern is compared to existing patterns. It should be appreciated that a plurality of existing patterns is stored in the memory unit 18. Each existing patterns is related to a level of vigilance. In fact, it has been contemplated that in the case where a decrease of the level of vigilance of the individual occurs, the amount of alpha frequencies (which may be measured using an EEG) increase, the eye fixation position is concentrated roughly in one point and a reduction in saccade length is observed. Moreover, the eyes fixation positions become more structured, the frequency of the eye fixation decreases while the duration of an eye fixation position increases. It is therefore possible to relate a level of vigilance of the individual to a workload allocated to the individual and further to the gaze pattern of the individual.

According to step 52, an indication of a level of vigilance is determined using the result of the comparison of the gaze pattern of the individual with the plurality of existing patterns. The indication of a level of vigilance is determined using the processing unit 12.

More precisely, the level of vigilance is selected using the corresponding level of vigilance for each of the existing patterns which are found to be close, as a result to the comparison performed in step 50, to the existing pattern for the individual. An interpolation may be performed using more than one corresponding level of vigilance.

While it has been disclosed that an indication of a level of vigilance for the individual is provided, it should be also understood by the skilled addressee that an indication of a variation of the level of vigilance for the individual may also be provided. Also the skilled addressee will appreciate that the indication of a level vigilance is preferably provided together with an indication of a corresponding temporal location which is not shown in Fig. 1 for clarity purposes.

According to step 54, the determined indication of a level of vigilance is provided to the data providing unit. It should be also understood that the determined indication of a level of vigilance may also be provided to the memory unit 18 with a corresponding gaze data stream pattern.

Referring back to Fig. 2 and according to step 26, an action is performed according to the generated indication of a level of vigilance. The action depends on various criteria such as an application sought, a level of vigilance, a variation in the level of vigilance, etc. For instance, a first given threshold may be provided for a level of vigilance or a second given threshold may be provided for a variation of the level of vigilance. In such case, an information signal may be provided in the

case where the variation in the level of vigilance reaches the second given threshold or when the indication of a level of vigilance becomes lower than the first given threshold. The information signal may comprise an alarm signal.

The action is performed via the user interface 16 of the individual. Alternatively, the action may be performed at a remote location.

In an alternative embodiment, the apparatus for generating an indication of a level of vigilance of the individual comprises a gaze acquisition unit providing a gaze data stream of at least one eye of said individual, a processing unit receiving and using the provided gaze data stream to generate an indication of the level of vigilance and a data providing unit receiving and providing the indication of the level of vigilance. The gaze acquisition unit is preferably an image acquisition unit. In one embodiment, the processing unit is using the received gaze data stream over time with a formulae in order to generate the indication of the level of vigilance. Such formulae is disclosed in "A new method for describing search patterns and quantifying visual load using eye movement data" by Chia-Fen Chi and Fang-Tsan Lin, International Journal of Industrial Ergonomics 19 (1997) 249-257, hereby incorporated by reference.

The skilled addressee will appreciate that the embodiments disclosed may be used in many applications where monitoring the level of vigilance of an individual is critical, such as for instance in the case where the individual is the operator of a moving vessel, in the case where the individual is the operator of a factory,

in the case where the individual is the operator of a power plant or the like.

Moreover, the skilled addressee will appreciate that such method and apparatus enable the detection of early stages of drowsiness (sleep stages); i.e., enable the prediction of drowsiness. Enabling such prediction is of great advantage as proper measures may be implemented in order to avoid potential fatal errors that may happen in later stages of drowsiness. The method and apparatus may also be used in order to monitor an evolution in time of a level of vigilance and may therefore be used in order to provide information indicative of remaining cognitive resources of the individual. The information indicative of the remaining cognitive resources may then be related to an indication of a risk of incident/accident. It should be then understood that various alert signals may then be provided to the individual. It may be possible for instance to provide a customized test to the individual in order to assess his cognitive capabilities. The individual may also receive information/suggestions suitable to the indication of vigilance such as stopping a car for instance. Also an operator may also receive the information concerning the individual in order take necessary measures at a larger scale.

