Master of Science

Minimizing Error Rate in Gaze Tracking System based on Electrooculogram using Machine Learning

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Department of Biomedical Engineering

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Minimizing Error Rate in Gaze Tracking System based on Electrooculogram using Machine Learning

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ABSTRACT

Electrooculography is considered the most perceived signal processing system for distinguishing distinctive eye movements or eye-tracking. EOG signal is been utilized for extracting features for making reliable assistance for physically impaired patients. Extracting new features has been common and frequent in EOG studies.

EOG system is less expensive than any other signal processing system and it incorporates disadvantages, which is the error rate. In our study, we calculated the Euclidean distance error and we got significantly less error rate, which is 4.02 cm.

The principal objective of our study is to make a minimum error free EOG analysis. It is likewise less expensive than previous studies and this proposed strategy can be applied for continuous client experience for physically impaired patients inside a base expense.

Key words: Electrooculography (EOG); Eye tracking; Arduino; BCI; Signal Processing

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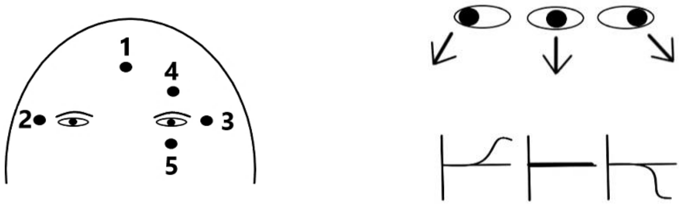
1. INTRODUCTION

1.1. Purpose of Research

The investigation of eye movement detection has presumably been a significant research topic in recent times. In some of the neurobiological disorders, movement of the eyeball is an indispensable symbol for this dysfunction. These kinds of disorders can be tracked by procuring electrooculogram (EOG) signals. EOG can record eye movement throughout sleep and wakefulness. Nowadays, there have several technologies, which help physically impaired patients. In that case, there is an immense number of methods that can enhance the essence of living the life of a physically disabled person. Which will improve their self-sufficiency and movement more stable. Electrooculography (EOG) can efficiently detect eye motion, eye gestures, and movements. EOG can measure the variance of potential between the cornea and retina [1]. They have been employed for different applications such as rehabilitations, robot controls, wheelchair control, and desktop control [2, 3, 4]. Furthermore, it will be supporting several other interfaces for physically impaired patients. Brain-computer interfaces (BCI) provide the users to generate the control commands with their basic thoughts which are generated throughout their brain. There have multiple varieties of BCIs, in this research represents the EOG based non-evasive BCI has been used.

1.2. Significance of Research

The previous studies showed that EOG based multimodal interfaces, which combined with the BCI. Here can be found multiple Euclidean error rates in the multiple stages in different height [5]. EOG is used for only feature extraction [6] where calculating the error rate is less highlighted. It was based on multiple support vector machine regression [7]. Earlier, EOG based human-computer interface has been shown the assistance feature for physically disabled persons. Different movements of the eye indicated the response of impaired persons. Here only extracted the features did not show the error handling of the study [8]. Several studies concern with the extraction of features, which will make physically impaired patients easier. Most cases used SVM classifiers for feature extraction in different eye movements in the state of sleep and wakefulness [9]. We used SVM in our eye-tracking studies, and we got a better result. Classification has been used in several EOG studies. In EOG, deep learning based classifier has been used in sleep stages [11, 12]. EOG signal was differentiated various eye movements of different subjects and extracted multiple feature by using multiple classifier. Classifier has been prominent for detecting the peak detection, blinking detection and rejection, pattern recognition [13]. Moreover, classification method provide an effective method for identifying eye movements (up, down, left, right, up-left, up-right, down-left and down-right) [14]. The Eye writing recognition system has been used classification for performance evaluation over EOG [15]. In our study, we have been used classification method for identifying eye movements through EOG.



(A) **(B)**

Fig. 1. EOG gaze tracking. (A) EOG electrodes positions. 1: ground electrode; 2 and 3: horizontal eye movement; 4 and 5: vertical eye movement. (B) Ocular dipole model shows variation by horizontal eye movement.

EOG is cheaper than any other signal processing system. Many impaired patients cannot effort high ranges technological services. So, the Eye tracker and Brain Computer Interface (BCI) are appropriate system for physically impaired people but their main drawback is their cost. Here, EOG can make affordable for the users and EOG provide better accuracy [16]. A fully reconfigurable bio-potential sensing amplifier can be utilized in EOG, which will helpful for reducing EOG sensor noise [17].

1.3. Background

The aim of the study is Minimizing error rate. It is important in the EOG based research work. However, minimizing the error rate in any study can be enhanced the accurateness of the study. Whether showing new method, which is saccades extraction from EOG data has been used [18, 19, 20]. Detecting eye movement based on EOG renewed in this line of research. Based on EOG and detecting eye movements by using the Euclidean distance is prominent. Several studies detect the eye movements based on EOG by using Euclidean distance. Where presenting new features in different movements of eye such as left and right directions, upward and downward directions and clockwise and anticlockwise directions [21]. Eye tracking based on multiple behavior for developing the intelligent system have been developing [22]. Using forehead based on EOG extracted feature have been done in previous studies [23]. Some other studies only measured the Euclidean distance in various input [24] such as driving safety [25]. However, the error of the Euclidean distance is not presenting most of the studies. But previous research work has found an average Euclidean error of 12.3 cm, which is quiet high [26].

