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Classification of Eye Movement Signals Using Electrooculography in order to Device Controlling

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Abstract

Electrooculography (EOG) signals contain biological information and some existing techniques were developed to analyze these signals for diagnose of illnesses and some of the physiological conditions like sleep depth, thought conditions and so on. These signals are usually accompanied by noise and different artifacts. In this paper, some of the artifacts are examined to be used as different features of EOG signals. To do this, EOG signals with special and precise physiological experiments, are recorded from 28 healthy people aging from 18 to 26 involving men and women. Then, movement artifacts and other features existing in these signals have been extracted by extreme point strategy and have been classified using K-nearest neighbor algorithm. The goal was controlling some devices such as wheelchair movements to right, left and forward also braking. The proposed method only uses two electrodes and because of its strength in classification, could be a useful method for disabled people.

***Keywords:** EOG signals, artifact, feature extraction, classification.*

1. Introduction

Nowadays, many suggestion and attempts have been done to improve life quality of disabled people with computer and electronic infrastructure. One of these technologies is brain-computer interface (BCI). This system has been designed to record brain signals and send them out to be used in different ways. A typical application could be control of a robotic arm or an electronic gadget [1, 2]. Recording EEG signal while brain doing different tasks also could be used for illness diagnosis. These signals are the result of bioelectric activities in brain with weak amplitude which are recorded by means of proper electrodes and could have different colors depending on the brain activities. Their current ranges from 10 to 100 µV and frequency bandwidth are 0.5 to 100 Hz [3]. EOG signal recorded from head or face is usually accompanied by several noises from different sources; some of these artifacts involve eye movements electro-ocolu-gram (EOG), electro-mayo-gram (EMG), or outer effective body activities or noise from power distribution network [4]. These noises have very large amplitude which must be considered carefully in signal processing. From these artifacts, noise resulting from eye movements has got attention of the researchers and many investigations have been done about it. With this background, feature extraction method and analysis of these artifacts is one the most important challenges in this field [5]. There are many peoples who cannot move their body organs because of some reasons like brain stroke, cerebral palsy, motor neuron disease (MND) or spinal cord injury. As a result, they hardly interact with their environment. Brain EEG signal and face movement signals specially EOG are under investigation to help these patients [6]. Barea et al [7] point to use of

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EOG to control wheelchair. They have proposed a special model with eye movements. EOG signal has been extracted using five electrodes on face connected to a computer on wheelchair. Two of the electrodes have been used for right and left movements and two for up and down movements. In [8], a powerful algorithm is propos to analyze EOG which analysis all eye movements (right-left, open-shut and several blinking). Also, they have devised novel methods for noise cancellation. One of them is quicksort algorithm. The use this method, the noises existing in signal are cancelled to acceptable levels and these fixed signals can be used to control a computer or electronic gadgets. In other works, a method based on independent component analysis (ICA) has been proposed to analyze and omit EEG artifacts which separates muscle activity and eye movement from heart activities and uses them for disease diagnosis and awareness tracking of patients [9, 10].

Although, several attempts have been done on Electronic device control with brain signals; but they suffer from some advantages like too many electrodes on face or head, having to use a special hat on head or significant error on classification of positions. In this work, three eye movements (right and left movement and double blinking) are recorded only by two electrodes. The number of electrodes in this work is an advantage over other methods. For feature extraction, extreme point strategy and polynomial fitting method have been used and eye movement's artifacts have been detected and classified. By using the method proposed in this paper, higher percentage of classification precision is tracked in comparison to the literature.

2. Materials and Methods

In this research, a device called BSA (biomedical signal analyzer) has been used to record EOG signal. Two electrodes in addition to a reference electrode have been connected on the face of subjects as shown in Figure 1. This system has been widely used to specify points on face for electrodes. Sampling frequency for signal recording was 1000 Hz. For 50 Hz noise cancellation, a band-reject FIR filter with cut-off frequency of 50 Hz was used. EOG signal and EMG artifacts are usually bigger in front side of head, so electrodes were used on two sides of the face near the eyes.

Figure 1: Electrode positions.

