Electro-oculogram based human computer interface system to help handicapped persons

M.A. Fkirin [1], A.S. El-Sherbeny [2], El saadany A [3], S. Badawy [4]

[1.] Faculty of electronic engineering, Menufia University, Menuf, Egypt, mafkirin@yahoo.com
[2.] Faculty of electronic engineering, Menufia University, Menuf, Egypt, easayed@gmail.com
[3.] Faculty of Medicine, Menufia University, Shebin El-Kom, Egypt, aelsaadani@hotmail.com
[4.] Faculty of electronic engineering, Menufia University, Menuf, Egypt, drsamirb@gmail.com
easayed@gmail.com

Abstract: This research is concentrated on the eye gaze and the corresponding electroculographic result signal and how to make use of this signal to command the computer. Several previous techniques for eye gaze detection are mentioned, artificial neural network, numerical integration and a new multipoint detection technique for eye signal manipulation are then explained, and the difference and the advantages of this technique are mentioned. Several applications are implemented based on eye movement. The real time work results assure the high quality of the new technique and its ability to be applied to several applications for aiding disabled peoples.
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1. Introduction

Disabled peoples considered to be an important part of all societies their percentage not small in each country. Statistics recorded the number of people in the U.S. Who are alive in 2014 and have SCI has been estimated to be approximately 276, 000 persons [1].

In this research, the goal is to reduce the effect of this problem to minimum levels with great efficiency with simplest methodology, so as to improve their quality of life as well as provide them more independent life [2].

Several researches carried out to aid in solving this problem, some of these researches on brain electro biological signals -electro encephalogram- "EEG" [3], [4], [5]. Some other researches based on muscle electro biological signals - Electromyogram - "EMG" [4], [6],[7]. Researches based on voice recognition also done [8]. Visual information is also used in several researches [9]. Several techniques based on eye movement detection also used in several researches for this purpose. Eye movement detection is done with several techniques, pupil tracking, corneal reflection, laser Doppler, direct contact and electroocculography (EOG) system [10].

The selected techniques in this research is EOG system, because of the advantages of the system which summarized in the easy to construct using surface electrodes, good face access, low cost, light in weight, good accuracy and resolution, great range of eye displacement and easy to work in real time [11], [10].

Eye anatomy:

The human eyeball is a spherical structure, which is just under 25 mm in all diameters, the eye as shown in fig (1) formed by segments of two spheres of different size: a prominent anterior segment, which is transparent and forms about one sixth of the eyeball, is called cornea, and a larger posterior segment, which is opaque forms about five-sixth of a sphere. The eyeball is formed by three coats: a fibrous outer coat, a vascular middle coat and inner neural coat (the retina). The retina holds the nerve fibers which leave the eye through the optic nerve (clinical anatomy) [12].

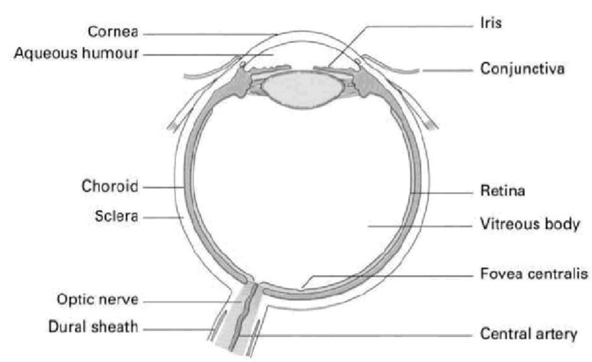

Figure 1. The eyeball in section.

Eye signal:

Electrooculogram -EOG- electrobiological signal is originated due to the large presence of electrically active neurons in the retina compared to the front of the eye as shown in fig (2) [13], this difference generate a standing electrical potential across the eye, making it acts like a weak battery with positive potential at the front of the anterior segment -cornea- and negative potential at the back [14], [12].

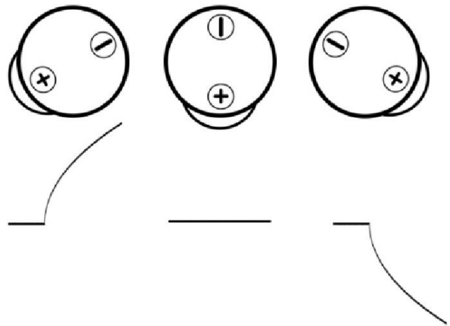

Figure 2. Ocular dipole movements according to eye ball rotations.

