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A Review on Classification of Eye Movement using Electrooculography

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Abstract: In the recent trend most of the researchers are payed their attention towards to improving the human computer interaction through EOG. EOG technique using eye movements are playing important role in diagnostic, medical and industrial fields. EOG is based on eye blinks and movements. Eye blinks are typically classified into three categories one is a spontaneous eye blink which occurs frequently, another is a reflexive eye blink which is evoked by an external stimulus, and the other is a voluntary eye blink which is caused by intentional eye closing. EOG is a biosignal technique for measuring the resting potential of the membrane. The ensuing signal is named the Electrooculogram. Eye movements are used to detect were the people look. The main purpose of the EOG is to assist disabled persons. This paper gives an outlook on various works done by the researchers in the field of eye blink, detection, Eye tracking and other eye movements and different classifiers which attempts to classify the eye movement using Electrooculography. Finally it gives a light on various issues related to Electrooculography and its classification techniques.

Keywords: Electrooculography (EOG), eye tracking, eye blinks, Human Computer Interaction (HCI).

I. INTRODUCTION

Eye tracking is the process of electronically locating the point of a people look, or following and recording the movement of the point of look. Electrooculography process is used to measure the resting potential of retina. The voltage difference is measured between cornea and retina .This device measures the voltage between two electrodes placed on the face to detect eye movement [1]. Electrooculogram (EOG/E.O.G.) is a technique for measuring the resting potential of the membrane. The ensuing signal is named the electrooculogram. The human eye is polarized, with the front of the eye being positive and the back of the eye being negative. This is caused by an amount of charged nerves within the tissue layer on the back of the eye because the eye moves the negative pole moves relative to the face and this transformation within the dipole potential will be measured on the skin in micro volts. To translate this voltage into a grip, 2 sets of electrodes are wont to measure the differential voltage within the vertical and horizontal direction and one electrode is act as ground.

Five electrodes are used to measure the signals. The electrodes are pasted with Ag-AgCl. The positive horizontal channel electrode (H1+) was placed on the right canthus of the right eye and the negative horizontal channel electrode (H2-) was placed on the left canthus of the left eye. And the positive vertical channel electrode (V1+) was placed above the cornea and the negative vertical channel electrode (V2-) was placed below the cornea of the eye. The common reference signal was taken from the reference electrode (R) placed on the forehead is shown in Fig.1. These electrodes are placed in the face for keep on watching the eye movements.

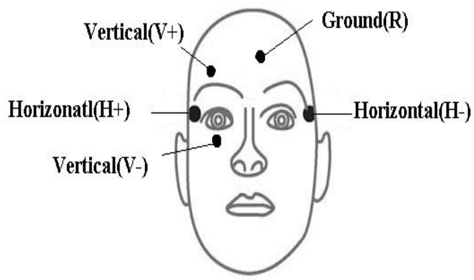

Fig.1. EOG electrode placement locations

The EOG value varies from 50-3500 µV with a frequency range of about DC-100Hz. Its behaviour is practically linear for gaze angles of ±30°. The EOG signal changes approximately 20 µV for each degree of eye movement. Its signal bandwidth range is between 0.1 to 15 HZ, amplitude range is 0.001 to 10 mV with quantization of 4 to 6ts. The frequency range is between 0.1 to 10 HZ. Eye position and motion is controlled by six muscles in each eye. Horizontal eye movements are controlled by the medial and lateral rectus muscles.

Every movement it want the participation of a minimum of 2 muscles as a result of the axis of the orbit and also the muscles of the attention aren't directly in line with the visual axis. Consequently, isolated contraction of the

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superior or inferior rectus muscles or the superior or inferior oblique muscles leads to torsion and deviation of the attention throughout the method of elevation and depression. For this reason, a minimum of 2 muscles are primarily active whenever the eyes are elevated or depressed. Once trying straight up, the superior rectus and inferior oblique act along. Trying straight down employs the inferior rectus and superior oblique.

