Another method of detecting OKN is with the use of video-oculography techniques. The position of an eye is tracked by reviewing live or recorded video. Video-oculography is appealing because it is a non-invasive and can be implemented using low cost and basic video hardware, US patent 7,380,938 describes a video-oculography technique where video footage of an eye is recorded, the vertical and horizontal movement of an eye isolated and displacement of the eye in the vertical and horizontal directions is measured. The displacement measurement can be analysed to determine the presence or absence of OKN patterns.

One disadvantage of video-oculography techniques is that they require a fixed positional relationship between the camera and eyes in order to eliminate performance errors introduced by head movement. To prevent head movement, the subject is often required to place their head in a fixed chin-rest or wear head mounted equipment such as cameras and lighting equipment to improve the video recording. Young children and infants do not tolerate head fixing or head-mounted gear which precludes them from an objective assessment of their visual function using video-oculography techniques.

Embodiments of the present invention relate to ways of assess optokinetic nystagmus which overcomes or at least ameliorates some of the abovementioned disadvantages or which at least provides the public with a useful choice.

In this specification, where reference has been made to external sources of information, including patent specifications and other documents, this is generally for the purpose of providing a context for discussing the features of the present invention. Unless stated otherwise, reference to such sources of information is not to be construed, in any jurisdiction, as an admission that such sources of information are prior art or form part of the common general knowledge in the art.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention, there is provided a method of evaluating visual performance or visual health, including: providing a visual stimulus in front of the eye(s) of a subject, the stimulus effective to elicit optokinetic nystagmus, obtaining video footage of the subject watching the stimulus, detecting at least part of an eyeball in at least two frames of the video footage, applying an optical flow algorithm to the at least two frames of the video footage to extract information relating to linear movement of at least part of the eye, and determining a statistical measure from the information, characterised in that said information relating to linear movement of at least part of the eye comprises pixel velocity information including both magnitude and direction information, determining a statistical measure comprises determining an average pixel velocity, and by evaluating visual performance or visual health of the subject from the statistical measure.

According to a second aspect of the present invention, there is provided an eye tracking system for evaluating visual performance or visual health including: a visual stimulus arrangeable in front of the eye(s) of a subject, the stimulus operable to elicit optokinetic nystagmus, a camera arranged to capture footage of an eye, a controller configured to receive the footage of the eye and perform the steps of: detecting at least part of an eye in at least two frames of the footage, applying an optical flow algorithm to the footage to thereby determine information between at least two frames of the footage relating to linear movement of at least part of the eye, and determining a statistical measure from the information, characterised in that said information relating to linear movement of at least part of the eye comprises pixel velocity information including both magnitude and direction information, and determining a statistical measure comprises determining an average pixel velocity, and evaluating visual function performance or visual health of the subject from the statistical measure.

Disclosed herein is a method of extracting eye velocity information from a video footage having a plurality of frames, comprising detecting at least part of an eye in at least two frames of the video footage, applying an optical flow algorithm to the at least two frames of the video footage to extract pixel velocity information, and determining a statistical measure from the pixel velocity information within the detected at least part of the eye.

Disclosed herein is a eye tracking system comprising a camera arranged to capture footage of an eye, a controller configured to receive the footage of the eye and perform the steps of detecting at least part of an eye in at least two frames of the footage, applying an optical flow algorithm to the footage to thereby determine pixel velocity information between at least two frames of the footage, and determining a statistical measure from the pixel velocity information within the detected at least part of the eye.

Disclosed herein is a controller device programmed to perform the steps of detecting at least part of an eye in at least two frames of the footage, applying an optical flow algorithm to the footage to thereby determine pixel velocity information between at least two frames of the footage, and determining a statistical measure of the pixel velocity information within the detected at least part of the eye.

Some embodiments further comprise one or more of the steps of (in any order): determining the velocity magnitude and direction of at least part of an eye from the velocity information, determining any velocity maxima and minima from the velocity information, comparing any maxima or minima to a lower velocity threshold and discarding any maxima or minima below the threshold, comparing any maxima or minima to an upper velocity threshold and discarding any maxima or minima above the threshold, comparing the inter-frame distance between adjacent maxima or minima to a frame threshold and discarding any maxima or minima below the frame threshold, determining any sole maxima or sole minima in the velocity information and discarding

sole maxima or sole minima, averaging the maxima or minima velocity magnitudes, and/or normalising the maxima or minima velocity magnitudes.

