ELECTROOCULOGRAPHIC SIGNALS: AN ASSISTIVE TECHNOLOGY APPLICATION CONTROLLING MOUSE COMMANDS

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Abstract: *The human computer interface (HCI) based on biopotentials, has attracted more and more attention of researchers all over the world in recent years. This paper describes the development of a system for acquisition and processing of electrooculography (EOG) signal in order to perform a real time emulation of a mouse commands. The results obtained may allow improvements of life quality, aiding people with severe physical disabilities, by providing them the ability to communicate using only eyes movements.*

Keywords: *Electrooculography, Signal Processing, Assistive Technology, Biopotential Signals, Biomedical Engineering.*

Introduction

According to World Health Organization, there are millions of people worldwide, who due to physical, sensory or mental damage lose part or full control of body muscles. This data is about spinal cord injury, which estimates an annual global incidence of 40 to 80 cases per million population. [1] In some cases of spinal cord injuries and correlated diseases, as well as the incarceration syndrome and amyotrophic lateral sclerosis, people eventually lose control over the body movements, remaining only the eye movements control [2]. Considering these people needs, such as to communicate and perform simple activities, aiding their development, it is worth to attempt the creation of an inexpensive homemade device capable of allowing users non-conventional computer interaction, by using only their eyes movement. The creation of this device/prototype appeals communication between the subject and environment, providing favorable living conditions for both patients and friends, also family who lives daily with people affected by those before mentioned conditions.

Electrooculography measurement technique, the method, that captures the existence of small electric potential between the cornea and retina, known as electrooculographic (EOG) signals [3], is an inexpensive method for mobile eye movement recordings; it is computationally lightweight and can be implemented using wearable sensors [4]. Sensors, in this case, are electrodes placed around the eyes, which pick up EOG signals. The processing of these signals allows knowing the direction of gaze and blinks movements recognition. Thus, this work aims the creation of a prototype to replace the conventional mouse-based control for EOG signals, i.e., a system that allows capture the EOG signals, doing the bio-data processing and performing the emulation of a mouse commands from these signals, using knowledge from biomedical engineering course at UFU.

The following work enables the user to move the cursor on the screen and perform operations that generate corresponding commands to single and double clicks and clicks with the right mouse button. Therefore, the goal is to improve the life quality of people affected by severe motor disabilities through access to several resources available on a computer, interacting and communicating in a simple and quick way.

Besides recording EOG signals attends easy electrodes placement, due to eyes vicinity be full of facial muscles and very close to the brain, the different signals may affect each other by creating artifacts. Its features may afford misinterpretations among EMG and EEG signals.

Nowadays, applications of capturing EOG signals are usual in the investigation surveys of the human oculomotor system as a diagnosis method. Often uses of EOG happen for recording eye movements in sleep and dream research, in recording eye movements of infants and children method, in addition to evaluate reading skills and visual fatigue [5]. A modern relevant study is highlighted in Borghetti *et. al.* [6], which approached a system for writing by using two EOG channels (vertical and horizontal).

Materials and Methods

The stationary dipole, shown below, at the center of Figure 2, may allow measuring the position of the eye by placing surface electrodes on the left and right eye (disposable electrodes of silver/silver chloride – Ag/AgCl). When the gaze is straight ahead, steady dipole is located symmetrically between the two electrodes, and the output EOG signal is zero. When the gaze shifts to the right, the cornea nearest to the right electrode, which becomes more positive, as shown in Figure 2. Electrodes might also place above and below the eye for obtaining vertical eye movement [5].

Therefore, knowing the position of an individual's head, the EOG signals may provide finding the direction he is looking at. There is an, almost linear, relationship between the angle of the gaze and the EOG signal to movements of approximately 30º [5], also for each 1 degree of eye movement, there is a variation of about 20 microvolts (μV) in EOG signal [3].