II. ORIGIN OF ELECTROOCULOGRAPHY

Electrooculography (EOG) signal is one among the helpful electro-physiological signals. This process is used to measure the resting potential of retina. The voltage difference is measured between cornea and retina .This device measures the voltage between two electrodes placed on the face to detect eye movement. The signals provided by EOG using eye movement can be used to control signals in human computer interface (HCI). This device measures the voltage between two electrodes placed on the face to detect eye movement [1]. Emil Du Bois-Reymond (1848) discovered that small positive potential is flow back on the cornea of the eye. The evolution of eye tracking method is boomed after the 18 century. During the 1792 the scientist wells describes that movement of eyes according to the motion of the image. After that Javal (1879) and Lamare (1892) find audible eye movements using an emotionless pairing of the eyes and the ears with a rubber band. In the 1901, Dodge and Cline made the first unremarkable measurements of horizontal eye movements using a photographic method and light reflections from the eyes [2].

III.EYE MOVEMENT CLASSIFICATION

There are two types of classification are applied to classify the eye movements they are before classification and after classification. In before classification raw signals are attempting to categorize by using some standard classifier. In after classification signals are individually categorized by different channels and integrated in to super classifier to perform a single eye movement output.

A. Some Standard Classifiers

Standard classifiers are used to check some limitations on the testing condition. Some standard classifiers are Decision Tree Induction, Bayesian Classification, Neural Network approaches, Fuzzy Classifiers, Genetic Algorithm Based Classifiers, etc. Each category itself consists of several classification algorithms and several individual classification algorithms.

B. Some Biological Motivated Classifiers

Biological classifier is used to classify the signal dynamically in the system. It collected the entire raw signal in to classification network dynamically. The classifier propagates and aggregates information about feature relationships.

C. Section Headings

Many methods are available to classify the features from the EOG signal. The classification can be performed by using Support Vector machine (SVM), Neural Networks (NN), Linear Discriminant Analysis (LDA), Genetic Algorithm (GA) Pattern recognition model, non pattern recognition, Digital signal processing and so on. The Multi Layer Perceptron Network is also used to classify the EOG signal features. Because it's a capability to find out and generalize, smaller training set needs, quick operation, simple implementation and thus most ordinarily used neural network. Some of the HCI developed using EOG has been explained below.

Qiuping Ding et al, (2005) designed an inexpensive user computer interface for helping the disabled persons to communicate with their caretakers using computer applications. EOG signals acquired from 12 subjects aged between 23 to 27 using three electrode systems for right and left task and signals are applied to smoothing and filtering to eliminate noise to contro1 the line of sight for controlling the motor rotation velocity, acceleration and direction of the motor that guide the line of eye. This method replaced the hand operated mouse, allowing users to select icons and menus in a graphical user interface with an average mean accuracy of 93.60% [3].

Adithya Rajan et al, (2006) designed EOG through a two channel signal system for wheelchair control through Neural Network. Commercially analog digital converter is used for digitization with sampling time period less than 10ms. This neural network uses 5 inputs in that 4 hidden layer neuron and one output neuron system. This network detects the eye movements and helps the enable person to judge the absolute direction of wheelchair movement and set raw EOG response.[4].

Ayush Bhandari et al, (2006) investigate a completely unique and straightforward technique for signal acquisition of EOG signals that primarily involves denoising corrupted signals and post process for signal improvement. The non stationary and time-varying EOG signals are processed, development, methodologies anchored on multi resolution analyses and therefore the wave transform theory. This analysis shows that certain primarily based threshold choice for de-noising the EOG signals improves the SNR by 49.65%. Coiflet wavelets are used for resultant removal of noise from the corrupted EOG signals exploitation the construct of constant thresholding. SURE (Stein’s unbiased risk estimate) is employed for threshold choice. Haar primarily based wavelets of upper orders are used for post-processing of EOG signals [5].