In some embodiments the statistical measure of the pixel velocity information is an average pixel velocity.

In some embodiments the at least part of the eye is a region of contrast discontinuity of the eye.

In some embodiments the at least part of the eye is a limbus portion of the eye.
Some embodiments further comprise generating a list of pixel velocity averages for each consecutive frame in the video footage.

Some embodiments further comprise comparing the determined velocity information to healthy velocity information to make a determination of the health of the eye and/or visual pathway.

Some embodiments further comprising comparing the determined velocity information to healthy velocity information to make a determination of the presence and/or strength of OKN.

In some embodiments the limbus portion of the eye is determined by an edge detection algorithm.

In some embodiments edge detection is performed by application of a Prewitt operator.

In some embodiments the optical flow algorithm is a Lucas-Kanade optical flow algorithm.

In some embodiments the optical flow algorithm is applied to determine pixel velocity information between consecutive frames of a length of video footage corresponding to several reset events.

Some embodiments further comprise a visual stimulus arranged in front of the eye, the stimulus operable to elicit optokinetic nystagmus.

Some embodiments further comprise comparing the average velocity information to known optokinetic nystagmus velocity information to make a determination of the health of an eye in response to the stimulus.

In some embodiments the video footage is obtained from a subject watching a stimulus.

In some embodiments the stimulus is a screen.

In some embodiments the camera and screen are contained within an enclosure.

In some embodiments the camera, screen and controller are integrated within an enclosure.

In some embodiments the enclosure is any one or more of a smart phone, tablet or portable computation device.

In some embodiments detecting at least part of an eye does not include detection of a feature of the eye.

Disclosed herein is a method of improving the attention of a subject for eye tracking comprising operating at least one display to show a video of an video functional to gain the attention of a viewer, operating at least one display to show an OKN stimulus video, and recording an eye watching the OKN stimulus video with a camera.

In some embodiments the video functional to gain the attention of a viewer is an animated video.

In some embodiments the statistical measure is applied to determine information relating to one or more of a person's behaviour, a person's response to advertising, security purposes, or consumer attention.

Some embodiments further comprise extracting head image trajectory information from the video footage by a method comprising detecting at least part of a facial region of the head in at least two frames of the video footage, determining a measure of the movement of the at least part of a facial region between the at least two frames, and determining a transformation map from the measure of the movement.

Some embodiments further comprise determining the inverse of the transformation map, applying inverse of the transformation to each frame in the video footage such the facial region within the frame is held substantially constant.

Some embodiments further comprise detecting the facial region from within a frame of the video footage using the Viola-Jones algorithm.

Some embodiments further comprise identifying one or more particular portions of the facial region within the frame using a Harris corner detection algorithm.

Some embodiments further comprise determining the measure of the movement of the facial region or one or more particular portions of a facial region between consecutive video frames using a Kanade Lucas Tomasi (KLT) point tracker.

In some embodiments the measure of the movement comprises one or more of rotation, scale and/or translation movement.

In some embodiments the transformation map is created from the movement information.

Some embodiments further comprise applying an inverse similarity transformation to offset each frame in the video footage such that the facial region within the frame is held substantially constant with respect to each frame.

Some embodiments further comprise applying an inverse similarity transformation to crop each frame in the video footage to generate a new frame such that the facial region within the frame is held substantially constant with respect to each frame.

In some embodiments the head trajectory information is used to improve the eye velocity information.

In some embodiments head trajectory information is offset against the eye tracking information to substantially remove eye velocity information caused by head movement.

Disclosed herein is a method of processing video footage having a plurality of frames to determine the presence of OKN, the method comprising: extracting head trajectory information by a method comprising detecting at least part of a facial region of the head image in at least two frames of the video footage, determining a measure of the movement of the at least part of a facial region between the at least two frames, and determining a transformation map from the measure of the movement, and extracting eye velocity information by a method comprising detecting at least part of an eye in at least two frames of the video footage, applying an optical flow algorithm to the at least two frames of the video footage to extract pixel velocity information, and determining a statistical measure from the pixel velocity information within the detected at least part of the eye.

In some embodiments the head trajectory information is offset against the eye tracking information to substantially remove eye velocity information caused by head movement.

Disclosed herein is a method of extracting head image trajectory information from a video footage having a plurality of frames, comprising: detecting at least part of a facial region of the head image in at least two frames of the video footage, determining a measure of the movement of the at least part of a facial region between the at least two frames, and determining a transformation map from the measure of the movement.