1.4. Electrooculography

Electrooculography (EOG) is a technique for measuring the corneo-retinal standing potential that exists between the front and the back of the human eye. The resulting signal is called the electrooculogram. Primary applications are in ophthalmological diagnosis and in recording eye movements. Unlike the electroretinogram, the EOG does not measure response to individual visual stimuli. To measure eye movement, pairs of electrodes are typically placed either above and below the eye or to the left and right of the eye. If the eye moves from center position toward one of the two electrodes, this electrode "sees" the positive side of the retina and the opposite electrode "sees" the negative side of the retina. Consequently, a potential difference occurs between the electrodes. Assuming that the resting potential is constant, the recorded potential is a measure of the eye's position.

1.5. Human eye anatomy

The human eye is one of the important sensory organs of the human body. It is very sensitive and exposed to various diseases, thus protection and prevention is necessary to keep the eye safe and healthy.

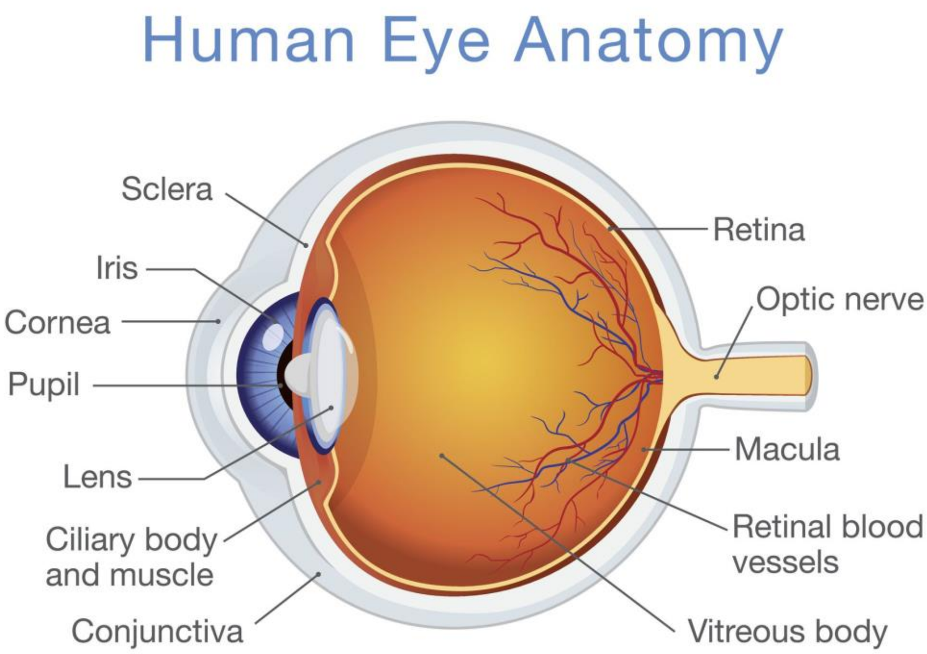


Fig. 2.: Human Eye Anatomy[1]

[1] www.thoughtco.com/

Human eye anatomy in shown in Fig. 2. Three layers of human eye. The eyeball has three coats as given below:

1. External fibrous coat
2. Middle vascular coat
3. Internal nervous coat

1.6. External fibrous coat:

The anterior, transparent, one-sixth part of the eyeball is called cornea. This refracts the rays of light into the eye. Cornea further extends with a membranous structure called conjunctiva. The connecting area of cornea and conjunctiva is limbus. External fibrous coat is formed of cornea and sclera.

Middle vascular coat: This coat is formed by the iris,ciliary body and choroid (anterior toposterior). This coat is vascular and pigmented, underlying the sclera.

Internal Nervous coat: Internal nervous coat is formed of retina. The retina receives an inverted image of the objects seen. These images are conducted to the brain through a nerve called the optic nerve, which is connected at the posterior end of the eyeball.

1.7. Parts of Human Eye:

(a) Anterior chamber: It is the one-third part of the eyeball which is bound by the cornea anteriorly, and the lens posteriorly. It contains the iris and a fluid called the aqueous humour.

(b) Posterior chamber: It forms the rest of the two-thirds of the eyeball, bound by the intraocular lens anteriorly and optic nerve head and retina posteriorly. It contains a gelly-like fluid called vitreous humour.

(c) Pupil: It is an aperture of variable size in the centre of iris, which regulates the amount of light entering the eyeball.

(d) Iris: It is the coloured membrane behind the cornea and in point of lens with an aperture of variable size called pupil. It has a circular and long muscle fibre. Iris is attached to the ciliary body.

(e) Lens: It is a transparent, biconvex structure situated between the iris and vitreous humour. Its function is to focus the luminous rays; these rays form a perfect image on the retina. With age, the central portion of the lens compresses by the surrounding fibres and results in opacity, which is called cataract.