Andreas Bulling et al, (2009) proposed embedded eye tracker for context awareness and eye-based human-computer interaction by using wearable EOG glasses. It consists of glasses with dry electrodes integrated into the frame and a little pocket worn element with a strong microcontroller for EOG signal process. The system is additionally used for saccadic eye movements. To complete EOG signal artifacts caused by physical activity

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and changes in close lightweight and accelerometer and a lightweight detector have to be compelled to be used. On the wearable EOG glasses, blinks are detected with a model matching approach: employing a model created manually from example blinks of various persons, blinks are detected by shifting this model over the vertical EOG signal element. Concurrent movements of each eye within the same direction are referred to as saccades. For those segments of the signal wherever the similarity to the model is more than an outlined threshold, a blink is detected and faraway from the signal. Saccade detection is performed and extracted by Continuous wavelet Transform- Saccade Detection (CWT-SD) algorithm. The CWT-SD initial computes the continuous 1-D wavelet coefficients from the signal at scale twenty exploitation Haar wavelet. Typical characteristics saccadic eye movements are 400°/s for the maximum rate, 20 µV for the amplitude and 80 ms for the period. A saccade is detected for all samples wherever absolutely the value of the constant vector exceeds a graduated threshold.[6].

Andreas Bulling et al, (2010a) discovered eye movement activity recognition by applying new methodology. Eye movement activities are recorded by exploitation associate EOG system. They investigate and developed the algorithmic rule for classifying the characteristics of 3 eye movements referred to as saccades, fixation, and blinks. EOG usually shows signal amplitudes starting from 5µV=degree to 20 µV=degree and an important frequency content between 0 cycles/second and thirty cycles/second. The feature choice was in the main supported minimum redundancy maximum relevance (mRMR). Using this they classify 5 activity like repeating a text, reading a printed paper, taking hand written notes, looking a video, and browsing the online by exploitation support vector machine(SVM).They get a mean exactness of 76.1% and recall of 70.5% over all categories and participants. The work show the secure of eye-based activity recognition (EAR) and exposes discussion on the broader relevance of EAR to different activities that are tough, or maybe not possible, to find exploitation common sensing modalities [7].

Usakli et al, (2010) Presented EOG based Human computer Interaction system based on nearest neighborhood (NN). This system was mainly designed with microcontroller and data acquisition system based on CMRR with 88DB, electronic noise 0.6µv (p-p) and sampling rate 176 HZ. Five electrodes were used in this experiment two electrodes were placed above and below of the right eye to measure the vertical movement and two electrodes were placed right and left side of the canthus to measure the horizontal movement. One electrode is placed on forehead acting as a ground. Agcl is used as a conducting gel. This circuitry can be used for measuring the EOG, EEG, and EMG. This system is applied to virtual keyboard to count the character. The speed is five letters/ 25 seconds.[21].

Andreas Bulling, et.al, (2010b) presents a replacement technique to regulate and guide a mobile mechanism. To notice saccadic eye movements and fixations a neural network (RBF) is used. A Radial Basis function Neural Network, which has only one hidden layer, is employed during this work to detect wherever one person is trying as a operate of detected EOG. The network inputs area unit this EOG signal and also the last nine delayed as a result of a RBF tapped delay network is employed and also the network output is the angle of the gaze desired. Finally, the output of neural network is employed to regulate an electrical wheelchair by generating numerous EOG codes. It is necessary to eliminate the irregular resting potential (mean worth) as a result of this value changes with time. To avoid this drawback associate ac differential amplifier with a high pass filter with a cut-off frequency at zero.05 cycles/second and comparatively lasting constant has been employed in this paper [9].

Fuming Fang et al, (2012) develop an efficient means of communication for those who cannot move muscles of the body except eyes using EOG to control speech synthesizer. Signals are acquired for five tasks namely up, down, left, right and centre from two subjects using six electrode systems. Speech recognition technique based on Hidden Markov Model was proposed to recognition the eye movements. Experimental result shows that 96.1% of recognition accuracy is obtained for five classes of eye actions by user dependent system using six channels [10].

