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Design and Implementation of an EOG-based Mouse Cursor Control for Application in Human-Computer Interaction

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Abstract. Human Computer Interaction (HCI) has turned into an emerging technology due to the advancement in the field artificial intelligence and biomedical engineering. Acquiring different bio-signals such as Electro-oculography (EOG), Electromyography (EMG) and Electroencephalography (EEG) to control external machine or computer is the essence of HCI technology. In this research, we attempt to extract the EOG signal from different ways of eye movements and process it for HCI application. By utilizing Arduino, EOG data can be transmitted to computer and those signal characteristics is analysed through MATLAB. We have designed and implemented hardware and interfaced it with software to control a computer mouse cursor only by eye movement. Certain classification module like Support Vector machine (SVM) and Multilayer Perceptron (MLP) are used to classify different EOG data generated from different eye movement. According to the eye position, cursor automatically moves in that specific direction and PyAutoGUI module is used for this task. Results after experimentations with different subjects to control mouse cursor in real-time show that the average classification accuracy can reach up to 93% across all directions.

1. Introduction

In recent years technology based on Human Computer Interface (HCI) collaborated with different bio signal. This is considered to be the new era of Biomedical Engineering that is becoming more popular day by day. Bio-potential such as EOG, EMG, EEG, fNIRS etc. can be used for HCI applications [1-2]. Electro-oculogram (EOG) is reliable, cost efficient and non-invasive technique. EOG is a bio-signal which refers to the standing potential between the cornea and the retina [3]. The eye acts as a dipole, anterior side is considered to be positive and posterior side is negative. So at a certain moment EOG signal can either produce positive or negative voltage. An EOG is produced because of the iris of the eye, it induces some voltage drop which can be detected through electrodes. Potential across eyeball which exist in between Retina and Cornea is the source of EOG. Then the signal received by the electrodes is being processed to implement in design an EOG recorder for application in computer mouse control. Normally, EOG signal has a different potential between 0.05-3.5mV of amplitude and frequency range 0.1 - 20Hz [4]. This EOG signal can be used for HCI application.

There were proposals on advancement of HCI technology using EOG acquisition circuit has been interfaced with a wheelchair and can be moved by eye movement. Motorized wheelchair controller was also developed, which is useful for disable person [5]. Another approach was two channel and four-way cursor movement which had an ability to control mouse cursor using EOG signal [6]. Most of the research work tried to focus on paralyzed or spinal cord injuries patient. This is a new

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technology should be spread out in market by making the device simple to use, cost effective, available and portable. A device is built where individuals can apply it to communicate and control in a computing environment. In this work, we have designed and implemented an EOG device which is portable, affordable, wireless and low power consumption, and can be interface with the computer. EOG signal is firstly acquired and processed in real time. The main objective of this work is to control computer cursor in real time using EOG signal with respect to eyeball movement by those patient.

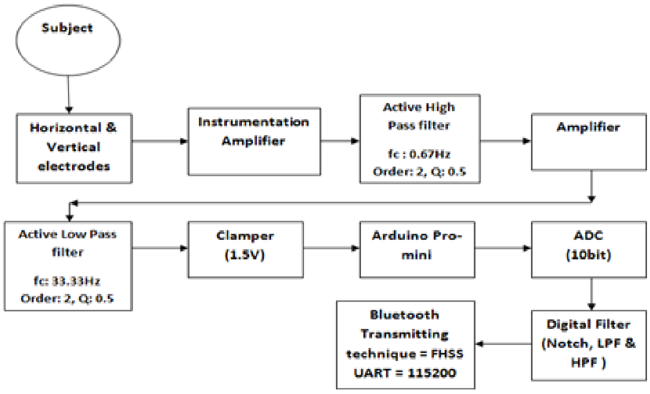

Figure 1. Block diagram of the Transmitting End

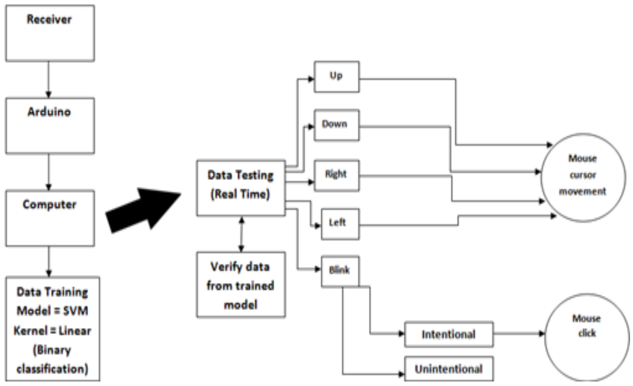

Figure 2. Block diagram of the receiving end

2. Materials and Methods

EOG signal acquisition and processing for HCI application involves different stages and interfacing between hardware and software. The procedure is explained below.