(f) Vitreous humour: This is a gel-like substance which maintains the shape of the eyeball. It is also a refractive media.

(g) Retina: It is a transparent layer forming the inner coat of the eye, it supports the choroid layer. The rays of light, on entering the eyeball, converge and form an image on the fovea—the posterior part of the eye on retina.

(h) Sclera: It is the outermost coat of the eyeball. It maintains strength and structure of the eyeball. It is also known as the white of the eye.

(i) Cornea: It is the clear, transparent, anterior portion of the external coat of the eyeball. The rays of light enter this layer. Cornea accounts for two-thirds of the total optical power of the eye

1.8. Approaches

In the previous study EOG based eye movements varied from subject to subject EOG signals. It's also been shown the Fast Fourier Transform signal and in classification shown the Layered Recurrent Neural Network) LRNN. In our proposed method have been applied subject-to-subject EOG signal and Fast Fourier Transform time signal. We also have been used the SVM and analyzed the performance by single trial [27]. In modern years in several studies have been involved in designing and developing system using electrooculogram with the assistance of digital amplifier and electrodes [28]. Most of the research commonly finding the movements of the eye such as right, left, upright, downright, up and down. Developing a system by using EOG is an common in pervious several studies. In addition, different applications were created utilizing the EOG signal as a control sign to control or command various applications for neural disordered people [29, 30]. In our study, we have been proposed the method where we were minimized the Euclidean error rate. Conventionally other studies without minimizing the error rate, extracting feature and developing system commonly have been shown.

1.9. Overview of Thesis

Most of the research work highlighted the new feature extraction in different possible way without showing the error handling or minimizing of the study. In our research, we have been found Euclidean error 4.2 cm, which is lower than other studies. We showed the error rate of the distance for Euclidean distance. It will provide robust result in our study, which will be helpful for extracting new feature easily. It will provide in a cheapest rate than before. Moreover, we have been used classification method for detecting eye movement accurately through EOG.

2. MATERIALS and METHOD

2.1 Subjects:

Data was collected from one healthy right-handed subject with self-reported normal or corrected-to-normal vision. During the study subject was relaxed. The placement of electrode, data acquisition, set up of the room was pre-processed, shown in Fig. 1. The subject had never faced any previous history of psychiatric, neurological, visual or reading disabilities that can affect this study. During the experiment subject had attention focus toward the visual stimuli. Subject takes part in the experiment in a proper way.

2.2 Apparatus:

Stimuli were presented using a LCD color monitor with 1920×1080 resolution and a refresh rate of 60Hz. The distance of the view was 20 cm. Eye-movement were recorded via a PhysioLab PSL-iEOG-2V-100 electrooculography device and further the ADC port of the Arduino Uno microcontroller is used to convert the analog signal to digital signal with a sampling rate of 1000Hz. For graphical user interface we used MATLAB and Python. We have been used EOG signal processing system for detecting the eye movements.

2.3 Stimuli:

A 50° × 50° visual angel square region was configured with a dark background for the experiment. A green dot target (size ~0.5°) appears at the center of the screen and simultaneously shifts its direction toward each of 5 calibration point at each direction. Similar visual stimuli paradigm also applied in several EOG based eye tracking studies [6, 31]. The direction of the stimuli were right, left, up, down, up-right, up-left, down-right and down-left.

2.4 Experimental Setup:

In our experiment, we have been used one subject and 30 trials for individual trial. We have been used EOG for tracking the eye movements of the subjects. The position of the EOG electrodes was vertical electrode up, horizontal right, vertical bottom and horizontal left. Here we have been measured the eye movements in degree. The signals of EOG electrodes will be in volts and the subject take sits 20 cm from the monitor. The subjects fixed the ball on the center for two second. Then give focus on the next appeared ball at 15 degree for two seconds. Afterword focuses on the next appeared ball at the center and continue for 5, 10, 15, 25 and 30-degree angle for 2s. Maintaining this process, we collected all the eye movements data and successfully completed our experimental session.

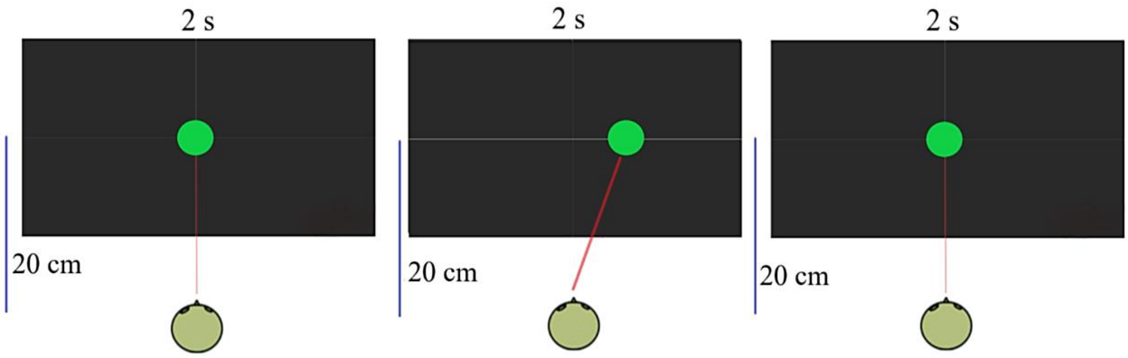


Fig. 3. Eye movement paradigm for the experiment trial, shows the initial target condition for 2 sec then the target dot moves to next visual position, and then back to its initial position.

