Eye Tracking

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***Abstract*- In this paper we will make a route by the most usual techniques of eye tracking used nowadays. We will see as these techniques have been used for years but it is now when the existing technology allows better results.**

I. INTRODUCTION

Eye tracking is the process of measuring either the point of gaze ("where we are looking") or the motion of an eye relative to the head. There are a number of methods for measuring eye movements. An instrument that does eye tracking is called an eye tracker.

The Eye tracking has been studied for a long time. In 1879 in Paris, Louis Émile Javal observed that reading does not involve a smooth sweeping of the eyes along the text, as previously assumed, but a series of short stops (called fixations) and quick saccades [5].

Huey built what might be the first eye tracker, using a sort of contact lens with a hole for the pupil. The lens was connected to an aluminum pointer that moved in response to the movements of the eye. Huey studied and quantified regressions (only few a small proportion of saccades are regressions), and showed that only a portion of the words in a sentence were actually fixated [5].

The first non-intrusive eye trackers were built by George Buswell in Chicago, using beams of light that were reflected on the eye and then recording on film. Buswell made systematic studies into readed and picture viewing.

In the 1950, Alfred L. Yarbus [21] did important eye tracking research and his 1967 book is one of the most quoted eye tracking publications ever. For example he showed the task given to a subject has a very large influence on the subjects eye movements. He also wrote about the relation between fixations and interest.

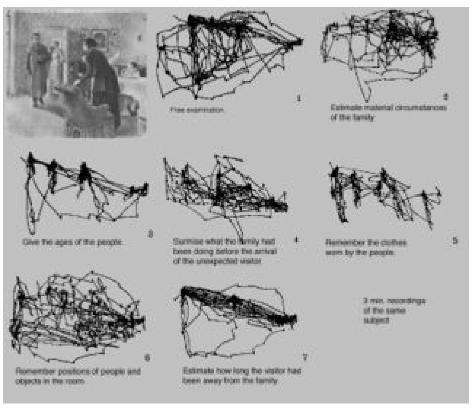

Fig.1. This study by Yarbus (1967) is often referred to as evidence on how the task given to a person influences his or her eye movements

In the 1970, eye tracking research expanded rapidly, particularly reading research. A good overview of the research in this period is given by Rayner. In 1980, Just and Carpenter formulated the influential *Strong eye-mind Hypothesis*, the hypothesis that "there is no appreciable lag between what is fixated and what is processed". During the 1980, the eye-mind hypothesis was often questioned in light of covert attention, the attention to something that one is not looking at, which people often do. If covert attention is common during eye tracking recordings, the resulting scan path and fixation patterns would often show not where our attention has been, but only where the eye has been looking, and so eye tracking would not indicate cognitive processing.

But the technology was not developed mainly because the power of the machinery available did not reach to the handling of data in real time, at the moment we used such systems (improved) but the best technology available allows the handling of data in real time [5].

II. EYE TRACKING SYSTEMS

The measurement device most often used for measuring eye movements is commonly known as an 'eye tracker'. In general, there are two types of eye movement monitoring techniques: those that measure the position of the eye relative to the head, and those that measure the orientation of the eye in space, or the "point of regard" [14]. The latter measurement is typically used when the concern is the identification of elements in a visual scene, (interactive applications). Possibly the most widely applied apparatus for measurement of the point of regard is the video-based corneal reflection eye tracker. In this paper, most of the popular eye movement measurement techniques are briefly discussed first before covering video-based trackers in greater detail.

There are four broad categories of eye movement measurement methodologies involving the use or measurement of: electro-oculography (EOG), scleral contact lens/search coil, photo-oculography (POH) or video-oculography (VOG), and video-based combined pupil and corneal reflection. [2]

A. Electro-oculography (EOG)

EOG is a method for sensing eye movement and is based on recording the standing corneal-retinal potential arising from hyperpolarizations and depolarizations existing between the cornea and the retina; this is commonly known as an electrooculogram. This potential can be considered as a steady electrical dipole with a negative pole at the fundus and a positive pole at the cornea [see Figure 2]. The standing potential in the eye can thus be estimated by measuring the voltage induced across a system of electrodes placed around the eyes as the eyegaze changes, thus obtaining the EOG (measurement of the electric signal of the ocular dipole). [10]