Masaki Nakanishi et al, (2012) developed brain computer interface for real life application. This paper review and investigate voluntary eye blink detection using Electrooculogram. The proposed systems detect the voluntary eye blink detection method and apply the trigger switch of BCI systems. These investigate the normal blink, double blink and wink can be detected from both vertical and horizontal EOG signals. EOG signals were recorded with 1000Hz sampling interval. In this study, electrical activities are detected by using four electrodes put on the upper and lower part of the dominant eye, and left and right side of each eye.

The reference electrode was put at the mastoid and the ground electrode was put at frontal lobe. Standard wet Ag/AgCl electrodes were employed. The recorded EOG data were first preprocessed to extract 0.53-15 Hz signals using Fnite Impulse Response (FIR) filter. Secondly, we extracted the EOG segment of 800ms from the time that the fixation cross was appeared on the screen, and EOG segment of 800ms during resting state through visual inspection. EOG signals are resampled from 1000Hz to 256Hz and band-pass filtered at 0.53-15Hz. Third, feature values are calculated, and classified by using SVM with RBF kernel. Eye blinks are classified by support vector machine. The average accuracy with 97.28% was obtained. The best accuracy investigate for voluntary eye blinks obtained for wink with accuracy of 97.69% [10].

Ramkumar et al, (2013) presents Human Computer Interaction using eye movements through

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Electrooculography for HCI with the help of Neural Networks. Two feature extraction algorithms are used to extract the features from raw EOG signals for sixteen eye movements. The signals are classified into sixteen states using two networks namely Feed Forward Neural Network and Elman Neural Network. The performance of the proposed algorithms have an average classification efficiency of 83.36% and 98.50% for Singular Value Decomposition features and 84.60% and 98.46% for band power features using Feed Forward Neural Network and Elman Neural Network respectively. From the results it is observed that Elman Neural Network classifier using band power features outperforms the Feed Forward Neural Network classifier marginally [11].

Ramkumar et al, (2014a) proposed algorithms for classifying eleven eye movements acquired through electrooculography using dynamic neural networks. Signal processing techniques and time delay neural network were used to process the raw signals to identify the eye movements. Simple feature extraction algorithms were proposed using the Parseval and Plancherel theorems. The performances of the classifiers was compared with a feed forward network, which is encouraging with an average classification accuracy of 91.40% and 90.89% for time delay neural network using the Parseval and Plancherel features[12]

Ramkumar et al, (2014b) proposed algorithms for identifying eleven eye movement signals acquired from twenty subjects using static and dynamic networks. Convolution technique is used to extract the features. These features were trained and tested with two neural networks, namely time delay neural network and feed forward neural network. The results obtained were compared with Singular Value Decomposition features for same networks. Classification accuracies varied from 90.99% and 90.10% for convolution features and 90.88% and 89.92% for SVD features using time delay neural network and feed forward neural network respectively. From the results it was observed that Convolution features using Time Delay Neural Network has better classification rates in comparison with SVD features [13].

Ramkumar et al, (2016c) presents paper eleven different eye movement tasks from ten subjects were studied. The proposed Parseval Theorem was implemented for feature extraction. A Feed Forward Neural Network (FFNN) and Time Delay Neural Network (TDNN) were implemented for classification. The average classification accuracies were observed to vary from 80.72% to 91.48% and 85.11% to 94.18 % for the eleven different eye movement tasks for each of the subjects to create nine states Human Computer Interface. The results confirm that dynamic neural networks were more suitable for designing nine states HCI system for disabled person to control external devices [14].

Ramkumar et al, (2016d) presents Human Computer Interface (HCI) to control external devices like computers, wheelchairs, Mouse, Keyboard etc. In this study they focused to increase the possible states of the HCI to nine states from conventional four states. Two new eye movements are proposed. Layered recurrent neural networks are used to classify the EOG eye movement signals. Experimental results validate the feasibility of using EOG for designing nine states HCI [15].

IV. CONCLUSION

Eye tracking by computers is becoming very popular nowadays. This paper attempts to present various techniques that can be used to recognize eye movements using EOG signals and also reviews on different classification techniques used to classify the different types of eye movements.

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