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A Review on Different Methods of EOG Signal Analysis

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ABSTRACT*:* Eye tracking based Human Computer Interaction (HCI) systems are becoming more popular day by day. In these systems Electrooculogram (EOG) can serve as primary source of input. The whole process of measurement of EOG is known as Electrooculography. The fact that the oculomotor system is one of the last capabilities that people suffering from neurodegenerative diseases or trauma retain allows us to develop a system to provide a means of communication for this particular target group. The retinal resting potential causes an electric field around the eyeball, centered on the optical axis, which can be measured by placing electrodes near to the eye. In this paper, we are reviewing different methods which are available for gaze estimation through EOG signals.

KEYWORDS: EOG, EYE TRACKING, EYE MOVEMENTS, HCI, HMI

I. INTRODUCTION

In the last years, there has been a significant increase in the development of assistive technology for people with disabilities, improving the traditional systems. Also, the growing use of the computer, both in work and leisure, has led to the development of PC-associated handling applications, mainly using graphic interfaces. This way, the traditional methods of control or communication between humans and machines (joystick, mouse, or keyboard), that require a certain control motor on the part of the users; they are supplemented with others that allow their use for people with severe disabilities. [6] For example, using voice recognition it is possible to control some instruments or applications by means of basic voice commands or write a text in “speech and spell” applications. Other options are based on videooculography (VOG) or infrared oculography (IORG) for detecting gesture or eye movements, on infrared head-operated joystick for detecting head movements or even on Electrooculographic mouse for displacing a pointer on a screen.

Many intuitive interfaces have been developed which make use of potentials generated from the minute movements in various parts of the body and translated them into control signals for machine commands. However directional movements of eye are recorded and interfaced with computers. This control technique should be useful in multiple applications in HCI as well as in HMI (Human Machine Interface) and many other such applications uses EOG signals as a control signal

There are several methods for sensing eye movement, some are more accurate than electro-oculography (EOG), but most of them are far more expensive and bring much inconvenience and discomfort to users. The EOG method is non-invasive, low cost and easy to use.

A. Eye movements

There are four different types of eye movements, which are fall into two specific categories:

1. Reflex Eye Movement: Eye movements that function to stabilize the position of the eye in space during head movements.
2. Voluntary Eye Movement: Eye movements that function to redirect the line of sight to follow a moving target to attend to a new target of interest.

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There are four basic types of eye movements:

i. Saccadic Movement
ii. Smooth Pursuit Movement
iii. Vergence Movement
iv. Vestibulo-Ocular Movement

B. Electrooculograph (EOG)

The electrooculogram (EOG) is the electrical signal produced by the potential difference between the retina and the cornea of the eye. This difference is due to the large presence of electrically active nerves in the retina compared to the front of the eye. Many experiments show that the corneal part is a positive pole and the retina part is a negative pole in the eyeball. Eye movement will respectively generates voltage up to $16\mu V$ and $14\mu V$ per 1° in horizontal and vertical way. [5]

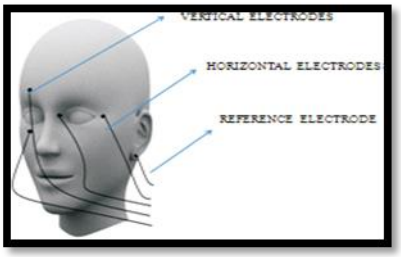

Figure: Electrode placement of EOG [1]

Figure shows the electrode placement of EOG signal. For horizontal channel, electrodes are placed at the both adjutants sides of the eye. Reference electrode is placed at the middle of the forehead. For vertical channel, electrodes are placed at the below and above of the eye.

II. METHODS OF EOG SIGNAL ANALYSIS

A. Pre-processing of Signal

Several EOG signal characteristics need to be preserved by the denoising. First, the steepness of signal edges needs to be retained to be able to detect blinks and saccades. Second, EOG signal amplitudes need to be preserved to be able to distinguish between different types and directions of smooth pursuit eye movements. The median filter performed denoising best; it preserved edge steepness of smooth pursuit eye movements, retained EOG signal amplitudes, and did not introduce any artificial signal changes [1]

For baseline drift removal the author employed level nine 1-D wavelet decomposition using Daubechies wavelets. After applying median filter and wavelet decomposition, square wave pulses of EOG signals are obtained which is useful for the further processing. [3]

