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Eye Tracking Computer Control-A Review

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Abstract- *With the advancement in the technology, more modern and advanced devices and computers have been developed. This advancement in technology has necessitated the growth of the economy as well as the business world. However, the advancement in the technology has resulted into negative implications such as accidents that sometimes lead into paralyzing of the whole body of an individual. It may give rise to an end of one's career as since one may not be able to work or walk again. The research paper, therefore, aims at the development of computers that are controlled by detection of eye movements so as to enhance the paralyzed people realize their lifetime dreams. The paper will outline the various mathematical proofs such as linear and polynomial calibration functions. The relevant algorithms necessary for the development of eye-controlled computers will be discussed. Also, the different algorithms will be highlighted which have to be taken into consideration for the proper operation of the eye-controlled computers. The paper will also highlight various techniques that have been developed with an aim of enhancing computer interface so with an aim of improving communication of the physically disabled people. It will also focus on the various types of eye trackers and the basis upon which they operate. The study will highlight the application of eye-controlled computers in the medical field by neuroscientists, physically disabled people and radiographers. The study will end with a conclusion highlighting how the application of the eye-controlled computers has transformed life and a recommendation for the advancement of the eye-controlled computers. It can be enhanced by carrying out more researchers so as to develop new eye-controlled computers.*

Keywords: Eye trackers, eye tracking algorithms, computer user interface, eye movement, eye computer control, eye pixels.

1. INTRODUCTION

The development of Eye controlled computers dates back to the 18th century with the development of an eye tracker by an educational psychologist Edmund Burke Huey. The eye tracker consisted of contact lens that was connected to aluminum pointers. The eye tracker operated by moving along with the eyes so as to track the eye movement. However, these early eye trackers had some shortfalls. They usually made their users uncomfortable as the users had to take care of them whenever worn. Later a non-intrusive eye tracker that operated on the principle of beams of light reflected by an eye was invented [1]. An eye movement camera was later discovered that recorded the eyes motion in a film. During this era, the eye trackers were mainly discovered so as to advance the field of science and engineering. Since then studies have been undertaken to help scientists. These studies are aimed at the development of more advanced eye tracking devices. Today's studies on eye tracking devices are mainly carried out so as to develop new devices that would assist those paralyzed and physically challenged perform their duties and enable them to communicate effectively [2].

2.EYE TRACKERS

An eye tracker is a scientific device that is designed to increase the computer user interface so as to enhance communication and enable one to perform a particular task. These devices operate by the eye movement [3].**Fig 1** below shows the block diagram of an eye tracker.