2.1 EOG signal acquisition

The block diagrams of the overall proposed system shown in Figure 1 and Figure 2 has two stages: Transmitting and Receiving End.

Two pairs of electrode are attached around subject eye to detect both vertical and horizontal eye movement. Than those detected signal are being amplified about 500 times due to its very low amplitude. This gain can be set by the resistor, R_G which is connected between pin 1 and 8 of AD620. An active 2nd order high pass filter is used to cancel the DC components and its cut-off frequency is 0.67 Hz. Before sending the signal to 2nd order low pass filter it is being amplified again about 20 times. Clamper circuit is there to shift any negative voltage to positive side because Arduino receives only positive voltage. Arduino also converts the analog signal to digital signal. Then the signal is digitally filtered again where IIR (6th order, High Pass, cut-off 0.5 Hz & 6th order, Low Pass, cut-off 35Hz) and FIR (50Hz Notch, order 20) filters are used. Now the signal is ready for transmission via blue-booth, baud rate of 115200 & sampling frequency 256Hz. Bluetooth is a short link radio technology it uses FHSS (Frequency Hopping Spread Spectrum technology. Bluetooth module and Arduino is there at the receiving side. To operate with blue-tooth module Arduino is needed and send those signal to computer. Computer uses machine learning to classify different pattern generated from an eye movement, classification model known as SVM (Support Vector Machine). Then the signal are trained accordingly, during data testing which is in real time those data are being classified with trained data. Eventually will generate a command to move the mouse cursor. In case of mouse click intentional option blink is trained for it. Advantage of using blue-tooth for transmission, signal were encoded even if the receiving end corrupted by power line noises but it won't affect the signal.

Overall system costs approximately 2500 BDT (approx. 30 USD) which is very low and large scale production in future can reduce the cost even more. Whereas devices in market for recording EOG only costs minimum of 100 USD.

2.2 Detection of EOG Signal

Ag-Ag/AgCl electrodes are placed as close to the eyes as possible to maximize the measured potential

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(as shown in Figure 3). A change in potential is detected as the poles come closer or move away from the electrodes while moving the eyes. The sign of the potential depends on the direction of the eye movement [7]. Data acquisition is done in two channels: one for horizontal and the other for vertical eye movement. Placement of multi electrode is shown in Figure 3. The change in potential can be tracked when eye moves from right to the left, same case occurs for up and down movement. Since eyes have a sphere shape, the range of horizontal eye movements is wider than the vertical movement [6].

2.3 Working System
After detecting the signal from the eye movement by electrodes then those signal process, pre-process, amplified and clamped sent to the Arduino pro mini. Inside Arduino pro mini signal are converted from analog to digital and sent to the receiving end via blue-tooth. Finally those data are transferred to the computer. With the help of machine learning different eye movement leads to mouse cursor movement. Using SVM classifier that classifies left, right, up, and down events which to control mouse cursor. The working system of this EOG mouse is shown in figure 4.

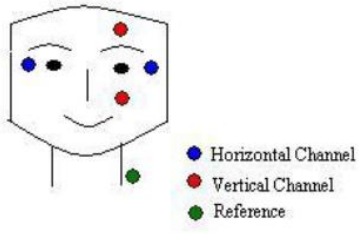

Figure 3. Placement of Disposable Electrode for EOG Signal Acquisition. [5]