While it has been disclosed that the data providing unit 14 provides a detection signal to the user interface 16, it should be understood that the detection signal may be provided to a remote location using at least one of a body area network (BAN), a local area network (LAN), a metropolitan area network (MAN) and a wide area network (WAN).

While illustrated in the block diagrams as groups of discrete components communicating with each other via distinct data signal connections, it will be understood by those skilled in the art that the preferred embodiments are provided by a combination of hardware and software components, with some components being implemented by a given function or operation of a hardware or software system, and many of the data paths illustrated being implemented by data communication within a computer application or operating system. The structure illustrated is thus provided for efficiency of teaching the present preferred embodiment.

It should be noted that the present invention can be carried out as a method, can be embodied in a system, a computer readable medium or an electrical or electro-magnetical signal.

The embodiments of the invention described above are intended to be exemplary only. The scope of the invention is therefore intended to be limited solely by the scope of the appended claims.

I CLAIM:

1. A method for generating an indication of a level of vigilance of an individual, said method comprising:

acquiring a plurality of gaze directions of said individual;

analyzing the acquired plurality of gaze directions of said individual to determine a gaze pattern; and

generating an indication of said level of vigilance using said gaze pattern; and

providing said generated indication of said level of vigilance.

2. The method as claimed in claim 1 wherein the acquiring of said plurality of gaze directions of said individual comprises acquiring a plurality of images with a corresponding indication of a temporal location, detecting in each acquired image a position of an eye of said individual and providing, for each acquired image, said detected position of said eye with said corresponding indication of a temporal location.

3. The method as claimed in claim 2, wherein said analyzing of the acquired plurality of gaze directions comprises determining an eye fixation position of said eye using said detected position and further determining a moving frequency between at least two consecutive eye positions.

4. The method as claimed in claim 3, wherein said generating of said indication of said level of vigilance comprises comparing said gaze pattern to a plurality of existing gaze patterns to provide said indication of said level of vigilance.

5. The method as claimed in any one of claims 1-4, wherein said generating of said indication of said level of vigilance comprises comparing said gaze pattern to a plurality of existing gaze patterns to provide said indication of said level of vigilance.

6. The method as claimed in any one of claims 1-4, wherein said generating of said indication of said level of vigilance comprises using a given formulae over time for calculating said level of vigilance.

7. The method as claimed in any one of claims 1-4, wherein said generating of said indication of said level of vigilance further comprises comparing said generated indication of said level of vigilance to a given criteria.

8. The method as claimed in any one of claims 1-7, further comprising providing an information signal if said indication of said level of vigilance is lower than a given threshold.

9. The method as claimed in claim 8, wherein said information signal comprises an alarm signal.

10. The method as claimed in any one of claims 1-7, wherein at least two consecutive levels of vigilance are generated, further comprising providing an

indication of a variation between said at least two levels of vigilance.

11. The method as claimed in claim 10, further comprising providing an information signal if said variation exceeds a given threshold.

12. The method as claimed in claim 11, wherein said information signal comprises an alarm signal.

13. The method as claimed in any one of claims 1-12, further comprising storing said indication of said level of vigilance with said gaze pattern.

14. The method as claimed in claim 2, wherein a corresponding black image and a corresponding white image are generated for each of said plurality of images and further wherein said detecting in each acquired image of said position of said eye is performed by subtracting said corresponding white image to said corresponding black image.

15. An apparatus for providing an indication of a level of vigilance of an individual, said apparatus comprising:

a gaze acquisition unit providing a gaze data stream of at least one eye of said individual;

a processing unit receiving said gaze data stream and using said gaze data stream to determine said indication of said level of vigilance; and

a data providing unit receiving and providing said indication of said level of vigilance.

16. The apparatus as claimed in claim 15, wherein said processing unit receives said gaze data stream over time and provides an indication of said level of vigilance using a formulae.