2.5 Procedure:

Total four function runs were conducted having 5 target stimuli in each direction. Over the four runs each subject gives their gaze attention on total 20 target stimuli. Directions are presented in clock wise rotation across each subject. In each direction condition total 5 green dot targets appears one by one in 5° visual angel displacement. At the beginning of each trial, a green dot target (size ~0.5°) appears at the center of the screen for 2 s. The subjects were instructed to fix their gaze at the target and follow that target when it appears in next stimulus location, shown in Fig. 3. Within each direction (up, down, left, right) 5 possible stimulus location in configured at 5°,10°,15°,20°,and 25°. After 2 s the green dot moves to next stimulus position suppose in left direction at 5°. After 1 s the green dot returns to the initial stimulus position at the center point for 2 s. Then it continues to move at 10°, 15°, 20°, and 25° visual angel and sequentially continues in each direction.

2.6 Eye movements:

Prior to each directional functional run, a five-point calibration point was applied to map eye position to screen coordinates. Successful calibration required an average of visual angular error less than 5°. A fixation point stimuli was presented on the center of screen before each trial run, with the first target in each directional run appearing at that location. Eye movements were recorded continuously via the Arduino Uno microcontroller throughout each run to ensure that normal baseline.

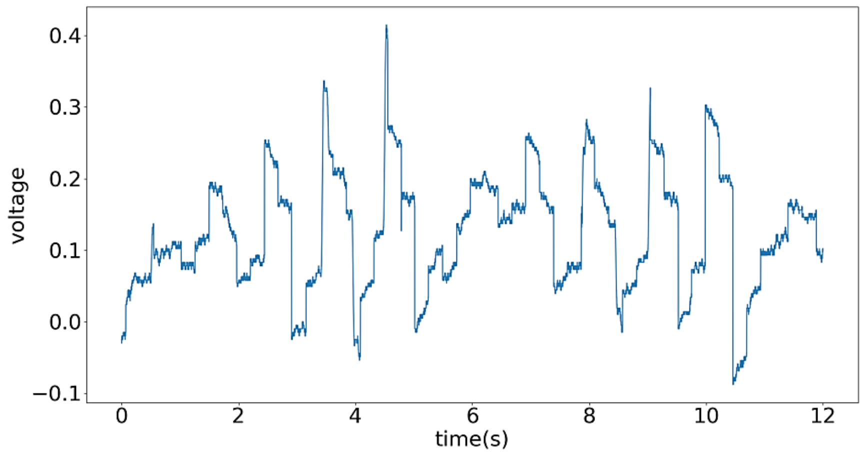


Fig. 4. Sample EOGH signal recorded. Where in each second the target dot moves towards far distance and its corresponding EOG signal also shows higher voltage in higher angel

2.7 Preprocessing and Analysis:

Five electrodes analog EOG signal obtained from each recording site were de-noised using an adaptive notch filtering procedure to minimize contamination with 60 Hz power line noise. Then the analog signal was converted to digital data by connecting the EOG device to the ADC port in the Arduino Uno microcontroller at a sampling rate of 1000 Hz. Each trial (5 visual angels) lasted 1000ms. Across trials the data baseline was first corrected by subtracting the mean value of the pre-stimulus reference interval (200 ms prior to stimulus onset), shown in Fig.4.

2.8 Peck Detection:

The peck detection is a method that considered minimizing the time of calculation and the number of misclassified cases by identifying the peck values of the vertical and horizontal signal. Classification algorithm will detect the peck values of the differentiated signal. The detection of peck value is been utilized to identify the various types of eye movements. In our study, we have been used peck detection to identifying the various types of eye movements by signal.

2.9 Feature Extraction:

In this study, three types of features are extracted from the EOG, including (1) power spectral density (PSD), In PSD the Delta Band shows more higher power in higher gaze angle. Afterword focuses on the next appeared ball at center and it will continue for 5, 10, 15, 25 and 30 degree angles. (2) Discrete wavelet transform (DWT), (3) wavelet coefficients.