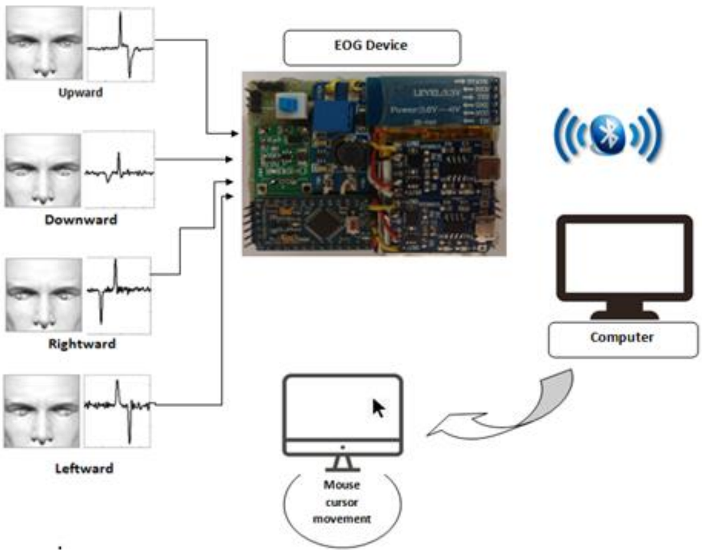

Figure 4. Working System of EOG-controlled Mouse

3. Hardware Implementation

3.1 Instrumentation Amplifier
Signal amplification is must because all these biomedical signals have very low amplitude which ranges from 4uV - 4mV whereas the power line noises has large amplitude. Also to keep the signal unharmed during transmission from an electrical interference. Amplitude of bio signal are very low which is not visible so to display it in an oscilloscope amplification is require. In this project AD620 is used due to its properties that makes it ideal for EOG signal acquisition. Gain can be varied by using one resistor only, which is connected between pin eight and pin one. The gain (G) is given in datasheet as the following formula:

$$G = 1 + \frac{49.4K}{Rg} \tag{1}$$

We chose R_g equals to 100Ω therefore, the gain will be 495. AD620 has eight pins pin no. one and pin no. eight will connected with a 100Ω gain resistor to acquire gain of 495. Pin no. two and pin no. three is the input pins for the signals that comes from a pair of electrodes. Pin no. four and pin no.

seven will be the pins for -5V and +5V voltage require for AD620 to power up. Pin no. five is the reference pin connected to the ground of the circuit which is the ground electrode. The output pin no. 6 will connect to the next step in the rest of the circuit.

3.2 Filter Design

We designed an active low pass filter with cut-off frequency of 33.8Hz and 0.677Hz for active high pass filter since the maximum usable energy of EOG signal is between 0.1 Hz to 40 Hz. To design this filter one pair of resistors 1 kΩ and one of capacitors of 4.7 μF were used. Another scenario was observed, if the difference between the value of resistor and capacitor is too high then there will be a system oscillation.

$$f_c = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}} \tag{2}$$

3.3 Microcontroller Unit

We have used ATmega328 as microcontroller which is based on the Arduino Pro Mini. There are two versions of the Pro Mini. One runs at 3.3V and 8 MHz, the other at 5V and 16 MHz [8]. We used the former version (3.3V, 8MHz) that has fourteen input/output digital pins which gives flexibility to the user to deal with many devices at the same time. This micro controller cheap, small in, software is easy to use and signal is displayed on the computer screen as numbers or by plotting. In this work, the Arduino analog input ports A0 and A1 were used for two channels. The EOG signal is passed to the Arduino from the EOG circuit. Arduino cannot read any below 0V, so a voltage clamper is there to shift it to the positive side.

The developed hardware module is shown in Figure 5.

4. Software implementation

4.1 Arduino Platform

EOG signal is being extracted from the subject and for controlling mouse cursor this signal should be interfaced with pc/laptop using Arduino. Arduino receives an analog signal from the circuit and converted the analog signal to digital. The mouse cursor control can be performed after the signal converted into digital. Python GUI (Graphical User Interface) establishes a link with windows mouse program and interprets it. A programming language interpreting windows mouse program is a high level API (Application Program Interface) because it allows to access the features of an operating system and other services.

4.2 Python Platform for Signal Classification

EOG signal generates different patterns of eye movement which needs to be classified. Classification is required because to identify each pattern like up, down, left, right and blink specifically. It is done by using machine learning, we used two model of classification i.e. SVM (Support Vector Machine) and MLP (Multilayer Perceptron) got better result in SVM. Accuracy of 80% in MLP and 93% in SVM. Three features of SVM i) RM (Rolling Mean), ii) FFT (Fast Fourier Transform) and iii) Gradient were used to extract a signal's statistical information and Linear function were applied here. Over here two classification method is presented, both of them are supervised machine learning. Each of them have different way of differentiating signal. SVM is a discriminative classifier uses a separating hyper plane to differentiate between data. The hyper plane divides a plane in two parts for two dimensional space. Classes could lay on either side. MLP is another classifier it's a feed forward artificial neural network A MLP consist minimum of three layers of nodes those are input layer, hidden layer and output layer. Each node act as neuron that uses a nonlinear activation function except for the input nodes. In this classifier it utilizes a technique known as back propagation for training. Multiple layers and non-linear activation helps to distinguish MLP from a linear perceptron. It can distinguish data that cannot be separated linearly.