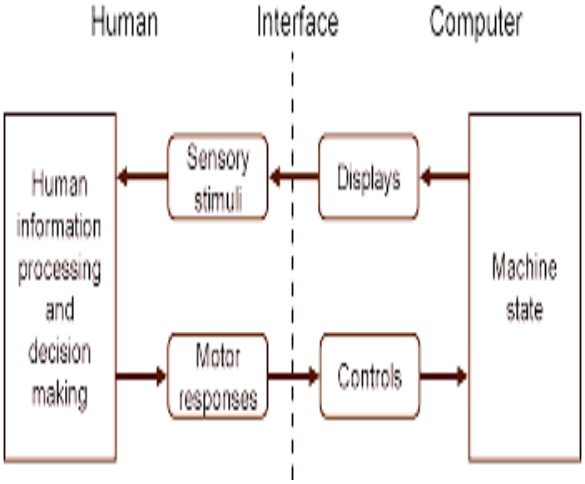

Fig- 1: Eye Tracker Block Diagram

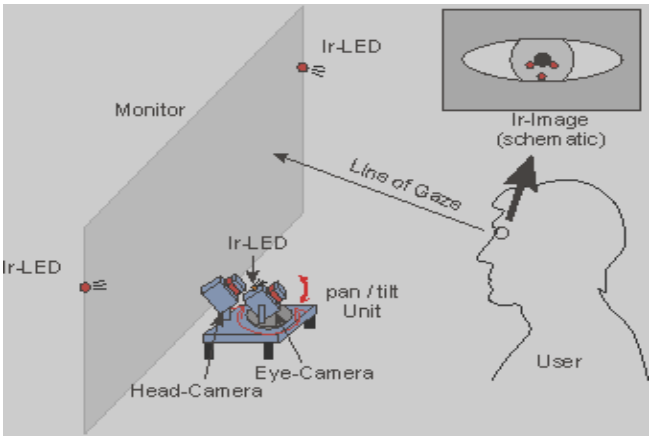

Fig- 2: Optical Tracker

3.OVERVIEW OF THE EYE TRACKERS IN USE

3.1 Eye-attached Trackers

These trackers mainly consist of contact lens with fixed magnetic field sensor. The lens is embedded in a way that it consistently moves in the same direction with the eye thus enhancing the measurement of the eye movement. These trackers are however unreliable as the eye movements affect the magnetic field of the trackers. As a result, the eye attached trackers are not commonly used in enhancing computer interface.

3.2 Optical Trackers

This type of eye tracker is a non-contact device that is commonly used around the world. It consists of a sensor and an LED light source. These non-contact trackers are based on the principle of video capturing of the eye movement that is then extracted by the frame. It was enhanced by the advancement in photonic devices and micro technology such as illuminators and sensors. With the development of optical eye tracker, it freed human being for the discomfort associated with eye attached trackers. **Fig 2** below shows how an optical tracker operates.

3.3 Electric Potential Trackers

The potential electric tracker is based on the principle of Electrooculogram (EOG)[4]. It involves placement of two contact electrodes around the eye. This consists of positive and negative electrodes. The two electrodes measure the eye movement by tracing the movement of the eye's positive pole cornea and negative pole retina. Thus, this device is more widely used due to its potential for tracking the eye movement when in total darkness or when the eye is closed. The trackers are also preferred as it involves attachment of simple, portable and tiny electrodes around the eye. However, the trackers normally are not the best devices to detect the accuracy of where the eye is looking. It is because the devices are affected by the slow movement of the eye.

3.4 Video-Based Trackers

This eye tracker consists of a computer interface that saves and analyzes the eye movement data. Also, it has a video camera that records the eye movements. There two types of video based tracker namely, the remote system where a camera is placed below the computer screen. The head mounted system as the other kind has its camera attached to the frame of the eyeglasses.

4. EYE-TRACKING ALGORITHM

These eye tracking algorithms consists of two approaches that are the model based and feature-based approaches. The feature-based approach operates by the position of the eye by detecting and locating the image features of an eye. The model-based approach, on the other hand, works by identifying the best fitting model of an eye image. This tracking algorithm can give a more accurate estimation of the eye pupil compared to the feature based approach. Thus, the model based algorithm is commonly used in enhancing computer user interface [5].
For each of the model based or feature based approach to be functional it has to the number of eye pixels. It is attained in five stages of the eye tracking algorithm [6].

4.1Algorithm

i. Frame search region stage
In this stage, a rough approximation of the eye position is adopted by the use of potential electric tracker.

ii. Pre-processing stage
This stage involves the identification and estimation of the eye pixels. It is usually done using eye's color properties. The estimation of the eyes pixels is enhanced so as to identify the intensity of the pixels. By doing so, the eye pixels are made more vigorous to lighting circumstances. The pixels intensity is typically estimated using the following formula.
I=0.33*(r+g+b)
Where b, r, and g represent the blue, red and green pixels intensities respectively

iii. Classification stage
The stage involves the identification of intensity of eye pixels from the pre-processing stage. The intensity pixels are either classified as belonging to either to the eye or not by the use of a Bayesian classifier.

iv. Clustering stage
The clustering stage involves the identification of pixels that do not belong to the user and interface eyes that might not have been identified in the classification stage.

v. Post-processing stage
It is the last stage of the eye algorithm which involves combining all clusters with less distance than that of a particular threshold. The threshold distance is calculated as :
{1/72*H} where H is the horizontal camera resolution. Also at this stage there is the elimination of all clusters with greater sizes than the threshold.