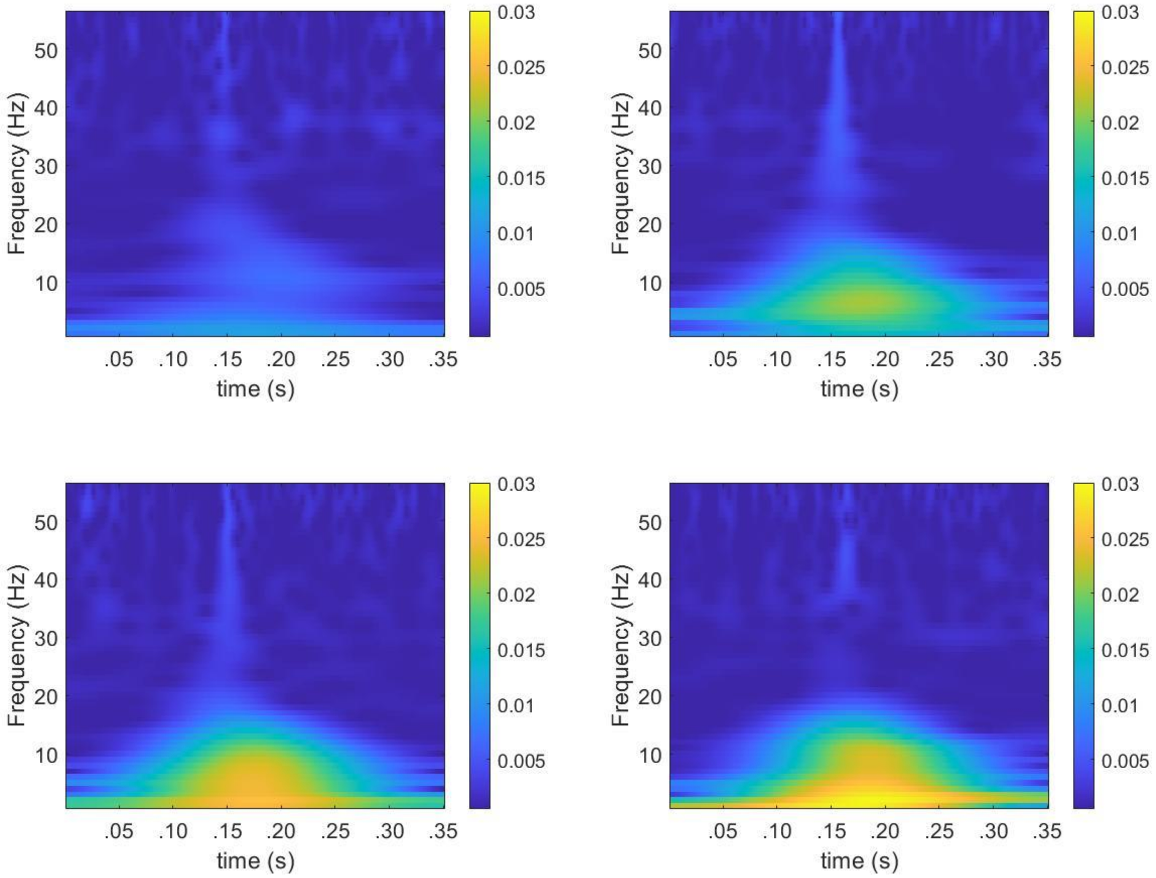


Fig. 5. Power spectral density shows strong power in low frequency band component from 0°,5°,10°,15° in the figure. This feature reveals that low band component from power spectra can make better classification.

2.9.1 PSD

Fast Fourier Transform is an algorithm, which is computes the discrete Fourier Transform of a sequence and inverse. Fast Fourier Transform converts the signal from its original domain to frequency domain. Fast Fourier Transform algorithm is beneficial for actual and symmetrical data analysis. By applying the power spectra in Fast Fourier Transform provides a plot of the portion of signal's power falling within given frequency bins. We compute the power spectra using Fast Fourier Transform (FFT) using following equation,

$$P = \frac{\sum_{fb=fb_1}^{fb=fb_2} P(f)}{\sum_{fb=fb_{lo}}^{fb=fb_{hi}} P(f)} \qquad (1)$$

here, fb_{hi} , fb_{lo} , fb_1 , fb_2 represents the frequency sub-band. Next, the band-power feature vectors are extracted from the power spectra in each of the following frequency bands: delta (1-4 Hz), theta (4-7 Hz), alpha (8-13 Hz), beta (14-30 Hz), low gamma (30-50 Hz), high gamma (70-200 Hz), and all frequency components (1-200 Hz). As shown in Fig.5; the low frequency component, specially the delta band in clearly responding according to the visual angels, we give a special focused on the delta band in this study. Finally, for normalizing the power spectra, we divided all trials into testing trials and training trials, and then calculated z-scores from each power spectra across the training trials for individual channel. To normalize testing trials without using those trials, we calculated z-scores from each power spectra across the testing.

2.9.2 Wavelet Transform

The tools of the wavelet transform are classified into two categories, which are continues wavelet and discrete wavelet tools. In our study we have been used discrete wavelet. The usage of continues wavelet tools is signal and time frequency analysis. The usage of discrete wavelet tools are signal processing, minimize noise, analyzing signal, detection of peak and data compression. Moreover, discrete wavelet transform identify the appropriate frequency band based on the characteristics of the signals. After that, frequency finding the similarities with spectrum, which will increases the time- frequency. In our study discrete wavelet transform the main signal of 10, 15, 20 degree gaze angles and processed the features. Wavelet transform is unique than other signal processing method and properties. Wavelet transform can process signal sparsely and it is a useful tool for feature extraction application and image processing also. Moreover, it will give accurate representation of signal processing. Wavelet transform is an applicable tool for analyzing the EOG signals. The benefit of the wavelet transform is for its much good frequency resolution for lower frequency components, also for its resolution for higher frequency components.