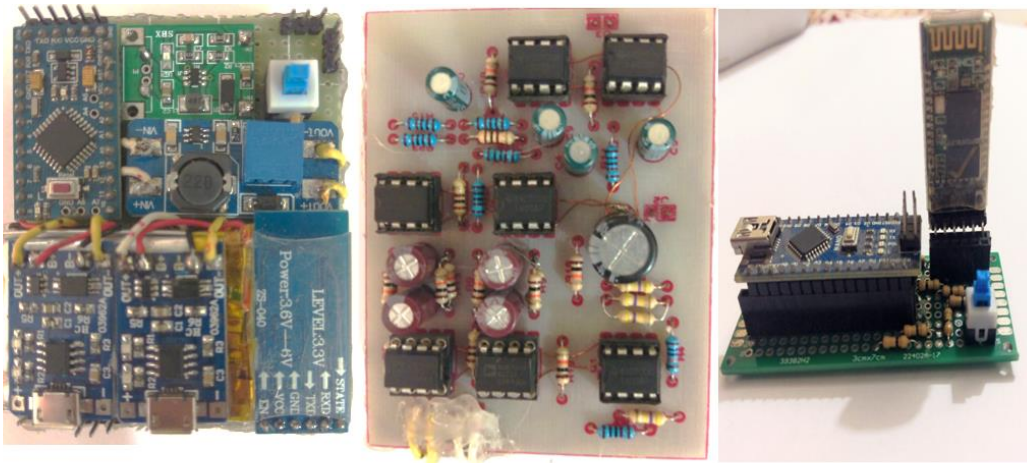

Figure 5. (from left to right) Transmitting module, EOG analog frontend and Receiving module

5. Result analysis and discussions

5.1 EOG signal acquisition

The output of the circuit viewed on an Arduino is shown in Figure 6 and Figure 7 and proves that it could successfully extract the EOG signal from a subject by eliminating the noises. X axis is the time in millisecond and Y axis is the amplitude of the EOG signal which is digitized by a 10-bit ADC. Two channels are displayed upper one is channel 1 and below is channel 2. It can be observed that some noise are due to slight moving artifacts.

5.2 Accuracy of the system

SVM algorithms use a set of mathematical functions that are defined as the kernels that take data as input and transform it into the required form. Different SVM algorithms use different types of kernel functions such as *linear, nonlinear, polynomial, radial basis function (RBF), and sigmoid* [9]. We tried four kernel functions in offline mode and observed different results respectively. The accuracy scores of SVM using kernel functions Sigmoid, RBF, Poly, and Linear are 0.23, 0.23, 0.83, and 0.93 respectively (refer to Figure 7). We got the highest score in Linear so we applied this Kernel in our project. If more data is trained then score will increase as well.

Five subjects have been tested to detect their eye movement in a specific direction. Each of them were asked to look at each direction for 10 times. We observed that result varies from subject to subject as shown in Figure 8. This happens due to some factors i) Electrode placement, ii) Not training appropriate data to the machine, iii) Everyone has different eye strength.