Disclosed herein is a method of extracting head image trajectory information from a video footage having a plurality of frames, comprising: detecting at least part of a facial region of the head image in at least two frames of the video footage, determining a measure of the movement of the at least part of a facial region between the at least two frames, and determining a transformation map from the measure of the movement.

Disclosed herein is a head tracking system for extracting head image trajectory information comprising: a camera arranged to capture footage of a head and a controller configured to receive the footage of the head and perform the steps of: detecting at least part of a facial region of the head in at least two frames of the video footage, determining a measure of the movement of the at least part of a facial region between the at least two frames, and determining a transformation map from the measure of the movement.

Disclosed herein is a controller device configured to perform the steps of detecting at least part of a facial region of the head in at least two frames of the video footage, determining a measure of the movement of the at least part of a facial region between the at least two frames, and determining a transformation map from the measure of the movement.

In some embodiments the method or steps further comprise: determining the inverse of the transformation map, applying inverse of the transformation to each frame in the video footage such the facial region within the frame is held substantially constant.

Some embodiments further comprise detecting the facial region from within a frame of the video footage using the Viola-Jones algorithm.

Some embodiments further comprise identifying one or more particular portions of the facial region within the frame using a Harris corner detection algorithm.

Some embodiments further comprise determining the measure of the movement of the facial region or one or more particular portions of a facial region between consecutive video frames using a Kanade Lucas Tomasi (KLT) point tracker.

In some embodiments the measure of the movement comprises one or more of rotation, scale and/or translation movement.

In some embodiments the transformation map is created from the movement information.

Some embodiments further comprise applying an inverse similarity transformation to offset each frame in the video footage such that the facial region within the frame is held substantially constant with respect to each frame.

Some embodiments further comprise applying an inverse similarity transformation to crop each frame in the video footage to generate a new frame such that the facial region within the frame is held substantially constant with respect to each frame.

In some embodiments the system or method is to be applied to infants, young children or impaired persons.

In some embodiments the system or method is to be applied to children under 10 years old.

In some embodiments the system or method is to be applied to children under 8 years old.

In some embodiments the system or method is to be applied to children under 6 years old.

In some embodiments the system or method is to be applied to children under 4 years old.

In some embodiments the system or method is to be applied to children under 2 years old.

In some embodiments the system or method is to be applied to children up to 2 years old.

In some embodiments the system or method is to be applied to children up to 3 years old.

In some embodiments the system or method is to be applied to children up to 4 years old.

The following embodiments may relate to any of the above aspects. Other aspects of the invention may become apparent from the following description which is given by way of example only and with reference to the accompanying drawings.

As used herein the term "and/or" means "and" or "or", or both.

As used herein "(s)" following a noun means the plural and/or singular forms of the noun.

The term "comprising" as used in this specification means "consisting at least in part of". When interpreting statements in this specification which include that term, the features,

prefaced by that term in each statement or claim, all need to be present but other features can also be present. Related terms such as "comprise" and "comprised" are to be interpreted in the same manner.

This invention may also be said broadly to consist in the parts, elements and features referred to or indicated in the specification of the application, individually or collectively, and any or all combinations of any two or more of said parts, elements or features, and where specific integers are mentioned herein which have known equivalents in the art to which this invention relates, such known equivalents are deemed to be incorporated herein as if individually set forth.

To those skilled in the art to which the invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the scope of the invention as defined in the appended claims. The disclosures and the descriptions herein are purely illustrative and are not intended to be in any sense limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

The Invention will now be described by way of example only and with reference to the drawings in which;

Figure 1 shows a picture of an eye. Figure 1(a) illustrates the region of an eye typically monitored for change in displacement. Figure 1(b) shows a graph of eye displacement over time exhibiting a saw tooth profile characteristic of healthy eye movement. Figure 1(c) shows a graph of eye velocity derived from the eye displacement signal.

Figure 2 shows an example where consecutive image frames are transformed into an estimate of pixel velocity. Figure 2(a) is an example image of an eye received from a camera. Figure 2(b) shows an example of pixel velocity vectors provided by an optical flow algorithm. Figure 2(c) is an example of a graph of the regional velocity average of the optical flow velocity vectors.

Figure 3 shows an outline of the preferred process steps of the invention.

