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Detection of directional eye movements based on the electrooculogram signals through an artificial neural network

Hande Erkaymaz [a,*], Mahmut Ozer [b], İlhami Muharrem Orak [c]

[a] Department of Computer Engineering, Bulent Ecevit University, 67100 Zonguldak, Turkey
[b] Department of Electrical-Electronics Engineering, Bulent Ecevit University, 67100 Zonguldak, Turkey
[c] Department of Computer Engineering, Karabuk University, 78050 Karabuk, Turkey

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ABSTRACT

The electrooculogram signals are very important at extracting information about detection of directional eye movements. Therefore, in this study, we propose a new intelligent detection model involving an artificial neural network for the eye movements based on the electrooculogram signals. In addition to conventional eye movements, our model also involves the detection of tic and blinking of an eye. We extract only two features from the electrooculogram signals, and use them as inputs for a feed-forwarded artificial neural network. We develop a new approach to compute these two features, which we call it as a movement range. The results suggest that the proposed model have a potential to become a new tool to determine the directional eye movements accurately.

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1. Introduction

Due to the importance of the eyes for a living human, the signals obtained from eyes have become a significant research subject [1]. Especially, an electrooculogram (EOG) is a widely used signal to detect the directional eye movements, some kind of eye defects such as nystagmus in computer–human interface systems, and in various engineering applications such as eye-controlled cursor mouse and wheelchair [2–5]. EOG signals are measured by skin electrodes placed around the eyes with two channels. One of them includes the potential occurred due to the vertical eye movements while the other includes the potential caused by the horizontal eye movements. EOG signals can be influenced by age, gender and environmental factors [6–8]. Especially, these signals are used in human–computer interface systems to make life easier for the patients who are paralytic [9–12].

On the other hand, artificial neural networks (ANNs) inspired from the biological neural networks have been used for modeling of many real systems from the different disciplines such as economy, medicine, engineering, and industry [13]. An ANN has a layered structure consisting of interconnected process units in each layer. Each process unit in the network consists of a simple mathematical model of the neuron [14], and produces an output signal, becoming an input for the subsequent layer. An ANN model may have different connection structures [15–20], and involves a learning algorithm to evaluate its output(s). Among the learning algorithms, the back propagation algorithm, which we use in this study, is the most widely used one [21].

A lot of studies devoted to the understanding of the properties and meaning of the EOG signals involve different ANN models. Guven and Kara [8] showed that EOG signals can be classified into detect the eye disorders by using an ANN model. Banerjee et al. [22] designed a human–computer interface system to detect the different types and directions of eye movements (straight, up, down, right, left, and blink) by using *k*-NN and feed-forward neural network classifier. They have performed classifications based on auto-regressive

* Corresponding author. Tel.: +903722574010
E-mail address: hande.erkaymaz@beun.edu.tr (H. Erkaymaz).

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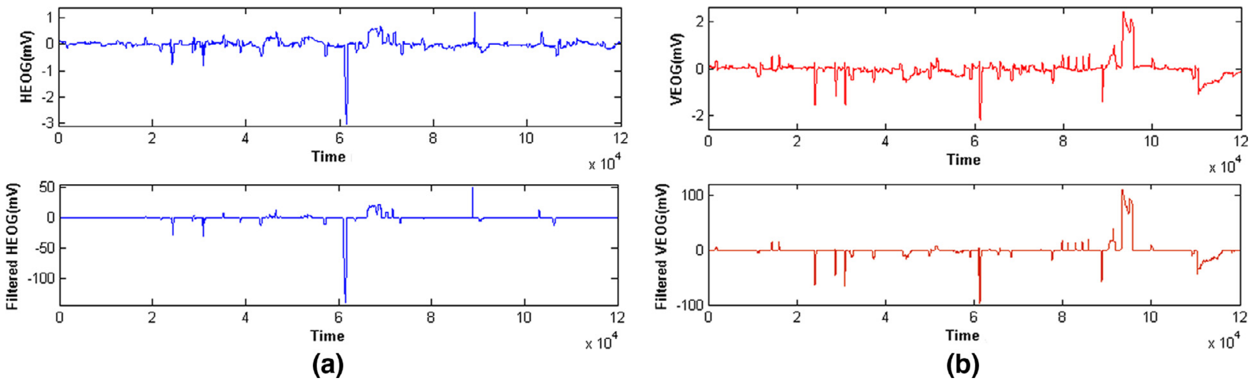

Fig. 1. The recorded (up) and filtered (down) EOG signals obtained (a) horizontally and (b) vertically.