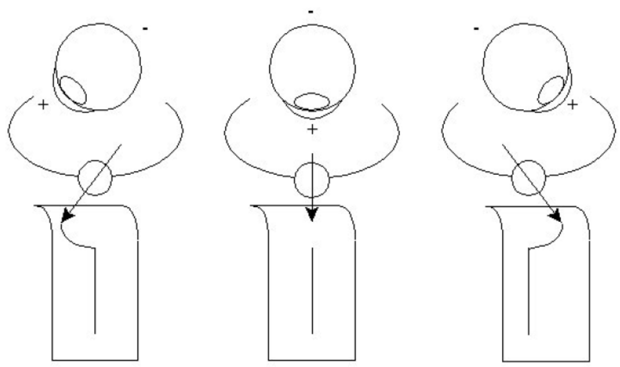

Fig. 2. Ocular dipole

The EOG value varies from 50 to 3500 μV with a frequency range of about dc-100 Hz. Its behavior is practically linear for gaze angles of ±30º. It should be pointed out here that the variables measured in the human body (any biopotential) are rarely deterministic. Its magnitude varies with time, even when all possible variables are controlled. Most of these biopotentials vary widely among normal patients, even under similar measurement conditions. This means that the variability of the electrooculogram reading depends on many factors that are difficult to determine: perturbations caused by other biopotentials such as EEG (electroencephalogram), EMG (electromiogram), in turn brought about by the acquisition system, plus those due to the positioning of the electrodes, skin-electrode contacts, lighting conditions, head movements, blinking, etc. To eliminate or minimize these defects, therefore, a considerable effort had to be made in the signal acquisition stage to make sure it is captured with the minimum possible perturbations and then during the study and processing thereof to obtain the best possible results. [16]

The electrooculogram (EOG) is captured by five electrodes placed around the eyes, as shown in figure 3. The EOG signals are obtained by placing two electrodes to the right and left of the outer canthi (D-E) to detect horizontal movement and another pair above and below the eye (B-C) to detect vertical movement. A reference electrode is placed on the forehead (A). The EOG signal changes approximately 20 microvolts for each degree of eye movement. The EOG signal is a result of a number of factors, including eyeball rotation and movement, eyelid movement, different sources of artifact such as EEG, electrode placement, head movements, influence of the illumination, etc. It is therefore necessary to eliminate the shifting resting potential (mean value) because this value changes.

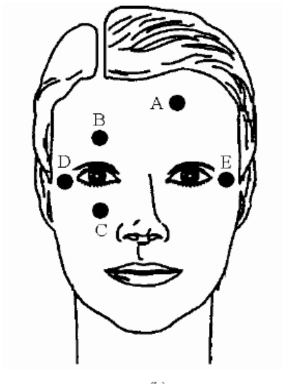

Fig. 3. Electrodes placement

B. *Scleral contact lens/search coil*

One of the most precise eye movement measurement methods involves attaching a mechanical or optical reference object mounted on a contact lens which is then worn directly on the eye. Early such recordings [14] used a plaster of paris ring attached directly to the cornea and through mechanical linkages to recording pens. This technique evolved to the use of a modern contact lens to which a mounting stalk is attached. The contact lens is necessarily large, extending over the cornea and sclera (the lens is subject to slippage if the lens only covers the cornea). Various mechanical or optical devices have been placed on the stalk attached to the lens: reflecting phosphors, line diagrams, and wire coils have been the most popular implements in magneto-optical configurations. The principle method employs a wire coil, which is then measured moving through an electromagnetic field. A picture of the search coil embedded in a scleral contact lens and the electromagnetic field frame are shown in figure 4. The manner of insertion of the contact lens is shown in figure 5. Although the scleral search coil is the most precise eye movement measurement method (accurate to about 5-10 arc-seconds over a limited range of about 5º [14], it is also the most intrusive method. Insertion of the lens requires care and practice. Wearing of the lens causes discomfort. This method also measures eye position relative to the head, and is not generally suitable for point of regard measurement.