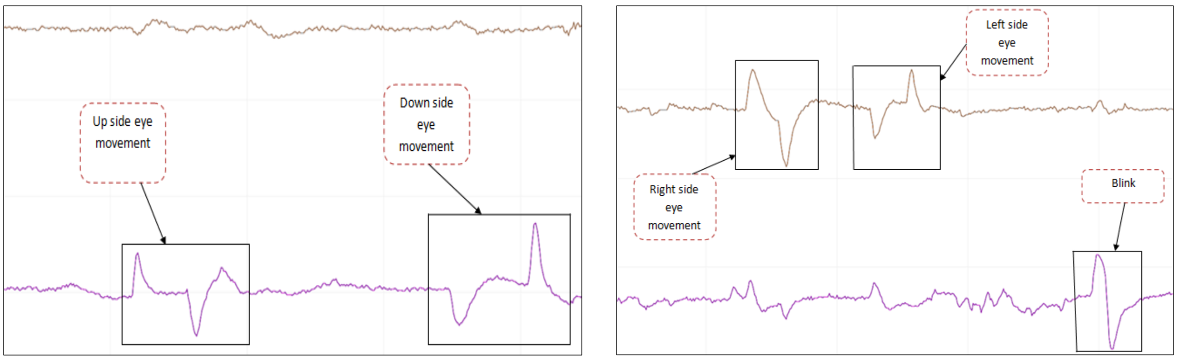

Figure 6. Four patterns of eye movement: upward, downward, right and left

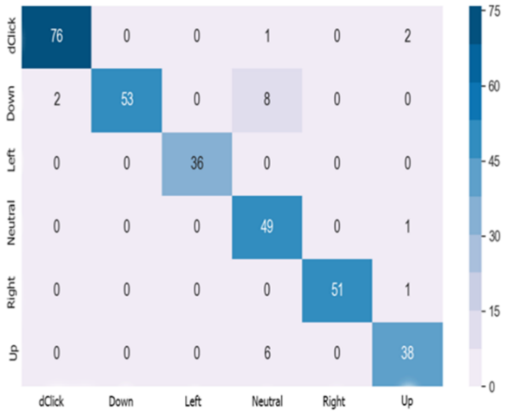

Figure 7. Confusion matrix using SVM Linear Kernel with 6 commands and 460 instances (Offline)

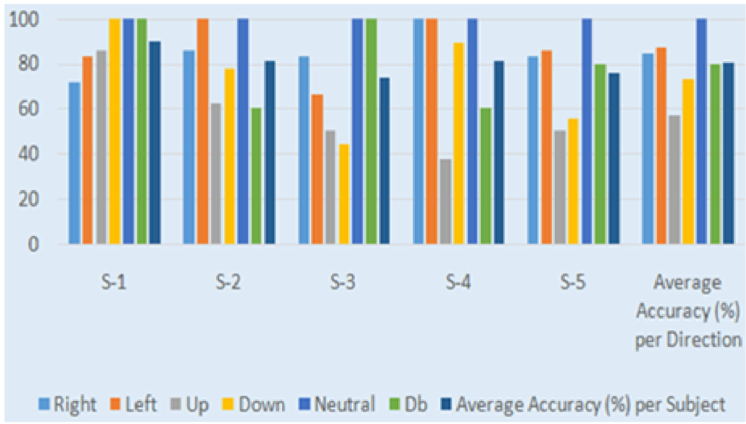

Figure 8. Average accuracy per subject (Real time)

6. Conclusion

The main target of this project was to design a module through which someone can control a computer mouse and eventually enables him/her to interact with a computer, making it feasible so those patients use it to full extent. The project was implemented successfully and interfaced with a computer mouse program using an Arduino pro mini. Our future plan is to make it more robust, affordable, compact, and make it more user friendly. We also hope to include other options of mouse i.e. scrolling, erasing etc. This will improve the quality of life to some extent for those people who are unable to move their hand/finger and being able to do something productive.

References

[1] Malik, Arslan Qamar, and Jehanzeb Ahmad. "Retina based mouse control (RBMC)." World Academy of Science, Engineering and Technology 31 (2007): 318-322.

[2] Hossain, Z., Shuvo, M. M. H., & Sarker, P. (2017, September). Hardware and software implementation of real time electrooculogram (EOG) acquisition system to control computer cursor with eyeball movement. In 2017 4th International Conference on Advances in Electrical Engineering (ICAEE) (pp. 132-137). IEEE.

[3] Chaudhuri, A., Dasgupta, A., Chakrborty, S., & Routray, A. (2016, January). A low-cost, wearable, portable EOG recording system. In 2016 International Conference on Systems in Medicine and Biology (ICSMB) (pp. 102-105). IEEE.

[4] Z. Hossain, M. M. H. Shuvo and P. Sarker, "Hardware and software implementation of real time electrooculogram (EOG) acquisition system to control computer cursor with eyeball movement," *2017 4th International Conference on Advances in Electrical Engineering (ICAEE)*, Dhaka, 2017, pp. 132-137.doi: 10.1109/ICAEE.2017.8255341

[5] A. N. Rajesh, S. Chandralingam, T. Anjaneyulu, and K. Satyanarayana, "Eog controlled motorized wheelchair for disabled persons," Interna- tional Journal of Medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering, vol. 8, no. 5, pp. 302-305, 2014.

[6] H. Tamura, M. Miyashita, K. Tanno, and Y. Fuse, "Mouse cursor control system using electrooculogram signals," in Proceedings of World Automation Congress (WAC), pp. 1-6, 2010.

[7] Banerjee, A., Datta, S., Pal, M., Konar, A., Tibarewala, D. N., & Janarthanan, R. (2013). Classifying electrooculogram to detect directional eye movements. Procedia Technology, 10, 67-75.

[8] https://store.Arduino.cc/usa/Arduino-pro-mini (Accessed on Oct 27, 2019)

[9] https://data-flair.training/blogs/svm-kernel-functions/ (Accessed on Oct 27, 2019)