Orthotic Arm Control using EOG Signals and GUI

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Abstract— Quadriplegic and non-verbal individuals, people suffering from cerebral palsy, stroke, traumatic brain injury, Galilean-Barre Syndrome, etc. find it difficult to convey their intentions as their voluntary motions are limited. In most of the cases the eye movements are unaffected and thus, the solution of using the eyes has the potential to develop a robust communication support method. Most of the contemporary techniques i.e. detection of eye movement using infrared reactance of the cornea, video-oculogram, the sclera reaction method are insufficient and not viable for practical applications. Several methods are been proposed that use electrooculograms (EOGs) occurring as a result of eye movements. In this paper we would like to propose a novel method to acquire EOG signals and control an Orthotic Arm with these signals. We also propose a method by which a second-person could control the arm.

Index Terms: orthosis, stroke patients, oculogram

I. Introduction

EOG signals are bio-physiological signals which could be extracted and characterized easily. Due to a very weak electric current from the corneal toward the retinal side in the eyeball, there is always a voltage called the retinal resting potential (RP). A record of RP is termed as an electrooculogram [1].

Towards the goal of controlling a machine with eyes, we have studied the properties of the EOG signal and its scope to be a human-machine interface. We successfully modelled and built an experimental system that could utilize the bio-physiological signal to control the orthotic arm only by eye movements.[2] In this case, the constraints are imposed such that the eye movement is assumed to be very limited ; UP, DOWN, RIGHT and LEFT. The problems due to other eye movement patterns, i.e. not much straight or in diagonal direction, are not discussed in this paper, which would be catered in future research. It is very important processing the eye movement into the correct motion control input into the arm. Any misjudgment of eye movement input classification would cause fault motion instruction of the orthotic arm. This can be catered by utilizing an intelligent classification method [3]. The hardware functional block diagram of the EOG control system is depicted in Figure 1.

EOG signals are acquired using the electrodes which detect the potential difference during the eye movements. The signals are pre-amplified and filtered [4]. The characteristics of the signal are extracted and processed and control signals are sent to the arm accordingly. The communication is done through EOG signals generated by the movement of eyes. [5]

A GUI is also developed to control the arm. This would be helpful in situations where any second person (maybe the doctor) wishes to control the arm. The block diagram of GUI based control mechanism is shown in Figure 2.

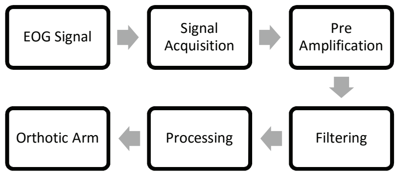

Figure 1. Hardware functional block diagram

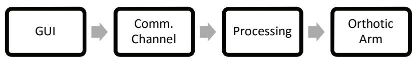

Figure 2. GUI based control block

II. EOG Based Control System Description

A. Signals Acquisition

Through Bi-channel signal acquisition system ie; horizontal and vertical channels, correspondingly used to detect the vertical and horizontal movements of the eye; EOG signals are acquired. Figure 3 shows the block diagram of Acquisition block.

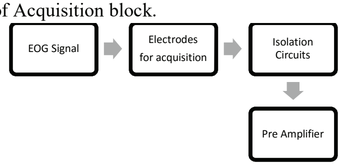

Figure 3. Signal Acquisition

To acquire the signals standard Silver/Silver-Chloride electrodes, which are active gel disposable, are placed on the foreheads of the patient. These electrodes can be used easily. Silver/Silver-Chloride electrodes are chosen because the half-cell potential is close to zero. Electrodes with the smallest amount of half-cell potential are

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desirable. The circuitry of Isolation block contains a barrier to the current from the power line (50 Hz). This barrier prevents dangerous currents from the patient through the amplifier to the ground of the recorder [6].

The most important part of neuro-physiological recording, especially for very small signals like EOG, is neither the hardware nor the software, but the quality of the electrical connections to the body and the acquisition equipment. This section of electrodes and electrolytes is hence very crucial. To remove dry and dead cells on the skin, before the placement of electrode the electrode placement area of the skin is either washed with alcohol solution or water. Five electrode should be used, two of which each for horizontal and vertical EOG signal acquisition, and fifth electrode is used as reference or ground electrode. The EOG signals are low amplitude bio-potential signals and bandwidth within DC-20Hz, it can be acquired with least discomfort for the patient [7] & [8]. Figure 4 shows how the signals are acquired.

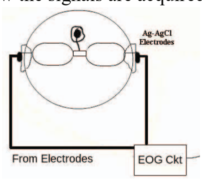

Figure. 4. EOG signal acquisition

There are different factors that affect the acquisition and analysis of the nature of the signal, some of them are cornea-retinal potential being not fixed, varying nature of the signal, eyelid movements, unwanted EMG signals acquired through the electrodes and other high frequency noise. These are to be removed for the proper extraction of the signal.