Starburst Algorithm is one of the eye tracking algorithm that combines model based and feature based approaches in its operation. The starburst algorithm locates both the eye pupil and corneal reflection by the use feature based techniques. The model-based techniques are on the other hand used in refining the ellipse fit. With the combination of the two features, the starburst algorithm a well and effective computer interface is enhanced by the device. Besides, the algorithm also depends on the detection of the white or black pupil. The device also is used in iris detection if the eye receives sufficient light. The starburst algorithm operates by first removing the corneal reflection and ends up with finding points on the eye pupil contour.

5.MATHEMATICAL EXPLANATION OF THE EYE TRACKER

The eye movements are measured by the eye tracker using either a simple linear or polynomial calibration models (Weber et al., 2013). These two models consist of a standard calibration set ranging from 5 to 9. The linear calibration function is based on the following equation.

$$Sx=a0+a1x$$
$$Sy=b0+b1x$$

Sx and Sy represent the screen coordinates and (x, y) is the pupil corneal reflection vector. The unknown coefficients are a0, a1, b0, and b1 and can be calculated using the least square method.

The polynomial calibration function, on the other hand, is based on the following equations

$$Sx=a0+a1x +a2y+a3xy+a4x2+a5y2$$
$$Sx=b0+b1x +b2y+b3xy+b4x2+b5y2$$

6.EYE TRACKING MEDICAL APPLICATIONS

With the development of the eye trackers, there has been an improvement in studies that are aimed at the improvement of the field of medicine. The neuroscientists have been able to carry out studies concerning the eye movements, brain damage, and neurological diseases. The psychologists, on the other hand, have been able to use the eye trackers in studying human's attention, memory, and language [7].

The eye trackers also are employed by the radiographers in the studying of the human anatomy. It has enhanced the diagnosis and treatment of patients as the eye trackers help them detect the infected parts of the body. The eye trackers also are used to enhance communication of the physically challenged and paralyzed people who cannot communicate effectively [8]. By the utilization of the eye trackers, the physically challenged can communicate through emails and social media without assistance from a third party. Thus, those physically challenged will be in a position to connect with others and live an ordinary life [9].

However, the operation of the eye trackers is mainly affected by the high cost of buying the equipment, and this makes it hard for those physically challenged people and hospitals to purchase this equipment. Another problem that hinders the operation of these devices is the movement of the eye. Unlike the mouse of a computer, it is hard to control the position of the eye consciously and precisely. The operation of such devices is also affected by the complicated calculation and a large amount of data required in the development of these devices. Lastly, the eye trackers may result in discomfort especially the mounted eye tracker devices.

7.CONCLUSION

The research paper explains the evolution of the eye tracker devices, the types of eye trackers and the various stages involved in the application of an eye tracker. From the results, it is evident that eye tracker algorithm is the most effective and efficient device that detects the eye movement. From our paper, it is clear that eye trackers are of great importance more so in medical applications. Hence, more studies should be undertaken to enhance the development of more advanced eye trackers. Hence, enhancing the improvement in the medical services as well as making life more comfortable.

8. RECOMMENDATIONS

From the research it can be recommended that there is a need for an improvement in the eye trackers so as to enhance computer-user interface. This can be enhanced by incorporating the technology with other input devices such as global positioning system (GPS), speech, touch and gesture devices.

This would in turn increase the interactions between human beings and the surroundings.More eye tracking devices should be developed that are simple and cheap to purchase. The technology should also be incorporated in other communication devices such as phones so as to help people appreciate the need for the eye tracking technology.

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