17. The apparatus as claimed in claim 15, further comprising a memory unit comprising a plurality of existing gaze patterns, each existing gaze pattern comprising an eye fixation position and a moving frequency between at least two eye positions and a corresponding level of vigilance; further wherein said processing unit compares said determined gaze pattern with at least one of said plurality of existing patterns to determine said level of vigilance.

18. The apparatus as claimed in any one of claims 15-17, wherein said gaze acquisition unit comprises an image acquisition unit.

19. The apparatus as claimed in claim 18, wherein said image acquisition unit comprises digital camera providing a black and white image data stream and an Infra-Red sensor.

20. The apparatus as claimed in any one of claims 15-19, further comprising a user interface receiving said indication of said level of vigilance and providing a signal to said individual in accordance with said indication of said level of vigilance.

21. The apparatus as claimed in claim 20, wherein said provided signal comprises a sensorial signal.

22. The apparatus as claimed in claim 21, wherein said sensorial signal is selected from a group consisting of visual signals, acoustic signals, stimulation signals and a motion signal.

23. The apparatus as claimed in claim 17, wherein said data providing unit provides said indication of said level of vigilance to a remote location using at least one of a body area network (BAN), a local area network (LAN), a metropolitan area network (MAN) and a wide area network (WAN).

24. A method for predicting drowsiness of an individual, said method comprising:

acquiring a plurality of gaze directions of said individual;

analyzing the acquired plurality of gaze directions of said individual to determine a gaze pattern;

generating an indication of said level of vigilance using said gaze pattern; and

providing an indication of drowsiness of said individual using said indication of said level of vigilance.

25. The method as claimed in claim 24, wherein said acquiring of said plurality of gaze directions of said individual comprises acquiring a plurality of images with a corresponding indication of a temporal location, detecting in each acquired image a position of an eye of said individual and providing, for each acquired image, said detected position of said eye

with said corresponding indication of a temporal location.

26. The method as claimed in claim 25, wherein said analyzing of said acquired plurality of gaze directions comprises determining an eye fixation position of said eye using said detected position and further determining a moving frequency between at least two consecutive eye positions.

27. The method as claimed in claim 26, wherein said generating of said indication of said level of vigilance comprises comparing said gaze pattern to a plurality of existing gaze patterns to provide said indication of said level of vigilance.

28. The method as claimed in any one of claims 24-26, wherein said generating of said indication of said level of vigilance comprises using a given formulae over time for calculating said level of vigilance.

29. The method as claimed in any one of claims 24-28, wherein said providing of said indication of drowsiness further comprises providing an alarm signal if said indication of drowsiness exceeds a given threshold.

30. The method as claimed in claim 25, wherein a corresponding black image and a corresponding white image are generated for each of said plurality of images and further wherein said detecting in each acquired image of said position of said eye is performed by subtracting said corresponding white image to said corresponding black image.

31. A computer readable medium comprising computer readable instructions which when executed cause a computer to perform the method as claimed in any one of claims 1-14.

32. A computer readable medium comprising computer readable instructions which when executed cause a computer to perform the method as claimed in any one of claims 24-30.