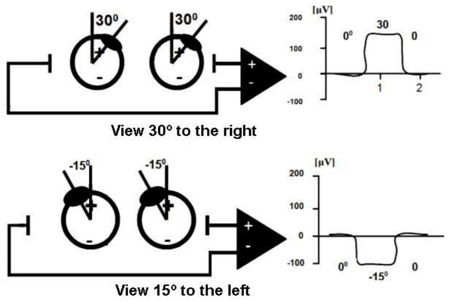

Figure 2: Corresponding Signals to Eyeball Rotation [3]

Regarding signal features, its amplitude varies between 50 µV up to 3.5 mV and the predominant frequency is in the bandwidth of 0.1 Hz to 35 Hz [3].

EOG signals records are susceptible to several artifacts, such as electrode and cable movements, ambient lighting, which must be treated. On the other hand, the advantage of handling it, is deal with low discomfort by the user, also it is a method for use under low light levels conditions.

Overview of the developed System – Initially, the system picks up electrooculographic signal by disposable sensors and send it to a surface conditioning system. Due to the low amplitude of the signal collected, it runs through the following processes: a pre-amplification stage, a pre-filtering, a second stage of amplification and filtering itself, composed of analog filters to remove undesired signal frequencies. Then, the signal passes to the stage at which the digitized analog-to-digital conversion, and signal transmission to a computer via a Universal Serial Bus (USB) is performed using a microcontroller. The completely physical system is compound of two fiberglass electric boards, being one responsible for power supply and one for the conditioning system.

The computer software makes the signal gathering, which one consists of three modules: a module for signal processing, a user interaction module and a visualization signal module. The Figure 3 shows the general system block diagram.

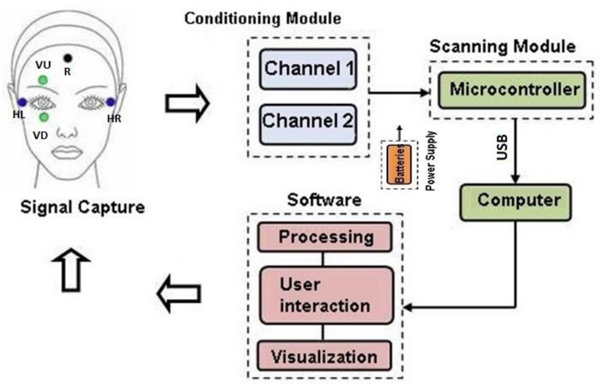

Figure 3: General System Block Diagram

In Figure 3 is also possible to see the correct positioning of the electrodes, to measure horizontal movements, the two blue ones (HR and HL) indicate the horizontal placement to detect horizontal eyes movements, at the ends of the sphenoid bone. Two electrodes (VD and VU), colored green in Figure 3, placed in this way to collect vertical eyes movements, and the reference electrode (R) places at the frontal bone, as shown in Figure 3 as a black dot.

Eyes under rest conditions will effectively stimulate electrodes on the same potential and there is no capturing voltage. Under eyeball rotation conditions, generates positive and negative pulses, such as shown in Figure 2.

Conditioning Module - The conditioning system consists of two differential channels. Because of the low amplitude, the signal collected in each channel passes through a pre-amplification. At this stage, an instrumentation amplifier (INA121), which has very high input impedance, low output impedance and common mode rejection ratio (CMRR) of 100dB, is used. In this first stage of amplification, 10 times gain reaches the signal. Then, the signal goes to a pre-filter, a passive high-pass, cutoff frequency settled 0.1 Hz, to remove the continuous level, mainly those related to the half-cell potential. Then, there is another amplification, summing up the gain of the collection system results in 2940 times. After this, two three-pole low-pass, Butterworth, cutoff frequency equals to 35 Hz and another one-pole high-pass set as 0.1 Hz cutoff frequency. Then, there is a high-pass filter providing decreased offset levels generated in previous stages. The EOG signal in this module has as reference the ground and it operates in a range between -2.5 V and 2.5 V.