2.9.3 Wavelet Coefficient

A wavelet is a wave-like oscillation with amplitude that begins at zero, increases, and then decreases back to zero. When a wavelet transforms consider a function in terms of oscillations, which are localized in both time and frequency. The estimation or scaling, coefficients are low pass presentation of the signal and the details are the wavelet coefficients. So, the importance of wavelength coefficients in EOG is for representing better signal.

2.10 EOG Signal Classifiers

The LIBSVM toolbox is applied to establish the SVM classifier [32]. SVM classifier is efficacious in high dimensional spaces and relatively memory efficiently. For the classification nu-SVC type SVM is selected and all other parameters are set to default. The z-score of the band power from the power spectra, DWT, and wavelet coefficients are fed separately into the SVM classifier for training.

3. RESULTS

3.1 Simulation Platform

The user was seated comfortably in front of the monitor and he was completed his task as per instruction was given. Five wet electrodes were used to measure the EOG signals and there were five channels to record the EOG signals. The eye movements experiment was consisted of the five parts. The first was a pretest used to adjust the classification parameters and the measurement system according to the user. Second, the aim of identifying the user's eye movements features. Then training the subject on the EOG measurement system. We checked each of the direction fifteen times. In the individual trials, the green dot was in the center of the screen and the center point was the starting point of the experiment. After two second the user were instructed to look towards the green dot that was presented on the screen. After that, another two second the green dot was vanished and a new trial have been started. The user should look on the angle that was instructed for the measurements. By following this instructed experimental procedure, we collected all the eye movements' measurements through EOG signal. So, according to our experimental results of the eye movements the EOG acquisition device can efficiently measure the EOG signals from our five electrodes. In the experiments total 20 target stimuli and 30 trails has been used. In our study, we calculated the distance and measured the distance error. In this research, we minimize the distance error where other studies represent the degree angle, which includes with error. The experimental data analysis of this study is implements in MATLAB. Here, we found that after minimizing the error rate, we represent the possible movements of eye. Which can provide us real time eye movements experience and it will added as a new feature extraction in this research work. In our research we showed that EOG can be make cheaper than previous others research work.

3.2 Applied Classifier

Differentiation and peck detection play a significant role in the classification algorithm. Here, differentiation has been applied to detect the difference of slopes which differentiate the blinking eye and other eye movements effectively. In our study we have been used SVM classifier. Using classifier is prominent for eye movements experimental results. By applying classifier in every angle of the eye movements and we calculated the distance error rate for individual angle.

3.3 EOG Analysis

Detecting eye movements EOG is efficient [33]. In our study we have been used higher positive potential is recorded for higher positive gaze angle and higher negative potential is also recorded for higher negative gaze angle. Here EOGH represents a linear relationship between potential and gaze angle. For measuring the degree of the angle we have been used total 5 stimuli and over the four runs give their gaze attention on total 20 target stimuli. Within each direction (up, down, left, right) 5 location for the stimulus have been used and the degree angle was 5°,10°,15°,20°,and 25°.

After 2 s the green dot moves to next stimulus position suppose in left direction at 5°. After 1 s the green dot returns to the initial stimulus position at the center point for 2 s. Then it continues to move at 10°, 15°, 20°, and 25° visual angel and sequentially continues in each direction. In every two point, we calculating the distance and detecting the error rate of that distance. We successfully made our experimental result and we found minimum error rate by calculating through Euclidean distance.

