



Electro-Oculography (EOG) Signal based Human Computer Interface (HCI)

R. Padmavathy¹, H. Syed Muzammil²,

¹Associate Professor, ²Assistant Professor,

Department of Electronics and Communication Engineering, Dhanalakshmi Srinivasan College of Engineering and Technology, Mamallapuram, Chennai-603104

Abstract: Many physically disabled individuals are not able to handle the home applications. If the directional discrimination of the movements of the eye can be achieved, then these individuals would be able to handle the home applications without the use of hands. Establishing an alternative channel without speaking and hand movements is important for handicapped people in increasing the quality of their life. The theory of bio potential and electrodes is described to provide a basic for understanding how signals are acquired from the human body and how the electrodes are placed in specific locations near the eye. An electro-oculogram (EOG) bio potential amplifier is designed and developed in order to obtain the signals due to eye movements. And this signal is used to control a mouse pointer in computers. The choice of bio potential over other possible methods was selected based on the ease of usage and the low cost of production. The EOG bio potential amplifier is capable of detecting low frequency ranges from 0.01-10Hz, the range at which most of ocular movements operates. Similar to the EOG based system, the Electromyography (EMG) based system also a bio potential amplifier, but the frequency detection is from 70-5000Hz, the range at which action potential are fired during muscle contraction in the jaw. The EOG signals is in the microvolt range while the EEG signals are in the millivolt range, it is challenging to obtain a strong usable signals. Therefore, sufficient gain is necessary to analyze the signals. EOG based systems are more efficient than EEG based system, since it is easy acquisition, higher amplitude and easily classified.

Keywords: Electro-oculogram (EOG), Eye movement detection, bio potential, Human Computer Interface (HCI).

I. INTRODUCTION

Communication with the outside world is necessary for paralyzed patients, here is a attempt to study the natural eye movements and its application for designing such kind of device that act more assisting for paralyzes patients. It is necessary to process the electrical signals that are obtained from nervous system via Human Computer Interface (HCI). HCI can be described as the point of communication between the human user and computer. The flow of information between the user and computer is defined as the loop of interaction. The loop of interactions includes task environment, machine environment, area of interface, input, output and feedback.

The primary function of HCI is to control the signal extracted from the patients. This task can be accomplished by apparent potential of the HCI machine that lies in providing aid to individuals with severe disabilities, such as amyotrophic lateral sclerosis (ALS) [1]. These patients are not able to move their muscles voluntarily. However, their eye movement function remains intact. Eye movement can be used for transferring information between the user and HCI system. It is a feedback system since user can select the desired response by fixing their eye gaze on it for a certain

time without the need of manual mouse and keyboard entry. The eye movement recognition reduces the time required to generate a message and for user interaction. Eye movement plays a vital role in regulating the conversation, the import of eye motion appears when humans communicate face to face, talking to each other. Thus analyzing eye movement into HCI improves the quality of communication [2]. The HCI system [3], [4] that utilize eye movement include infrared oculography (IROG) [5], [6], dual purkinje image [7].

The EOG based HCI system [8], [9], is one of the most useful system for providing information about human eye movements. The EOG signals are used for HCI system since they are easy to detect. The EOG signals have relatively large potential difference amplitude ranges from 15 to 200 μ V and relationship to eye movement is linear, due to this characteristics the EOG based HCI system are more popular. The EOG based HCI system application can be extended to control a wheelchair [10], keyboard [11], television [12]. This system provides convenience and communication for disabled users. The EOG signals resulting from eye movement are used for threshold analysis for classifying eye



movements. In this method both the time and frequency domain are used to classify eye movements for analyzing.

II. NEED AND OBJECTIVE RESEARCH

In recent years, many researches are conducted to make use of minimum movements of the body and use them in commanding machines. For paralyzed people the direction discrimination of eye movement is used to control machines, such as HCI. We need to consider about cost and complexity factor. As a result we need to design a device which is economically affordable, less complex algorithm and easy to carry away.

Our objective is to acquire the eye movements using EOG signals and then design a device using EOG based HCI, which allows user to control device by selecting activity from HCI by their eye movements.

III. ELECTRO OCULOGRAM (EOG)

Electro oculography is a technique for measuring the resting potential of the retina in the human eye. The resulting signal is called the electro oculogram (EOG). Primary applications are in the ophthalmological diagnosis and in recording eye movements. Unlike electro retinogram, the EOG does not measure response to individual visual stimuli.

The human visual system embraces a group of organs responsible for gathering information from the surrounding, reacting to the light, being able of focusing, in a balance between refraction and converting stimuli to signals. Their message is transported through neurons and other optical pathways until the forebrain, where are decoded, eyebrows, palpebrae, eyelids and lacrimal apparatus, supporting the visual function. Eye has three main tunics or layers: fibrous tunic- with the sclera and the cornea, vascular tunic- a thin membrane structure highly vascularised includes the ciliary body and iris, and nervous tunic- formed by the retina. A eye movement is controlled by six muscles as shown in Fig.1. The extra ocular eye muscles, considering their relatively small size, are incredibly strong and efficient. There are the six extra ocular muscles, which act to rotate an eye about its vertical, horizontal and anterior-posterior axe. Medial rectus (MR), Lateral rectus (LR), superior rectus (SR), Inferior rectus (IR), superior oblique (SO), and Inferior oblique (IO). Electro oculography is a technique for measuring cornea-retinal potential. Technique used for recording of eye movements and eye position provided by the difference in electrical potential between two electrodes placed on the skin on either side of the eye. The eyeball may actually be regarded as a small battery, with a positive pole in the

cornea and negative pole in the retina. Changes in the position of the eyeball cause changes in potential at the skin.