B. Pre-Amplification

The pre-amplification block mainly involves amplification of the EOG Signals to substantial levels. Due to the fact that an oscilloscope or a CPU cannot detect very small voltages, an EOG system should amplify those voltages in order to obtain a readable signal. However, other problems such as unwanted signal (noise) arise, such as the 50Hz signal (in India) caused by the AC electrical devices. Therefore, electronic filters are to be used in order to attenuate noise after amplification. The amplification system depends mostly in three basic factors: the differential voltage from the electrodes, noise, and offset. These three 'power sources' can be added in order to estimate the output voltage. This stage is characterized by high input impedance as well as high common-mode-rejection ratio [6]. Here we use INA128 for this purpose.

The amplification factor depends on the VCC supplied. INA128 is a low-power, general purpose instrumentation am-plifier which offers excellent accuracy. It is characterized by versatile 3-op amp design, small size, current-feedback input circuitry which provides wide bandwidth even at high gain [9].

$$G = 1 + \frac{50k}{R_G} \qquad (1)$$

C. Filtering

EOG signals typically have frequency range between 0.5Hz and 30Hz. Hence, a low pass filter with 30Hz cutoff would remove most of the high frequency noises. A high pass filter of 0.5 Hz is also used, which together form a band-pass filter of 50 Hz. Power line frequency could be easily removed, using a notch filter [10]. Figure 5 shows various types of filters used.

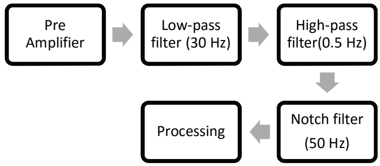

Figure 5. Filtering blocks used

Other artifacts are mostly transient, like by the turning of a switch ON/OFF in the vicinity of electrodes, expansion or contraction of facial or neck muscles, slippage of electrodes due to sweat and eye blinking. The signals produced by eye blinks are quite regular. They appear as sudden impulses with distinguishing amplitudes. Hence, it is possible to easily recognize. Here we implement Low Pass Butterworth Filter for filtering the EOG signals [11]-[12]. Figures 6 and 7demonstrates the change in the waveform after passing through the Filtering block.

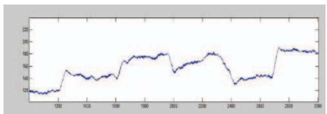

Figure 6. EOG signal extracted

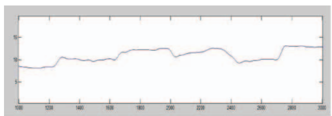

Figure 7. Filtered EOG signal extracted

The Butterworth Filter has a frequency response, whose function is referred to as maximally at (no ripples) response because the pass band is made to have a frequency response which should be as flat as mathematically possible from 0Hz (DC) until the -3dB cutoff frequency with no ripples [13]. Figure 8 shows the different order filter response of the Low Pass Butterworth filter.

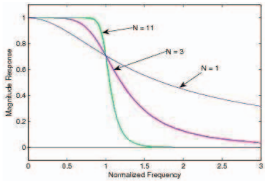

Figure 8. N order Low pass Butterworth Filter response [13]

Higher frequencies beyond the cut-off point moves down to zero in the stop band at 20dB/decade or 6dB/octave because it has a quality factor, Q of just 0.707.

D. Processing

The filtered signals are sent to the Processing block. It takes hard-decision on what movement has been made. Processing is typically divided into two steps: calibration and classification.

”Hey, look down please! I want to understand the nature of signals I get from your eyes while you look down.”- Calibration. The user is asked to wear the eyepiece and the back-end is calibrated for each eye position. ”Hey, the signals which I get from your eyes now look very similar to the signals which I got earlier while you were looking down. Hence you would be looking down now!”- Classification. The data-set stored for calibration is used as reference to do some live classification.

Initially, potential when the eye is STRAIGHT is measured. About 200 measurements are considered as training set and the mean is taken for accuracy. The mean is fixed as the threshold to determine the direction of the eye movement. According to the magnitude and direction of deviation in both horizontal and vertical channels, the eye movement is determined.

In the system, Arduino plays the role of processing the signals. It takes samples to determine the zero position of the eye ie STRAIGHT direction. Hard thresholds are determined for different movements. Once the training phase is completed, the device is ready to work. Arduino processes the samples and determines the movement made. Higher accuracy is obtained in this process. It sends the control signals to the Servo motors in the Orthotic Arm to move accordingly.

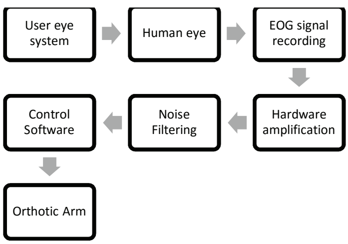

Figure 9. Control software design blocks

Figure 9 depicts the importance of the Control software. It also comes under processing block. Here we use MATLAB application to classify the signals.