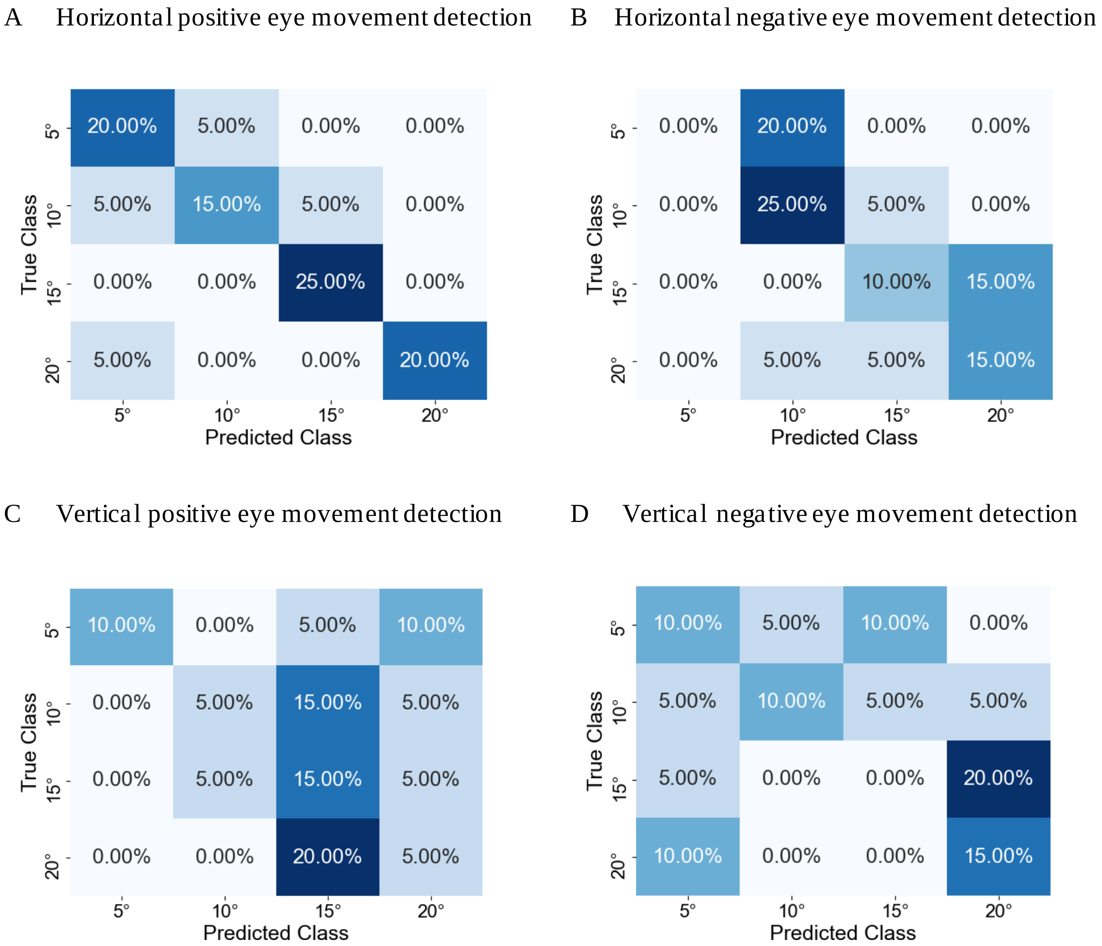


Fig. 6. Normalized confusion matrices of the SVM classification for all four directions. In each direction total four target class is classified.

3.4 Performance Evaluation

In our study, we calculated individual distance between the angles. When the eye movements detected it was count the time of each eye movements. After that, we have been applied SVM classifier. Fig. 6 shows the confusion matrix of SVM classification for four direction using delta band of PSD feature. The performance of the classification is evaluated using the following performance measures:

$$Accuracy = \left(\frac{TP+TN}{TP+FP+TN+FN}\right) \times 100 \qquad (2)$$

Where, TP stands for true positive, TN represents true negative, FP for false positive and FN for false negative. The model achieved 75% accuracy to detect the horizontal positive visual angel of four target stimuli. Where for horizontal negative angel, vertical positive and negative visual angel's the model makes 60%, 35%, and 45% accuracy accordingly, where the random chance label is 25%. Fig. 7 shows all applied features acquire accuracy for detecting horizontal positive visual angels.

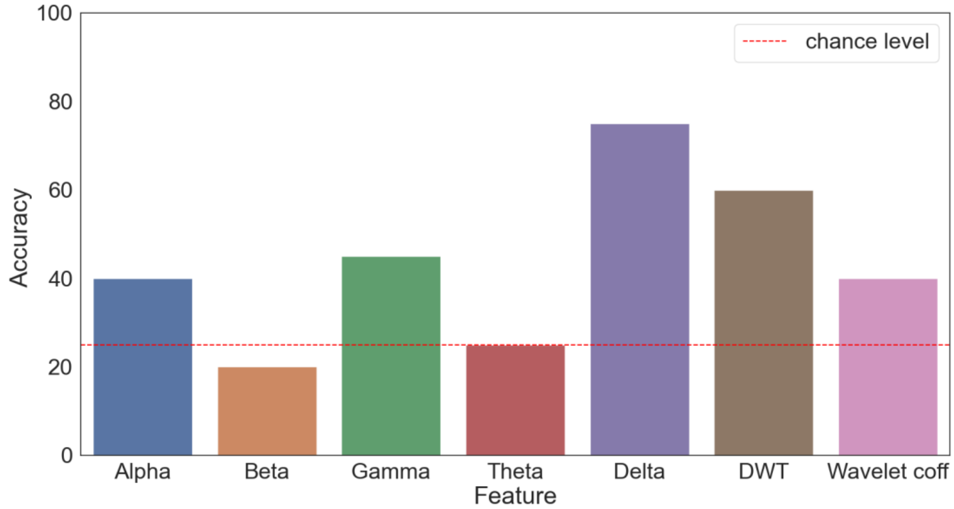


Fig.7. EOGH positive target point classification accuracy from all the features by SMV classifier. There the delta band power from PSD gives highest accuracy

3.5 Euclidean Distance

Euclidean distance calculates the distance between two points. In our study we have been used Euclidean distance for calculating the distance of eye movements. In previous, several studies represent the feature extraction for different EOG research but calculating error rate was not show before. In this study, we collected different angles eye movements through EOG and measured individual distance. Here the target visual stimuli position is the main reference point, where the error rate is measured by the distance error that makes by the classifier. The Euclidean distance error is calculated by given equation (3)

$$d_{err} = \sqrt{\sum_{i=0}^{N-1}\left(V_{ref\,(i)} - V_{unknown\,(i)}\right)^2} \qquad (3)$$