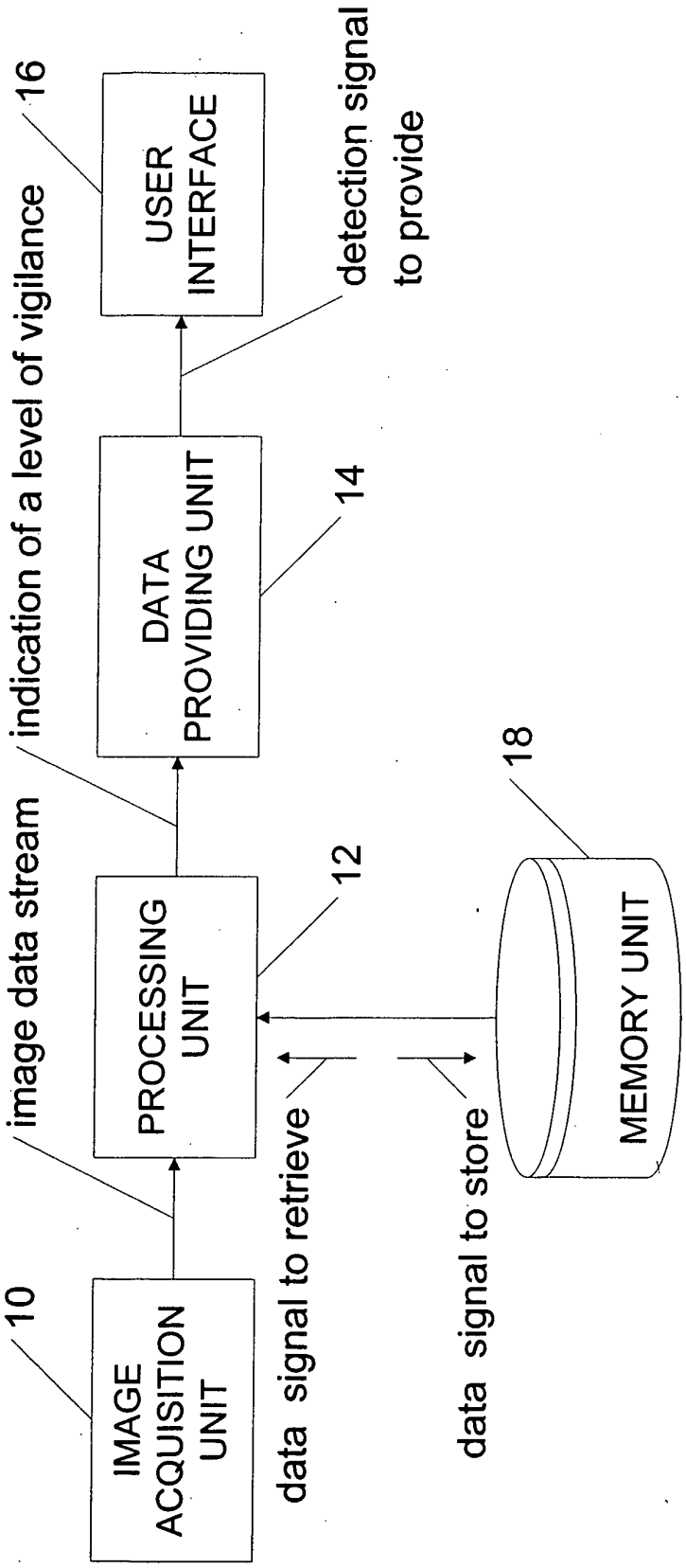
IMAGE ACQUISITION UNIT
10
image data stream
PROCESSING UNIT
12
indication of a level of vigilance
DATA PROVIDING UNIT
14
detection signal to provide
USER INTERFACE
16
data signal to retrieve
data signal to store
MEMORY UNIT
18