Scanning Module - At this stage, the microcontroller PIC18F2550 performs 10 bits resolution, 5 V full scale, resolution of 4.9 mV and a maximum input error to analog-to-digital conversion (ADC) of 2.4 mV. This component is responsible for performing ADC, based on a 2.5 V reference voltage and transmission of signals to the computer via USB. Thus, the EOG signal range in this stage is set 0 to 5 V, due to a 2.5 V DC added through a voltage divider, buffer and a voltage adder circuits. Agreeing with *Nyquist Theorem*, the sampling rate set is 150 Hz.

Power Supplies - The power supply system uses two batteries (9V) in order to make it more independent, secure to the user and reduce the amount of noise. Dimmers (LM7806 and LM7906) set up the voltage to -6 V and 6 V, allowing the battery power supply to the conditioning module and signal acquisition process. The hardware power supply is through the battery and the digital part is isolated in the ADC stage and fed by the USB power terminals; then the analog part does not share the same power supply from the ADC stage, so it comprises medical safety to the patient (user).

Software - The design of the software uses C# programming language and development platform Microsoft Visual C # 2008 Express Edition. Due to the need for real-time processing and the amount of data involved, it was necessary to use concurrent programming. The Producer thread collects the data and stores it in a *buffer1*. To make this collection, this thread down the HID protocol communication with the microcontroller. The *Consumer Thread* accesses the data *buffer1*, processes it in order to extract the commands, displays the data in *buffer2*, and unloads them so that allows saves. The developed software has three modules: *Signal-processing module*, *Interaction with User Module* and *Display Module Signal*.

Digital Signal Filtering - Before extracting the digital command, occurs the signal filtering by a low-pass filter of the moving average type for elimination of possible noise, its cutoff frequency is 30Hz, by diving the sampling rate (150 Hz) and the size of sliding windows (5 samples) [8]. Thus, eliminates high frequency noise without losing spectral content required for the commands recognition.

The moving average filter shows up some shortcomings related to other filters such as Butterworth, for example, but characterizing simplicity, ease implementation, consume little computational effort, it still is effective in filtering random noise. These characteristics are important to consider in the design of real-time systems factors. The Butterworth filter, for example, is at least 15 times slower than the moving average filter [7].

Processing Module – To perform extracting commands, by means of amplitude and time thresholds, the detection of a certain number of samples occurs, which ones reach a threshold value higher than an eye movement. The threshold determination making, on a trial and calibration basis, happens in order to maximize the amount of hits.

Therefore, the recognition of X_V as the channel sample value detecting vertical movements, and the channel sample value X_H detecting the major horizontal movement commands are explained at Table 1 below.

Table 1: Major commands Recognition

Conditions	**Recognized Command**
Xv > 300mV during t > 97,5 ms	Looking up
Xv < -300mV during t > 39,0ms	Looking down
X_H > 300mV during t > 65,0 ms	Looking to the right
X_H < -300 mV during t > 65,0 ms	Looking to the left
Xv > 700mV during t > 6,5 ms	Simple blink
Xv > 300mV during t > 97,5 ms	Looking up

The Refractory period adoption is important, providing at this term, non-recognition of user commands. Additional commands perform are added to increase the system functionality. Above commands combinations set recognition of secondary commands, as shown in Table 2.

Table 2: Secondary commands Recognition

Conditions	**Recognized Command**
Look up and to the right during t < 975 ms	Look to the upper right corner
Look up and to the left during t < 975 ms	Look to the upper left corner
Look down and to the right during t < 975 ms	Look to the lower right corner
Look down and to the left during t < 975 ms	Look to the lower left corner
Two consecutive blinks during t < 325 ms	Double blinking
Three consecutive blinks during t < 487,5 ms	Triple blinking
Four consecutive blinks during t < 650 ms	Four times blinking

User Interaction Module – The development of a simple user interface is shown in Figure 4. This interface is similar to a tool bar and placed at the top of the desktop screen. This allows quickly and directly user interaction with the software and it can interfaces other software and applications freely.

Figure 4: Software Interface

The main use cases of the software are Check connection: check the device connection to the computer USB; Start acquisition: enables receiving data, then starts the calibration phase (after the user calibration, it is possible to manipulate indeed the system); Stop acquisition: disables receiving data; Display signal: the module opens display signal; Exit: Exits the program.