To measure eye movements, pairs of electrodes are typically placed above and below the eye or to the left and right of the eye. If the eye moves from center position towards one of the two electrodes, this electrode "sees" the positive side of the retina and the opposite electrode "sees" the negative side of the retina. Consequently, a potential difference occurs between the electrodes. Assuming that the resting potential is constant, the recorded potential is a measure of the eye's position.

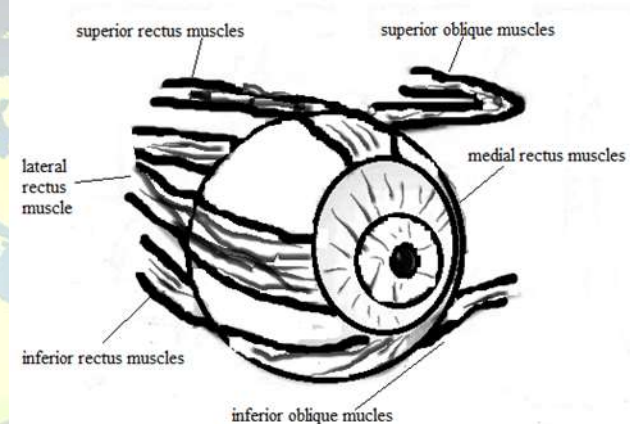


Fig.1. Type of eye muscles

IV. MATERIALS AND METHODS

The components of EOG based HCI system includes a electrodes to detect the EOG signals, the instrumental amplifier to amplify the very low EOG signals for processing, the filters to remove unwanted noise signals that are generated during EOG signal extraction. The microcontroller for processing to computer

There are five electrodes placed around the eye. Two electrodes one above and one below the eye of either left or right eye. Two electrodes one on left of left eye and one on right of right eye. One is reference electrode and this is placed behind the ear or on forehead as shown in Fig.2

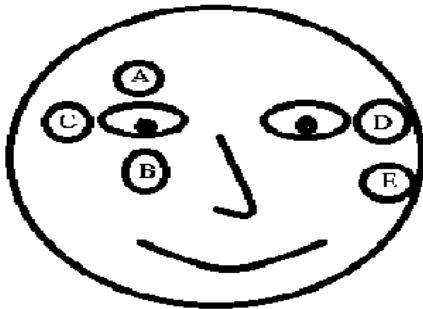


Fig.2. Electrode placement

The two electrodes A and B are used to detect the vertical movement of the eye, the two electrodes C and D are used to detect the horizontal movement of the eye and electrode E is ground. The electrode will then transmit this data to the amplifier. The amplifier is used for amplifying the very low EOG signal which is analog in nature. Then it is passed to the high pass filter where unwanted signals are filtered and again the signal is amplified to get the necessary gain that should be given to microcontroller and a low pass filter is used to remove the noise signals that are generated due to muscular movements. The system needs a high gain amplifier so AD622 is used. AD622 is a complete difference amplifier that provides superior linearity and common mode rejection ratio CMRR [13]. The AD622 replaces a low cost, discrete, two or three op amp instrumentation amplifier thus reducing the system size. Now the filtered signal must be converted to digital form and is given to microcontroller for classification and connecting to computer. The microcontroller used is LPC2103 which is a ARM type and has in built ADC in it. The architecture of the system is shown in Fig.3 below.

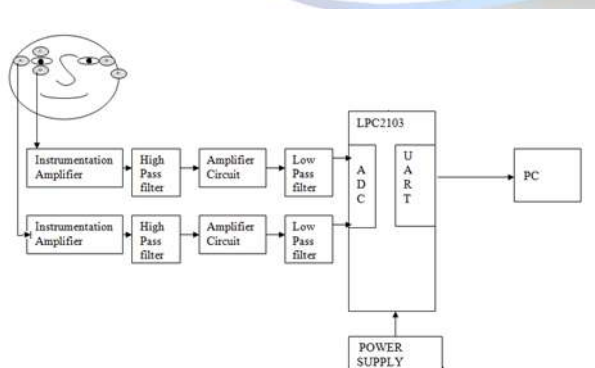


Fig.3. Block diagram

V. WORKING

There are two EOG circuits, one to determine the horizontal direction of gaze and one to determine the vertical direction of gaze. The two EOG circuits will be identical in design. They will differ only with electrodes used as input. The amplitude of obtained EOG signal ranges from 15 to 200 μ V, frequency ranges from 0 to 30Hz. The signal artifacts in the recorded EOG are similar to those observed for electromyography [14] and are unnecessary for the experiment. This EMG signals are considered as high noise and are suppressed using filters.