B. Feature extraction methods

In this paper, fourteen useful features extracted from two directional EOG signals: vertical (V) and horizontal (H) signals have been presented and evaluated. There are the maximum peak and valley amplitude values (PAV and VAV), the maximum peak and valley position values (PAP and VAP), the area under curve value (AUC), the number of threshold crossing value (TCV), and EOG variance (VAR), which are derived from both V and H signals. EOG signals obtained from three healthy subjects with eight directional eye movements were employed: up, down, right, left, up-right, up-left, down-right and down-left. They concluded that in order to extract the useful features for eyes, VAV, AUC, TCV and VAR features are recommended. [2]

By analysing the shape of different eye movements, they found that the slope of the signal is quite stable for fixations

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and typically increases sharply for saccades and blinks. It also increases for smooth pursuit movements but more slowly. The same applies to the mean velocity, range, variance, integral and energy of the signal. For the latter, smooth pursuit movements evolve more slowly than saccades but faster than fixations. [4]

C. Feature selection methods

Feature selection is important in many pattern recognition problems. Feature Selection improves recognition accuracy by reducing system complexity and processing time. Feature selection is a search problem for finding an optimal or suboptimal subset of m features out of original M features. These algorithms can generally be classified as wrapper or filter algorithms according to the criterion function used in searching for good features. Following algorithms are generally used for feature selection of EOG signal.

The minimal-redundancy-maximal-relevance (mRMR) algorithm is a sequential forward selection algorithm. It uses mutual information to analyze relevance and redundancy. The mRMR scheme selects the features that correlate the strongest with a classification variable and combined with selection features that are mutually different from each other have high correlation. [3]

Clearness based feature selection (CBFS) calculates the distance between the target sample and the centroid of each class, and then compares the class of the nearest centroid with the class of the target sample. The matching ratio of all samples in a feature becomes a clearness value for the feature. Clearness based feature selection (CBFS) algorithm which can be classified as a filter method. Clearness means the separability between classes in a feature. If (clearness of feature f 2) > (clearness of feature f 1), then f 2 is more advantageous to classification than f 1. [1]

D. Classification methods

Classification plays an important role in many real time applications. It is important to automate the classification process since hand processing is often not a viable option. The goal of EOG signal classification is to identify an input pattern with a category or class, which is a set of patterns grouped together based on similarity measures.

The authors classify smooth pursuit against all other movements recorded during the experiment. This is thus a two-class classification problem. They used a k-nearest neighbours classifier (k = 3) and calculated its performance for each five window sizes and for different values of α. They used a 10-fold cross-validation: for each repetition. The classifier's output for each movement was then compared to the actual labels of the movement. [4]

Support vector machine (SVM) is a margin classifier that draws an optimal hyper plane in the feature vector space; this defines a boundary that maximizes the margin between data samples in two classes, therefore leading to good generalization properties. A key factor in SVM is to use kernels to construct nonlinear decision boundary. They implement John Platt's Sequential Minimal Optimization (SMO) algorithm for training a support vector classifier. [1]

III. DISCUSSION

From the above review we can say that, Electrooculographic (EOG) method is preferred for eye tracking because of the following features of EOG: (i) EOG signals can be acquired using cheap and simple electrodes. (ii) Experiments showed that when the gaze vector is within the angular range of ±50° horizontally and ±30° vertically, the recorded EOG signals are almost proportional to the eye gaze displacements. (iii) EOG signals are very fast, thus real time implementation is possible. (iv)The system is operated by human's eye signal command, which contains human decision i.e. intelligence. (v) In comparison to VOG, cameras and other associated devices are costly as compared to devices required for EOG. (vi)The eyes are the origin of a steady electric potential field, which can also be detected in total darkness and if the eyes are closed. (vii) Measurement and processing of the EOG signal are easier than other biological signals like EEG signals, because, compared with EEG signal, EOG signals have greater amplitude.

EOG signal processing requires step by step implementation for the desired output. Identify important a feature from the denoised signal is the first and necessary step for further processing. Having larger number of the feature set lead to the proper classification of signal. Feature selection method is essential to find out the useful features of the signal. Using proper feature selection method, few most useful features can identified which reduce the classification time eventually. Classification is needed to identify different class of eye movements. These identified eye movements can

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be used in many applications based on EOG signal like wheelchair control, video games, rehabilitation, driving simulation, fatigue detection, cognitive science, marketing research, eye typing and many more.

IV. CONCLUSION

From this review we can conclude that wavelet denoising is the one of the most useful techniques for pre-processing. For saccadic movements we can use velocity profiles of EOG signal. But for the smooth pursuit movement identification we need to derive the shape based features of EOG signals. For feature selection CBFS method gives the most appropriate result. Classification can be done by any conventional classification method.

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