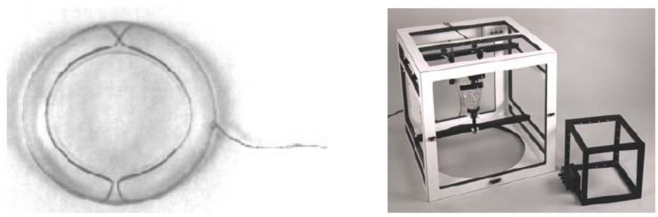

Fig. 4. Example of search coil embedded in contact lens and electromagnetic field frames for search coil eye movement measurement. From Skalar Medical [Ska00].

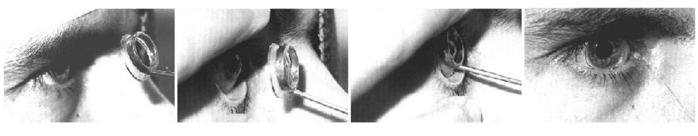

Fig. 5. Example of scleral suction ring insertion for search coil eye movement measurement. From Skalar Medical [Ska00].

C. Video-oculography (VOG)

This procedure is based in the identification of certain special characteristics of an image that has been obtained with a video camera such as the relative position of the pupil, the limit between the *limbus* and the *sclera*, the shape of the pupil, etc.

The video images of the laterally attached cameras (see Figures 6) are transferred to a wearable computer, whose image processing algorithms detect the position of the pupil. Based on the luminance histogram, a threshold for the dark pupil pixels is calculated with which a binary version of the image is generated: pupil pixels are marked with white (see Figure 7) and all other pixels with black. A principal component analysis is applied to the detected pupil pixels in order to test whether their circular arrangement is disturbed by blinks and other artifacts. Then a contour finding algorithm [7] extracts the pupil margin.

The center of an ellipse that is fitted to the pupil margin data [3] is subsequently used to estimate pupil position in the image coordinate space. These and similar image processing techniques yield typical yaw and pitch angle resolutions beneath 0.1° [8].

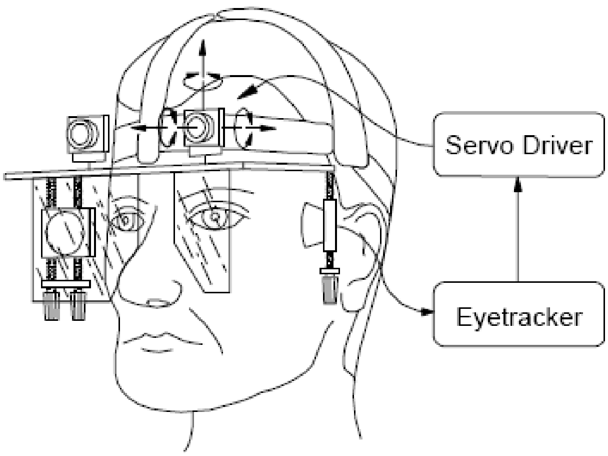

Fig. 6. An eye tracker that consists of video cameras, transparent hot mirrors (one for each eye), and a computer acquires and processes video images of the eyes and calculates servo driver signals from the eye movement data. The servo drivers move the head-mounted cameras around three rotation axes. One or two (stereo) cameras can be used.

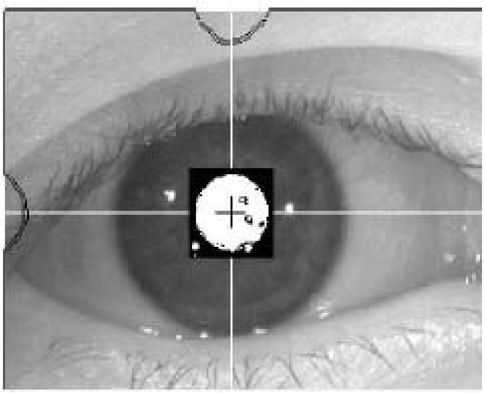

Figure 7. Eye tracking by pupil detection. Intermediate results of the image processing algorithms are shown. Detected pupil pixels are marked with white. A black cross is drawn at the position of the estimated pupil center.

The rotation angle around the line of sight is usually calculated by processing either natural landmarks of the iris [18] or artificial landmarks that are applied to the sclera with, e.g., dark pigments [9]. In the present version of the camera system only yaw and pitch eye movement angles are analyzed online in 2D by pupil detection.