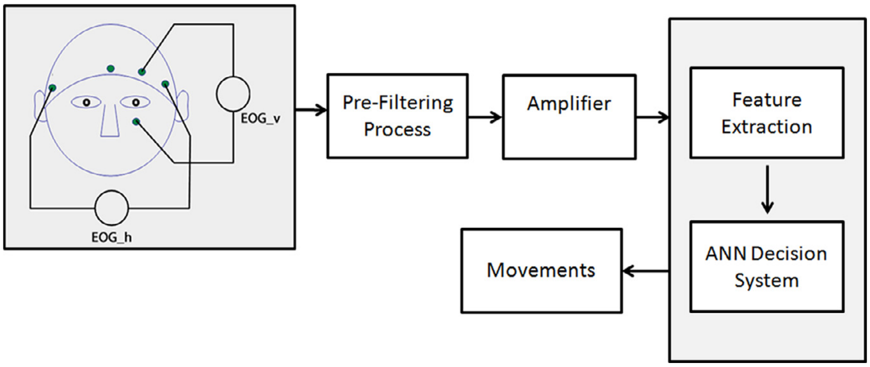

Fig. 2. The block diagram of the detection model for the directional eye movements. It consists of five steps; recording the signals, denoising the signals through the pre-filtering process, amplifying the filtered signals, feature extractions from the amplified signals, and making a decision for the eye movements by using an artificial neural network.

parameters, power spectral density (PSD) and wavelet coefficients as the features of the EOG signal. Barea et al. [23] developed a real-time eye-movement controller involving a radial basis function to detect the eye positions. Park et al. [24] proposed a human–computer interface system for patients suffered from amyotrophic lateral sclerosis (ALS) disease. Their system showed a good performance in determining four directional eye movements: right, left, up, and down. Their system was also able to detect the blinking movement of the eye with a classification accuracy of 87.5%. Tsai et al. [25] proposed an eye writing system using the EOG signals obtained during the pattern recognition of Arabic numerals and mathematical operators, and they arrived at an accuracy of 95%. Aungskan et al. [26] proposed a human–computer interface system detecting eight different eye movements by using a classification algorithm composed of the combination of the first derivative technique, threshold classification, onset analysis, and feature extraction. They attained 100% accuracy for three-subject testing.

The literature survey leaves us with an impression that the most of the studies consider only two or four movements of the eyes. In addition, to our knowledge, there is no any study dealing with the classification of tic movement. Therefore, in this study, we propose a new detection model of the directional eye movements based on the EOG signals through an ANN with a high classification accuracy. The model detects six different eye movements; up, down, right, left, blinking, and tic movements. All computations are performed based on only two features extracted from the EOG signals. Therefore, the model has also an advantage of a computational efficiency.

2. EOG dataset

We recorded the EOG data set by using a two channels BIOPAC MP45 product with 1000 Hz sampling rate during 120 s. The recorded signals are obtained from 10 different people (5 female and 5 male) who are between 19 and 25 years old. The Human Researches Ethics Committee of Bulent Ecevit University endorsed its approval for the study. One of the records are chosen empirically as the best dataset for the training phase. The chosen, sample EOG signals with filtered and 50 times amplified version (bottom panels of Fig. 1), and unfiltered versions (upper panels of Fig. 1) are shown in Fig. 1 for both the horizontal (Fig. 1a) and vertical (Fig. 1b) channel, separately. We also recorded additional EOG signals from eight different people to test the consistency of the performance of the proposed model.

3. The model and methods

We propose a detection model of the directional eye movements as shown in Fig. 2. In this study, an eye direction detection model working with five steps has been suggested.

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