The types of eye movements are smooth eye movement, vestibular ocular movement, vergence eye movement, optokinetic eye movement and the measured in this research, fast saccadic eye movement [13].

Problem in eye signal:

EOG signal as shown in fig (3), didn't have sufficient information about eye gaze direction, the signal at each direction, part of it is at the positive side and the other part is at the negative side, with addition the signal contains low frequency, noise at the base line of the generated EOG signal

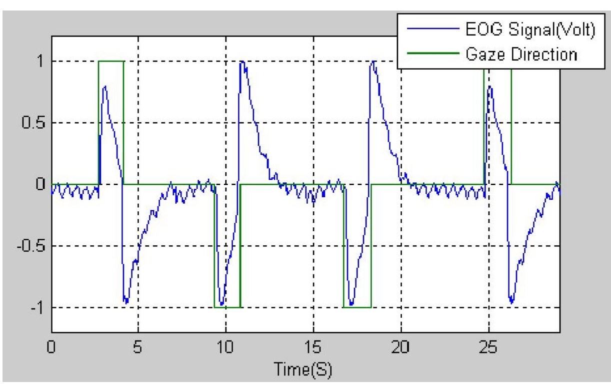

Figure 3. EOG signal generated with respect to eye gaze direction.

Previous solutions:

Several researches efforts done to overcome this limitation in the acquired signal, radial based function neural network is used for getting the inverse eye model [15]. As shown fig (4), the result didn't solve all limitations; the signal still contains two direction polarities at each eye gaze direction. As well as the computation time of neural network in real time systems may affects the system response.

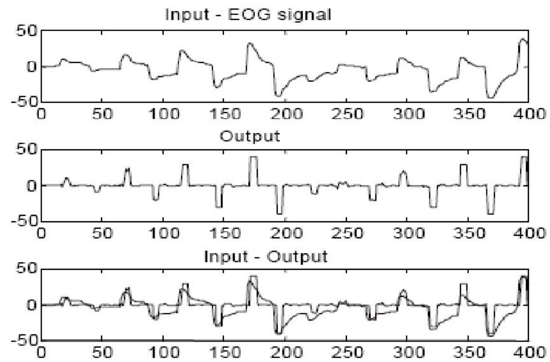

Figure 4. Result using R.B.F.

2. Material and Methods

EOG acquisition system:

According to the characteristics of EOG signal which are, signal amplitude range from 0.5 to 3.5 mV and frequency range from Dc to 100 HZ, with linear behavior for gaze angel range of +30 degree [14]. The acquired signal affected by several interference sources, EEG and EMG, positioning of electrodes, skin electrode contacts lighting conditions, need movements and blinking. These factors affect the signal and may shift the mean value of the signal.

A signal acquisition system was designed to capture such signal with mentioned problems. On AC high gain differential amplifier with 1000 to 5000 gain value, high pass filter with cut off frequency 0.1 HZ, another amplifier possesses an amplification factor of 10:50, low pass filter with cut off frequency at 100 HZ and Ag-AgCl floating metal body surface electrodes are used [2], [11]. The designed acquisition system is equipped with an optoisolation method to provide safety rating and reduce hazards to zero [10].

Our designed signal system depends on simple construction with powerful results, system depends on the change in gaze direction using the detection of the horizontal changes and system achieved by placing only three electrodes, two electrodes placed on the outer side of the eyes and the third electrode placed on the forehead as reference electrode.

Preparation of training data:

The acquired EOG signal is processed and sampled at rate of 50 samples per second. Data are collected in real time from human eye using LabVIEW software. More than one EOG signal data files are saved from group of peoples. EOG delta files are used in offline algorithm building, and then all built algorithms are then tested in real time.

EOG detection methodologies:

- *Artificial neural network:*

Researches in scientific disciplines are using artificial neural networks to solve variety of problems in wide area of fields as pattern recognition, prediction, optimization, modeling and control [16]. Artificial neural network can be used for modeling linear and nonlinear systems. Number of researches has been published showing that feed forward network of multilayer preceptors type with single hidden layer, where each unit in the hidden layer has continues sigmoidal non linearity can approximate well continues functions [17].

A feed forward N.N as shown in fig() with only one hidden layer is used to model EOG signal, 32 input nodes and 64 hidden nodes are used, and Back propagation algorithm is used in training the N.N.

If we consider the parameters of the N.N are:

I: N.N. input.
WI: input weights.
WO: output weights.
E: errors.
LR: learning rate.