The EOG circuit utilizes AD622 instrumentation amplifier. This instrumentation amplifier uses laser-trimmed resistor to provide better noise rejection characteristics and improved linearity over typical three op-amp instrumentation amplifier. The amplifier allows the user to set gain from 2 to 1000. The EOG circuit consists of four stages. The first stage amplifies the voltage difference between the two electrodes. The gain of the AD622 is set using a resistor as follows,

$$R_G = 50.5k\Omega / (G-1) \quad (1)$$

The gain of the first stage is set to 100 using a 510 Ω resistor, $R_G = 510.1\Omega$. The output of the first stage is given as input to second stage, which implements a high pass filter with a cutoff frequency of approximately 30Hz. The frequency above 30Hz is due to EMG and is filtered. The third stage further amplifies the voltage difference between the two input electrodes. In this stage the minimum gain is 51.5 the gain is determined using a 1k Ω variable resistor. This allows the amplification of the EOG circuit to be easily calibrated for each individual subjects. The minimal gain of the first three stages is $100 \times 51.5 = 5150$. This would amplify a 0.1mV EOG signal to 0.515V. The goal of the EOG circuit is to convert a 0.1mV signal to 2.5V. Therefore, the second stage gain should be about 250. The variable resistor will likely need to be set to about 200 Ω to achieve this performance, although this will vary from individual to individual $R_G = 202.8\Omega$. In the third stage, the reference input is connected to a voltage divider that sets the reference voltage to -2.5V.

$$V_{out} = [R_2 / (R_1 + R_2)] V_{in} \quad (2)$$

$R_2 = 10k\Omega$; $R_1 = 30k\Omega$; $V_{in} = -10V$.

Then we get,



$$V_{\text{out}} = -2.5V. \quad (3)$$

Therefore, an amplified voltage difference of -2.5V would be output as 0V. An amplified voltage of 2.5V would be output as 5V. This sets the output of the EOG circuit to 0-5V range. The fourth stage is low pass filter with a cutoff frequency of 0.16Hz. In the EOG circuit design the resistors in the first stage limit any potential short circuit current to a safe level. For example, if 10V was to flow through the 10.2k Ω resistor and into the body, the maximum current possible would be 0.98mA.

$$I = V/R = 10/10.2K = 0.98mA. \quad (4)$$

This is safely below the 5mA level at which the body begins to experience a slight shock and some involuntary movements. This filtered signal is given to LPC2103 where it is converted to digital form and after processing the microcontroller output is given to PC using a MAX232 circuit which helps in converting the voltage level for PC operation.

Advantages:

EOG based recording system are typically cheaper than visual based methods, as they can be made with inexpensive electrodes. Some methods like infrared light require an infrared transmitter and some expensive software to calculate the eye position from the captured image. But in EOG based system uses straightforward method rather than video based techniques that require complicated computations to analyze video frames and convert this into an estimate of eye position, and software is less expensive.

The visual based methods require the eye to remain open to know the eye position, whereas in EOG based system can able to record the eye movement patterns when the eye is closed even during sleep.

The EOG has a large range than the visual based system. In a vertical rotation of eye the cornea and iris tend to disappear behind the eyelid and difficult to visualize, but in EOG system it does not depend on cornea and iris rather it based on eye muscle movements.

Lighting conditions: The voltage level of the visual system varies with lighting conditions, when a light source enters a dark room the cornea and retina movement changes and results in unwanted movement. In EOG system there is no lighting problem.

VI. PERFORMANCE AND RESULTS

The EOG signal is divided into vertical and horizontal signals. The performance of eye movement is demonstrated as the action of looking up or down corresponds to vertical movements. The action of looking up initially generates a positive peak, which is then accompanied by a negative peak. The negative peak corresponds to eye returning to the centre of the eye. Similarly the action of looking down initially generates a negative peak, which is then accompanied by positive peak. Here the positive peak corresponds to eye returning to centre of the eye. The action of looking left and right also generates positive and negative peak, which is accompanied by negative and positive peak respectively, corresponds to horizontal movement. Based on the threshold value the position of mouse pointer is determined. The eye movement is accompanied by noise signals; the noise is removed using high pass and low pass filter as shown in EOG circuit design.

Some errors occur during the oblique movements, the oblique movements have higher level of classification. First, the eye movement signals resemble either horizontal or vertical signals. Some of these signals are due to mistake caused by the user during blinking. The classification results were affected by error observed during eye examining and some unwanted motion of eye. The vertical EOG signal includes EMG signals. For EOG signals, the blink EMG signals and EOG signals generated by vertical eye movements are identical some times.

VII. CONCLUSION

The proposed EOG acquisition device is able to discriminate between various movements, type and signal characteristics associated with it. The main thing is to set threshold for eye movements for EOG recording process. The main thing to be considered is electrode position and whether it is in contact with skin. It is a good classification performance indicating eye movement. Thus, EOG based HCI system is designed to detect eye movement will be useful in real life applications for paralyzed patients.

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