By calculating individual distance we found very low error. Most of the cases the Euclidean error rate was not detected. Here, we found only 1.86 cm error rate for Euclidean distance in horizontal positive direction, and 2.671 cm in horizontal negative direction, as shown in Table 1. In average the horizontal direction Euclidean error rate is 2.265 cm. As the vertical EOG signal does not has smooth linear relation with visual angel, thus the Euclidean distance error is higher than the horizontal direction error. We acquire 6.936 cm and 5.342 cm error rate for Euclidean distance in vertical positive direction, and in vertical negative direction accordingly. In average the vertical direction Euclidean error rate is 6.138 cm. The grand average Euclidean distance error rate achieved using the

Table 1. Euclidean distances error of the evaluation indices. Proposed method shows less Euclidean distance error (cm), and achieves a Euclidean distance error of 1.865 cm on average across all trails in horizontal positive (EOGH+) direction. And in horizontal negative (EOGH-), vertical positive (EOGV+), and vertical negative (EOGV-) direction the mean Euclidean distances error is 2.671 cm, 6.936 cm, 5.342 cm accordingly**.**

Trial	EOGH+	EOGH-	EOGV+	EOGV-
1	1.336	2.667	6.662	3.988
2	1.326	4.028	4.006	5.361
3	4.01	1.326	6.662	8.008
4	1.326	2.667	10.686	5.346
5	1.326	2.667	6.668	3.998
Avg.	1.865	2.671	6.936	5.342

proposed method in 4.202 cm, which is so far achieved minimum Euclidean distance error rate. Lower error rate will provide better user experience, increase usability, extraction feature in a cheapest rate. The cost of the feature will reduce and it will be affordable for any physical impaired patients.

4. DISCUSSION

The results of the different eye movements in different eye angle using SVM classifier indicated the performance of the system was robust across participants. The results also confirmed that our technique successfully estimate the angle and eye movements. Different participants took part in the experiment, provides different angle movement of eye, which made our study more accurate for measuring the distance. After successfully calculating the Euclidean distance, individually measured the Euclidean distance in every angle of the eye movements.

We analyzed the each movements of the eye and verify the patterns collected from the subjects. The performance of the single trial was analyzed by trial by trial. Verified the subjects data separately. The performance of the proposed technique also analyzed and compared the error rate with the previous other studies. The experimental result represents that SVM model was more suitable for identifying and recognizing EOG signal for detecting the eye-movements. Conventionally several studies have been represent the accuracy of the model where in our study we have been shown the error rate. We has been normalized the confusion matrices of the SVM classification for all four directions. In each direction total four target class is classified. We also have been represent the Euclidean distance error of the evaluation indices which has been represent in the Table-1. All applied features acquire accuracy for detecting horizontal positive visual angels is showed in the Figure-7.

Extracting feature we have been introduced three type of feature from EOG. Firstly, the power spectral density (PSD). In the PSD the Delta Band showed higher power in higher gaze angle. Then we considered on the next appeared ball at the center. After that, it continued for 5, 10, 15, 25 and 30-degree angles. Secondly, we extracted the Discrete wavelet transform (DWT) and then we represented the wavelet coefficients. Moreover, EOG signals responded spectrogram and showed strong power in low frequency component.

EOG signal was considered in this study to differentiate various eye movements of the subjects. We have been taken each trail carefully and efficiently. In our study, we have been used EOG signal for successfully measured the every eye movement. EOG bases eye movements system has some advantages. EOG system can detected the eye movements from EOG signal in real time. In that way, EOG can detect every eye movements in a minimum time. EOG is low cost than any other system for detecting the eye movement and it provides effective signal process. By using EOG for eye movements also can be efficient for several feature extraction in previous studies. The feature that extracted through EOG, which can implemented in any other platform easily. Moreover, EOG is the cheapest signal processing system.

SVM classification provides frame by frame comparison of every angle measurements. For every specific result of each participants precision and recall has been used. Here SVM classifier gives results within fastest possible time. Where we got our maximum accuracy 75%. We got minimum Euclidean error rate 4.2 cm for the distance. Other distance of this study provides result errorless Euclidean distance.

5. CONCLUSION

A major challenge of this study is detecting the eye movements in different angle accurately. In this paper, detecting the distance error by using Euclidean distance is the noble work. Here we not only measured the distance but also we finding out the Euclidean error rate for individual angle position in the eye movement's angle. We found 4.2 cm Euclidean error in our study, which is lower than any other previous study [26]. Moreover, EOG provide better signal processing for detecting the eye movements in any reliable eye movements angles. By minimizing the error rate feature extraction through EOG system will be more efficient. EOG is cheaper than any other system and EOG will be effective for the physically impaired patient, which will provide independence in their life. So reducing the error rate, it will create more efficiency and accurateness in our study. Here we were made the error rate minimum and it will make robust the system.

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