D. Video-based combined and corneal reflection

The method of video-oculography with pupil and corneal reflection determines gaze direction by comparing the pupil position with a reflection of incident light reflected from the cornea of the eye [6]. The detection of pupil and corneal reflection is illustrated.

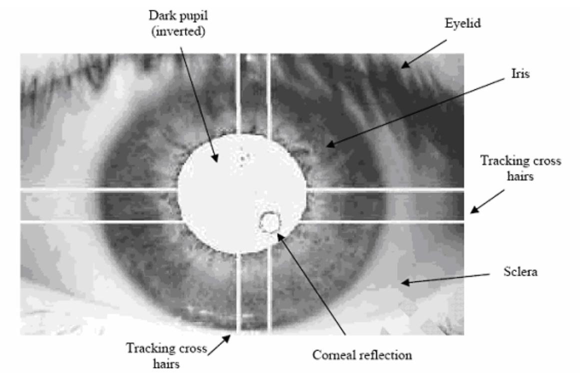

Fig. 8. Pupil and corneal reflection method.

Typically, the gaze-tracking system consists of a single eye tracker box with an infrared light source to illuminate the eye, an infrared camera to capture video of the eye, and automated camera focus and field of vision lens and steering mirrors to track head movements. The method determines gaze position by calculating the changing relationship between the moving dark pupil of the eye and the essentially static reflection of the infrared light source back from the cornea. This approach relies on shining infrared light (to avoid the tracked subject squinting) at an angle onto the cornea of the eye, with the cornea producing a reflection of the illumination source (see figure 8). The corneal reflection tends to remain stationary during eye movements of the pupil; this property typically is used to give a reference point in space for both the pupil and any head movements that might occur. A full system with infrared illumination and detection camera is illustrated (see figure 9).

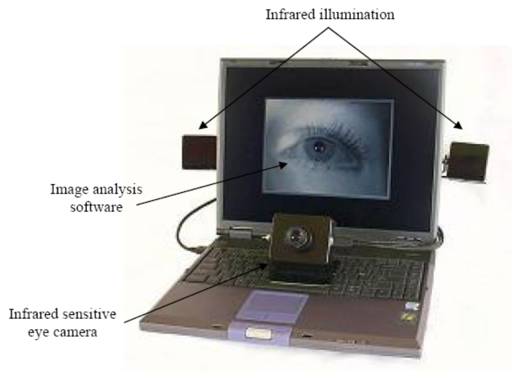

Fig. 9. Pupil and corneal reflection system

III. APPLICATIONS

A wide variety of eye tracking applications exist,

A. Aviation

An example of a recent combined use of relatively new eye tracking technology in a sophisticated flight simulator was reported by Anders [1]. Eye and head movements of professional pilots were recorded under realistic flight conditions in an investigation of human-machine interaction behaviour relevant to information selection and management as well as situation and mode awareness in a modern glass cockpit. Eye movements have also been used to evaluate the usability of specific instruments such as newly developed electronic maps.

B. Driving

It is widely accepted that deficiencies in visual attention are responsible for a large proportion of road traffic accidents [4]. Eye movement recording and analysis provide important techniques for understanding the nature of the driving task and are important for developing driver training strategies and accident countermeasures [17].

C. Visual Inspection

In [6] investigated the utility of eye movements for search training in a virtual environment simulating aircraft inspection. The user's gaze direction, as well as head position and orientation, were tracked to allow recording of the user's fixations within the environment. Analysis of eye movements leads to two observations. First, mean fixation times do not appear to change significantly following training. Second, the number of fixations appears to decrease following training. These results generally appear to agree with the expectation of reduced number of fixations with the adoption of an improved visual search strategy.

D. Others applications

Rehabilitation engineering [10]
Eye Tracking in Usability Testing [13]
Marketing/Advertising [19] , [15]
Copy Testing [11]
Print Advertising [12]
Controlling stimulus presentation in the conduct of perceptual studies [20]

IV. CONCLUSION

The pursuit of the Glance is a very old technique that has been used from last years.

The techniques of pursuit of the glance are same that for years only that now, had fundamentally to the powerful machinery which we have the obtained results are much more remarkable obtaining a pursuit of the glance in real time, due to which the applications to which it also goes destined have varied.

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