To do this project, EOG signals from 20 healthy male and female people aging from 18 to 26 have been recorded during different days of the week. Two electrodes as shown in figure 1, connected to specific points of the temporal bone. People asked to be relaxed and feel no stress or other feelings which can affect the results. They were asked to sit on the chairs and do the required eye movements (eye movement to right, to the left and double blinking). These movements were recorded using BSA and a MATLAB code specially developed for this purpose. All subjects did the movements 5 times and recorded movements were classified in three classes as class 1, class 2 and class 3 according to Table 1. EOG samples and related circuit have been shown in Figure 2.

Table 1: Subject's eye movements

Class	Movement Task
Class1	Move eyes to the right
Class2	Move eyes to the left
Class3	Double blinking

3. Preprocessing

Before main processing which is feature extraction from recorded signals, some preprocessing steps have to be done such as filtering, DC component removal and normalization. As mentioned before, because the strongest noise among other is 50 Hz noise from AC mains, a band- reject filter with 50 Hz cut-off frequency has been used to alleviate its effect. Because of the possibility of existence of DC component on EOG; DC component was deleted using the following equation:

$$X = x - E(x) \qquad (1)$$

Where X is DC omitted signal and x and E(x) are the recorded signal and its average value, respectively. Because the recorded signals from different subjects might have different amplitude ranges normalization has been done for the sake of extraction simplicity. After this step, data was in 0 to 1 range. Equation 2 has been used for this purpose.

$$Xn = X - \frac{min(X)}{Max(X)+Min(X)} \qquad (2)$$

Where X, X, Min(X) and Max(x) show the normalized signal, signal from equation 1, its minimum and maximum, respectively.

4. Feature extraction

In this paper, extreme point strategy (signal peaks) has been used for EOG feature extraction. In this method first, all extreme points (minimum or maximum) are detected. If they are more than two, the signal is classified as double blinking (class 3). If sum of minimum and maximum points equals 2, it means movements to the right or left. To separate these movements, time of occurrence of maximum and minimum were considered.

5. Time of occurrence of maximum and minimum

In order to obtain the time of occurrence of maximum and minimum, the find MATLAB function was used. If the maximum was earlier the signal was classified as Class 1 and if the minimum was earlier the signal was classified as Class 2. In this way, the features of the three classes could be determined and used for the classification step. This concept can be seen in Figure 3.

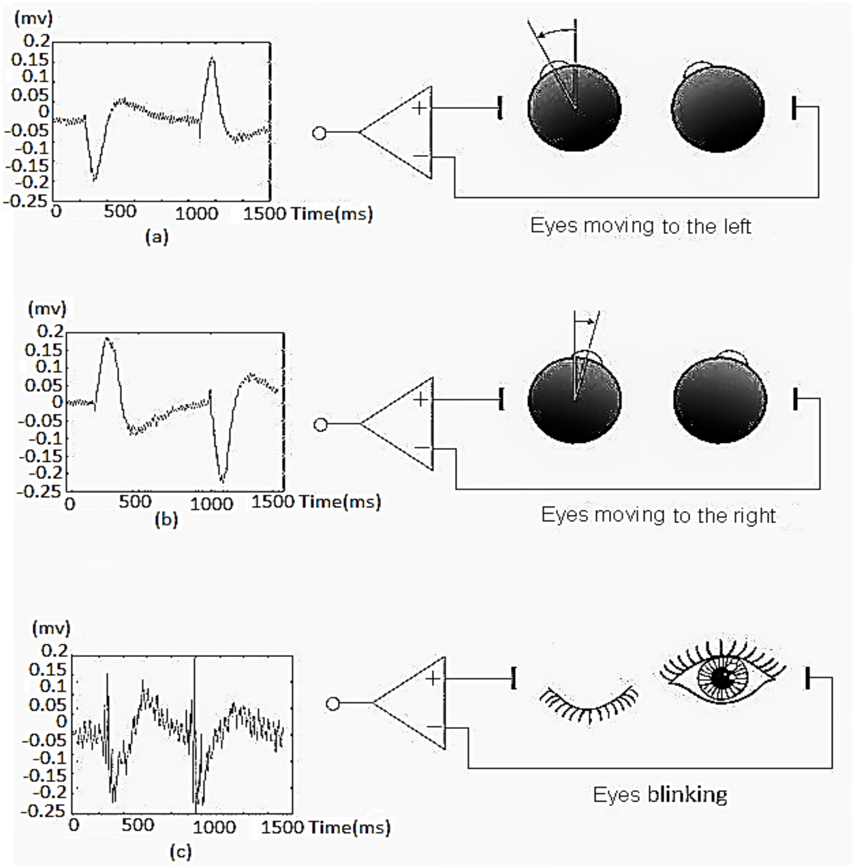

Figure 2: a) Eye movement to the left, b) to the right, c) double blinking.