FIGURE 1

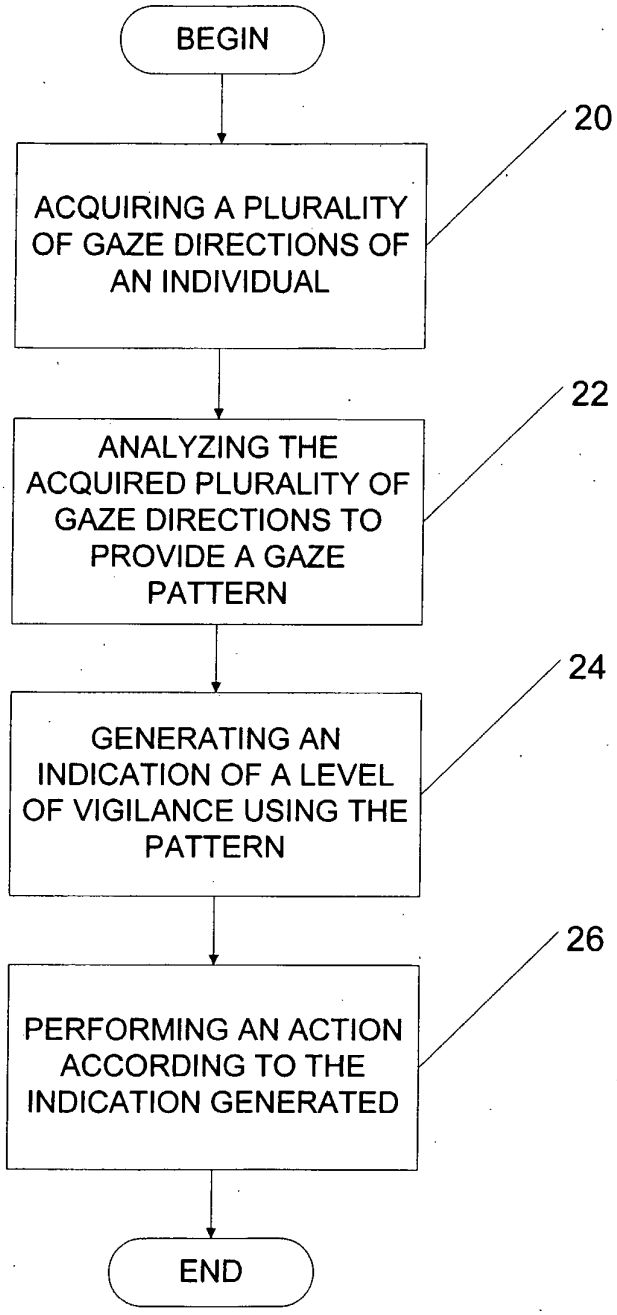
BEGIN
ACQUIRING A PLURALITY OF GAZE DIRECTIONS OF AN INDIVIDUAL
20
ANALYZING THE ACQUIRED PLURALITY OF GAZE DIRECTIONS TO PROVIDE A GAZE PATTERN
22
GENERATING AN INDICATION OF A LEVEL OF VIGILANCE USING THE PATTERN
24
PERFORMING AN ACTION ACCORDING TO THE INDICATION GENERATED
26
END

FIGURE 2

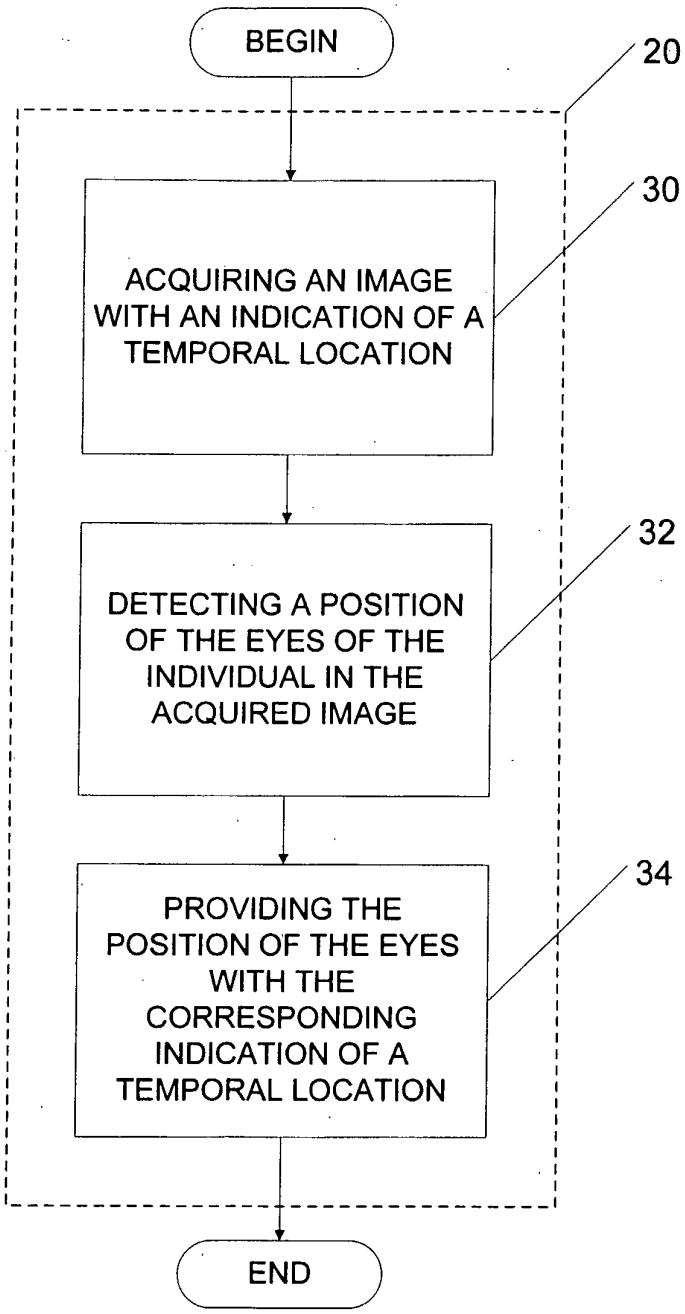
BEGIN
20
30
ACQUIRING AN IMAGE WITH AN INDICATION OF A TEMPORAL LOCATION
32
DETECTING A POSITION OF THE EYES OF THE INDIVIDUAL IN THE ACQUIRED IMAGE
34
PROVIDING THE POSITION OF THE EYES WITH THE CORRESPONDING INDICATION OF A TEMPORAL LOCATION
END