So the network output is calculated as:

$$N\,O = [\tanh(I\,T.WI)].WO \quad (1)$$

, calculating the parameter HO:

$$HO = [\tanh(I^T.WI)]^T$$ - the outputs of the hidden neurons (2)

Errors:

$$E = NO - DO \quad (3)$$

Where DO is the desired output of the N.N then the equations for weight adjustment are:

$$WO = WO - (LR \times E \times HID) \quad (4)$$

$$WI = WI - [LR \times [E \times WO \times (1 - HID)^2].I\,T]^T \quad (5)$$

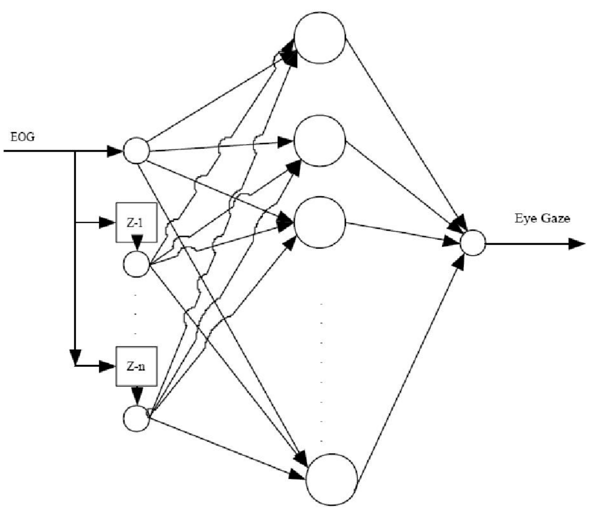

Figure 5. Feed Forward Neural Networks.

- *Integration:*

Numerical integration can be used efficiently in many mathematical functions that can't be integrated by analytical methods, as well as the signals which unknown its generation function such as our EOG signal. There are three methods of finding the area under curve, trapezoidal rule, mid-ordinate rule and Simpson's rule [18].

Mid-ordinate rule used in EOG integration, this rule didn't depend on the final point of the integrated signal, so it can work in real time. As shown in the fig (6) the interval width d assumed to be the sample period and the height equals to each sample value. Finally the integration is calculated according to the rule equation:

$$\int_a^b y\,dx \approx dy_1 + dy_2 + \ldots + dy_n \quad (6)$$

$$\int_a^b y\,dx \approx d(y_1 + y_2 + \ldots + y_n) \quad (7)$$

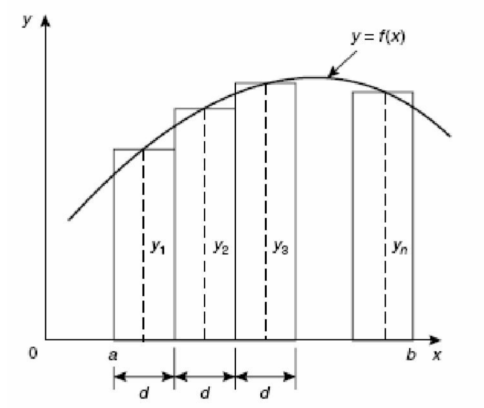

Figure 6. The mid-ordinate rule curve.

- *Multipoint detection technique:*

This new technique depends mainly on the shape of the signal, according to the shape of acquired signal multipoint is used to extract information from it.

According to fig (7), the procedures of these techniques as follow:

a. Acquire the signal.
b. Normalize the signal.
c. Cross over levels determination.
d. Detection points placement.
e. Real time programming.

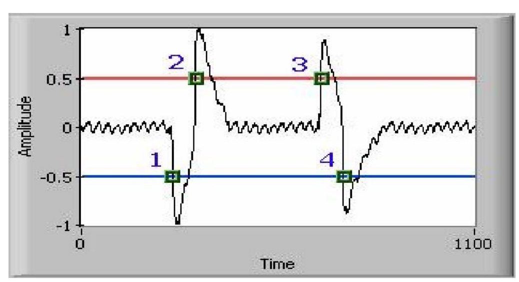

Figure 7. Multi point Detection Technique.

The great advantages of this technique are the simplicity with powerful results, calculation time consumption and generalization over EOG signals.

3. Results

- *Artificial neural network:*

Neural network model structure, learning process and testing is done using LabVIEW 8.6 program. At learning process, weights are adjusted to yield minimizing the global error.