Figure 4 shows graphs of simulated limbal edge and detector response. Figure 4(a) shows an example input edge similar in size (σ= 5) to that observed in. Figure 4(b) shows calculated response curves (for three examples velocities (v = 1; 3; 5 pixels/frame

CLAIMS

1. A method of evaluating visual performance or visual health, comprising:
providing a visual stimulus in front of the eye(s) of a subject, the stimulus effective to elicit optokinetic nystagmus,
obtaining video footage of the subject watching the stimulus,
detecting at least part of an eyeball in at least two frames of the video footage,
applying an optical flow algorithm to the at least two frames of the video footage to extract information relating to linear movement of at least part of the eye, and
determining a statistical measure from the information,
characterised in that said information relating to linear movement of at least part of the eye comprises pixel velocity information including both magnitude and direction information, determining a statistical measure comprises determining an average pixel velocity, and by evaluating visual performance or visual health of the subject from the statistical measure.

2. The method as claimed in claim 1, wherein the at least part of the eyeball is a limbus portion of the eyeball.

3. The method as claimed in either claim 1 or claim 2, wherein the optical flow algorithm is a Lucas-Kanade optical flow algorithm.

4. The method as claimed in any one of claims 1 to 3, further comprising comparing the determined pixel velocity information to healthy pixel velocity information to make a determination of the presence and/or strength of OKN.

5. The method as claimed in any one of claims 1 to 4, including compensating for head movement within video footage.

6. The method as claimed in claim 5 including compensating for head movement within video footage by detecting a facial feature in at least two frames of the video footage, determining a measure of movement of the facial feature caused by head movement between the at least two frames, and combining the information on the movement of the facial feature with information the pixel velocity information relating to linear movement of the eyeball.

7. The method as claimed in claim 5 including compensating for head movement within video footage by moving or cropping frames in the video footage such that the facial region within the frames is held substantially constant between frames.

8. An eye tracking system for evaluating visual performance or visual health comprising:

a visual stimulus arrangeable in front of the eye(s) of a subject, the stimulus operable to elicit optokinetic nystagmus,

a camera (60) arranged to capture footage of an eye,

a controller (80) configured to receive the footage of the eye and perform the steps of:

detecting at least part of an eye in at least two frames of the footage,

applying an optical flow algorithm to the footage to thereby determine information between at least two frames of the footage relating to linear movement of at least part of the eye, and

determining a statistical measure from the information, characterised in that said information relating to linear movement of at least part of the eye comprises pixel velocity information including both magnitude and direction information, and determining a statistical measure comprises determining an average pixel velocity, and

evaluating visual function performance or visual health of the subject from the statistical measure.

9. The eye tracking system as claimed in claim 8, wherein the controller (80) is configured to (in any order):

determine the velocity magnitude and direction of at least part of an eye from the velocity information,

determine any velocity maxima and minima from the velocity information,

compare any maxima or minima to a lower velocity threshold and discarding any maxima or minima below the threshold,

compare any maxima or minima to an upper velocity threshold and discarding any maxima or minima above the threshold,

compare the inter-frame distance between adjacent maxima or minima to a frame threshold and discarding any maxima or minima below the frame threshold,

determine any sole maxima or sole minima in the velocity information and discarding sole maxima or sole minima,

average the maxima or minima velocity magnitudes, and/or

normalise the maxima or minima velocity magnitudes.

10. The eye tracking system as claimed in in either claim 8 or claim 9, wherein the optical flow algorithm is a Lucas-Kanade optical flow algorithm.

11. The eye tracking system as claimed in any one of claims 8 to 10, wherein the controller is configured to compare the determined pixel velocity information to healthy pixel velocity information to make a determination of the presence and/or strength of OKN.

12. The eye tracking system as claimed in any one of claims 8 to 11, wherein the controller is configured to compensate for head movement within video footage.

13. The eye tracking system as claimed in claim 12 wherein the controller is configured to compensate for head movement within video footage by detecting a facial feature in at least two frames of the video footage, determining a measure of movement of the facial feature caused by head movement between the at least two frames, and combining the information on the movement of the facial feature with the pixel velocity information relating to linear movement of the eyeball.

14. The eye tracking system as claimed in claim 12 wherein the controller is configured to compensate for head movement within video footage by moving or cropping frames in the video footage such that the facial region within the frames is held substantially constant between frames.

15. The eye tracking system as claimed in claim 14 wherein the controller is configured to determine a measure of movement of the facial feature between the at least two frames using a Kanade Lucas Tomasi (KLT) optical flow algorithm as a point tracker.