FIGURE 3

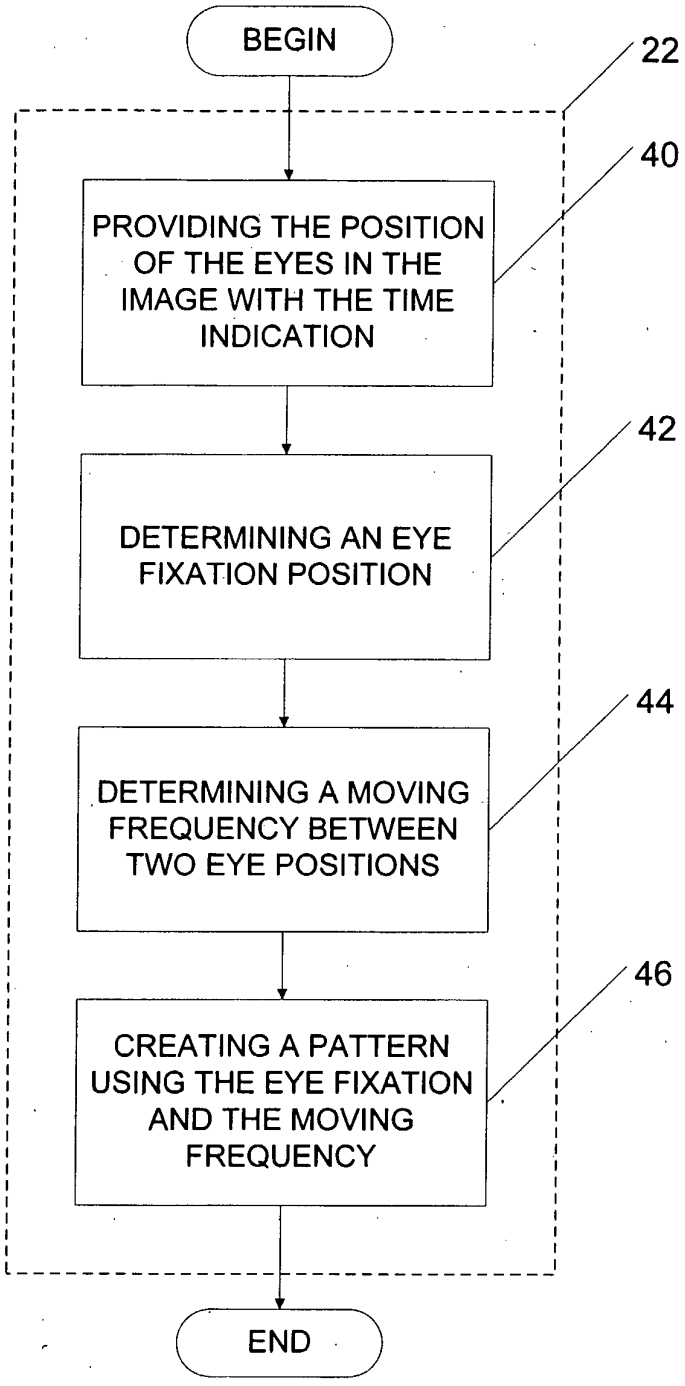
BEGIN
22
40
PROVIDING THE POSITION OF THE EYES IN THE IMAGE WITH THE TIME INDICATION
42
DETERMINING AN EYE FIXATION POSITION
44
DETERMINING A MOVING FREQUENCY BETWEEN TWO EYE POSITIONS
46
CREATING A PATTERN USING THE EYE FIXATION AND THE MOVING FREQUENCY
END