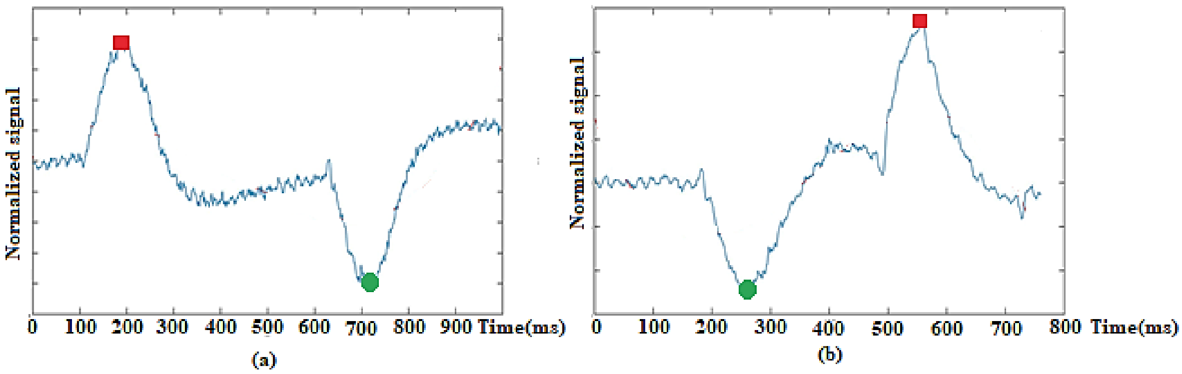

Figure 3: Time of occurrence of maximum and minimum in classes 1 and 2.

6. Classification

In this research, k-nearest neighbors' algorithm has been used to classify eye movement signals. This algorithm has been widely used in research related to brain-computer interface and produces appropriate results. K-NN algorithm is one of the simplest and most efficient algorithms for classification of samples among the others. The general procedure is that at first the parameter k (the number of neighbors) is detected. Then, the distance of unknown sample is calculated with all known samples. After sorting the samples according to their distance and value of k, the class which has the majority of nearest samples is chosen as the class of unknown sample [12]. Among different versions of this algorithm, one the famous version called random sub-sampling has been selected in this paper.

7. RESULTS

Table 2 summarizes the results obtained from the classification algorithm run on extracted features for 5 iterations and 3 different values for k (3, 5 and 7). In addition to truth classification rate, this table shows the False Negative (FN) and False Positive (FP) classification rates. It can be seen from table that the results of classification steps are very acceptable. It shows that the proposed method is appropriate for feature extraction and classification in applications like wheelchair control. Results show that best value for k is 3.

Table 2: Results of classification with different values of k

	***k*=3**	***k*=5**	***k*=7**
Repeat	**Classification correct rate %**	**Classification correct rate %**	**Classificatio n correct rate %**
1	98 FN=3 FP=0	97 FN=3 FP=1	96 FN=2 FP=1
2	98 FN=2 FP=1	97 FN= 2 FP=1	96 FN=3 FP=1
3	97 FN=5 FP=1	96 FN= 4 FP=0	94 FN=4 FP=2
4	97 FN=2 FP=1	97 FN=2 FP=1	97 FN=2 FP=1
5	98 FN=3 FP=0	97 FN=3 FP=1	96 FN=3 FP=0

CONCLUSION

In this paper, a solution was proposed for recording, feature extraction, and classification of EOG signals. It used only two electrodes to receive signals and its correct rate was very high for classification of different eye movements. The main goal of the proposed method was to be used in wheelchair control for disabled people who lack the power to move their body organs like hand or legs. Although, the results could be used for other purposes like controlling a computer, screen of a smartphone or similar devices.

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