The software acts like: The cursor must move to a reasonable time for the manipulation does not become tiresome speed; the cursor should enable small icons access, also the regular eye movement on the screen, without command intent by the user, shall not be recognized as a command. Designs of 'Normal Mode' and 'Quick Mode' perform using blinks as commands. Also, design of a visualization mode shows the signal acquired and its real-time linear average.

Results

The development of the prototype for conditioning and scanning EOG signals, called Eyes2Talk acquisition module occurs in order to minimize possible artifacts that restrict signals quality.

The physical prototype is compound of two reference channels, three input channels (to be placed down the midline of the eye by electrodes), four input channels (to be positioned above the midline of the eye by electrodes), five input channels (to be placed on the right edge of the sphenoid bone), six input channels (to be placed on the left edge of the sphenoid bone) and seven LED to indicate whether the device is on or off.

The digital signal filtering using moving average filter was essential to minimize signal noise. In this way the Signal Processing Module, enabled the recognition of real-time different eye movements. In the follow Figure 5, there are two pictures showing the recorded

EOG Signal, before and after application of the moving average filter.

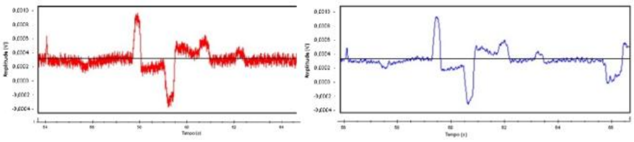

Figure 5: Eye movements Time (s) X Amplitude (V) - Left - Original signal and right - signal filtered by moving average filter.

The user was connected to the module and the acquisition Eyes2Talk connected to the computer, where the developed software for the tests was responsible for calibrating the signal according to the user, recognizing the commands and storing them in tracking. After this, data checking compares the commands defined by sequences of commands stored in memory by the software.

As a result, five tests were performed with the user, a satisfactory result for the recognition of the major movements happens, because, in this case, the system has an accuracy rate above 80 %. For the secondary movements recognition, the hit rate was lower, which is due to higher difficulty in recognizing such commands but also the user familiarity with the system, which increases as long as the user handles the computer by EOG signals.

Discussion

Handicapped people often have a limited life, which can be afflicted with difficulties in locomotion as well as to communicate. Projects like this prototype have the primary role to minimize these difficulties in order to improve the life quality of these people. EOG signals are a good tool to control, in relatively simple way and capture its waveform can present itself as more intuitive when compared to EEG signals, for example.

The developed system stands out from others by the amount of recognized commands. This makes the system more intuitive, easier to control and therefore accessible to people with severe motor disabilities. It also allows the user to use any computer resource.

Regarding test results, described in a satisfactory hit rate average around 90%; it is possible to notice that the homemade prototype does exhibits restrictions concerning noises from cables movements and electrodes (artifacts). Although those do not purport hindrance in validating the prototype, thus, the authors aim to improve the prototype by using wireless connection to transmit EOG signals, in a new future and improved version.

Conclusion

This developed paper involves knowledge on various relevant subjects to a professional regarding Biomedical Engineering field.

The prototype prepared exhibited satisfactory results, proved compact and low cost, it has allowed the development of a low complexity HMI for emulation of a mouse commands. The commands generated by processing the EOG signals allowed enabling cursor control, and performing actions equivalent to a single; double and right mouse button clicks. The tests analyzes were done by comparing the user intent and the real performance result. Any protocol was followed in this first project part.

Demanding a simple software and user-friendly interface, the handicapped user can manipulate easily and intuitively all offered commands after passing through a training phase.

Therefore, the present study showed the feasibility of using an EOG HMI (Human-Machine Interface). The obtained results in this work can be used in future studies, in order to improve the system even to engage controlling different devices, such as prostheses and wheelchairs. The implementation of an algorithm to differentiate voluntary from involuntary blinks and also the emulation command drag and drop mouse are future works that could be developed to improve this system.

Acknowledgements

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