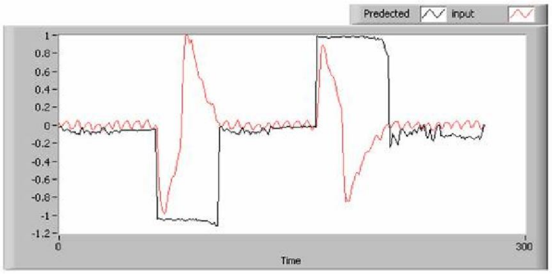

Figure 8. Neural Networks Model Result.

Fig (8) shows the result of NN model, EOG signal is the input and the eye gaze direction is the output of N.N model. As shown in fig(8) the model gives good results over the training signal, but at testing with and their EOG signal, unwanted output generated as shown in figure (9).

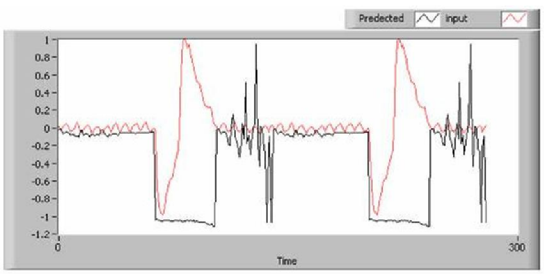

Figure 9. Neural Networks model real time test.

- *Integration:*

Fig (10) clarifies the ability of numerical integration in classification the eye gaze direction from EOG signal. A threshold noise can collation level is used to eliminate the shift of the base line of the integrated signal. Integration and signal processing is done using MatLab Program.

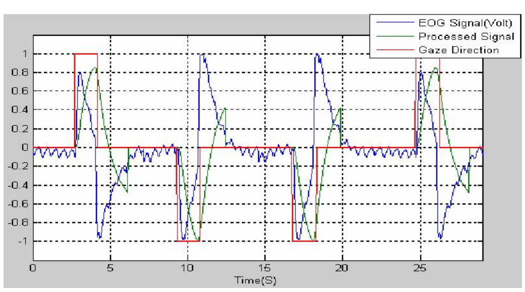

Figure 10. Neumerical Integration Results.

- *Multipoint detection technique:*

Real time results shows that this solution gives best results because of this technique is easy application on any electro biosignal -EOG- of the eye, no matter what the shape of the acquired signal, unlike the neural networks, new network will be needed to be built for each signal as well as the training of the network, integration also will be In need to be processed more according to the resulting signal. Also this is quick to be programed thus it takes short time in the execution unlike other methods that takes a time in calculations. For these reasons, the practical results proved that, the multipoint detection method faster and easier.

Fig (11) shows eye mouse, eye document reader, eye game and eye robot with eye wheel chair as an applications that work at real time upon this technique.

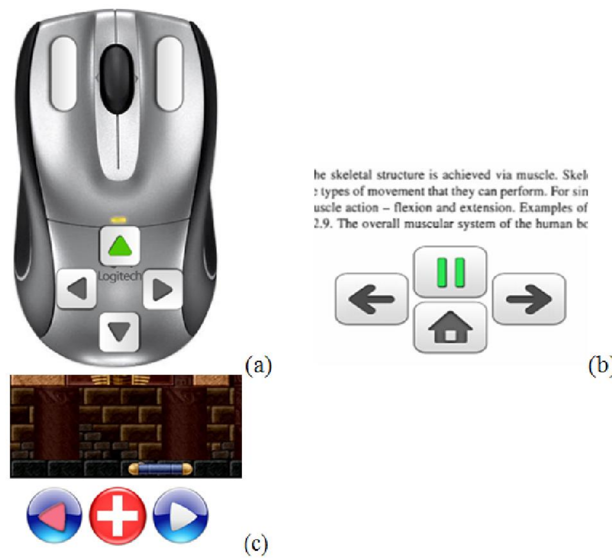

Figure 11. Multipoint Detection Technique application results,(a) eye mouse,(b) eye document reader, (c) eye game.

4. Discussions

According to all that mentioned in this paper the conclusions can be listed as:

First, neural network, numerical integration and multipoint detection technique are used to extract EOG information about eye gaze direction. Second, multipoint detection technique proved that it is the best way to carry out eye computer interface applications, this demonstrated by the practical results. Third four applications are designed for helping disabled peoples depending on eye movement.

Corresponding Author:
Dr. A.S. El-Sherbeny
Department of Industrial Electronics and Control Engineering
Faculty of Electronic Engineering

Menoufiya University – Egypt.
E-mail: easayed@gmail.com

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