FIGURE 4

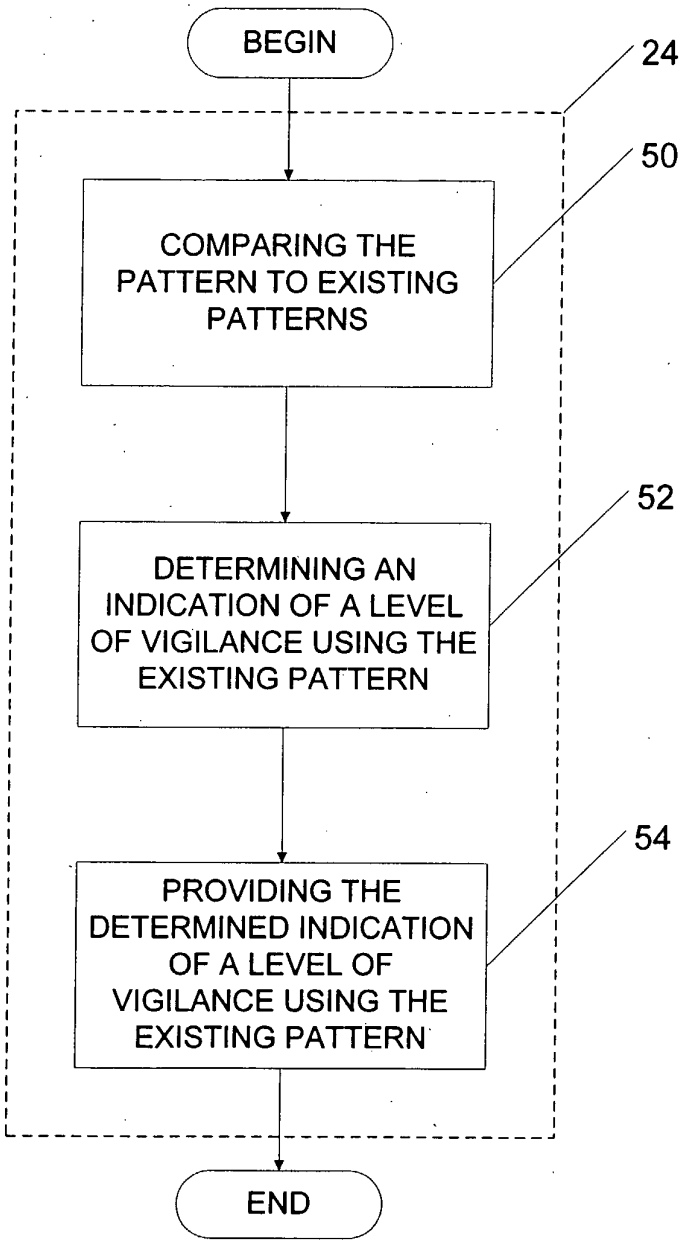
BEGIN
24
50
COMPARING THE PATTERN TO EXISTING PATTERNS
52
DETERMINING AN INDICATION OF A LEVEL OF VIGILANCE USING THE EXISTING PATTERN
54
PROVIDING THE DETERMINED INDICATION OF A LEVEL OF VIGILANCE USING THE EXISTING PATTERN
END

FIGURE 5