III. GUI Based Control System Description

This section describes the GUI control system of the Orthotic Arm. This system could control the angle and even the speed of the orthotic arm for which the EOG based control system is incapable.

GUI implementation of orthotic arm is done mainly through processing software which is interfaced with Arduino to control the two servo motors in the orthotic arm. Processing is a flexible software sketchbook and a language for learning how to code within the context of the visual arts. In the GUI for orthotic arm, there are mainly 14 functional keys .Each of the functions are defined below:

CONNECT: Establishes a connection with the Arduino board and gets it ready to receive the signals.

ANGLE CONTROL- Angle can be controlled in three phases LOW, MEDIUM and HIGH.

SPEED CONTROL- speed can be controlled at 1X, 2X, 3X phases

UP-controls the servo motors to facilitate the upward motion of the wrist

DOWN- controls the servo motors to facilitate the downward motion of the wrist

OPEN- controls the servo motors to facilitate the upward motion of the thumb

CLOSE: controls the servo motors to facilitate the downward motion of the thumb.

UP-DOWN: initiates the up-down motion of the wrist OPEN-CLOSE: initiates the Open-close motion of the thumb

STOP: stops the connection with the Arduino board

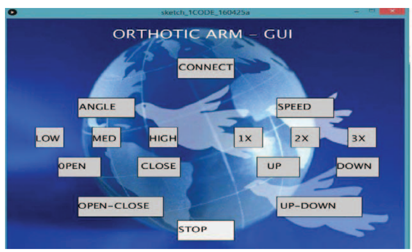

Figure 10. GUI Developed

Figure 10 shows the GUI used. Signals are produced corresponding to the option selected in the GUI. The rest of the flow diagram is same as that of the EOG based control system.

IV. Analysis

The amplitude of EOG signals typically varies from 200 to 500 V. The sampling rate is fixed between 400 Hz to 1 kHz.

There are different levels and degrees of eye movement for different people. This experiment is done to analyze levels of eye movement which would lead to different control signals at later. In this experiment, the Arduino was used to differentiate the various levels for eye movement. The minimum peak in the readings shows that when the eye moves downward, the signal would reflect to negative direction. The eye movement to the upward direction will give the positive maximum peak accordingly. When the eye moves rightward, the signal will be reflected to the right direction.

The maximum peak is having positive direction same as when eye moves upward, but the value for this peak, is smaller than the peak value during the upward eye movement. Similarly, the eye signal when the eye moves to the left has the minimum peak (negative), and the value at this peak is smaller than the minimum peak during downward eye movement.

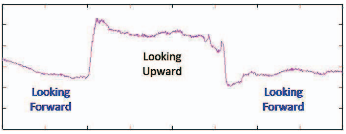

Figure 11. Waveform when eye moves up

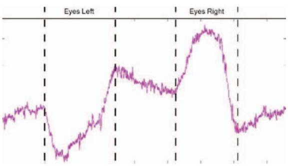

Figure 12. Waveform when eye moves left and right

	ARM Control
Eye Movement	Action
Right	Palm Open
Left	Palm Close
Up	Wrist Up
Down	Wrist Down
Straight	No Action

TABLE I. ORTHOTIC ARM CONTROL

Figure 11 shows the variation in waveform when the eye moves up. Figure 12 shows the difference in waveform when the eye moves left and right. The table I shows the eye movement and the corresponding action of the orthotic arm. Analysis of GUI based control system is similar. Signals corresponding to the option in GUI are generated. These are processed and control signals are sent to the arm

.

VIII. Conclusion

In this on-going research work, we have presented the need for indulging robots to clean facilities including houses, offices, schools and public buildings. The design considerations for such cleaning robots are explained in detail particularly the robots need to clean both the even surfaces / floor and staircase step as they are expected to climb several floors in a facility. One such robot which is implemented and tested by us is detailed in this paper. The testing environment and the evaluation of the robot points to a promising end result of this ongoing research.

Eye movements could be a very significant communication tool among quadriplegic and non-verbal individuals, people suffering from cerebral palsy, stroke, traumatic brain injury, Galilean-Barre Syndrome. The Orthotic Arm controlled by EOG signals has been designed. This system is proves to be efficient and more user friendly. It could be implemented in hospitals and would be greatly beneficial for paralyzed patients. The system has been implemented using few EOG characteristics. It could be further expanded for different kinds and combinations of eye movements. The GUI based control can be used by a second person to control the arm. The design has large scope of innovations. The system could be implemented in applications like tele-medicine. It could be modelled for wireless transmission of control signals

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