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Man-Machine Interaction Using Double Channel Electrooculogram (Eog) Signals

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ABSTRACT: Electrooculography (**EOG**/**E.O.G.**) is a technique for measuring the corneo-retinal standing potential that exists between the front and the back of the human eye. To measure eye movement, pairs of electrodes are typically placed either above and below the eye or to the left and right of the eye. If the eye moves from center position toward 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. The bio-potential signal also is one of the examples of human–machine interface using of nonverbal information such as electrooculography (EOG), electromyography (EMG), and electroencephalography (EEG) signals. The EOG and EMG signals are physiological changes; but here we are focusing the mainly on EOG signals for the human–machine interface. This paper has investigated that different EOG signals obtained from four different places around eye; (right, left, up, and down) have led to different level of distance and rotation of wheelchair. Those four signals are correspond to different levels of right and left steer, forward and backward motion.

Keywords*:* Brain computer interface, Electrooculogram, Electrodes, Robotic Prototype Model

1. INTRODUCTION

Over a several years there have been increasing in the interest on the wheelchair improvement among inventors, design engineer, and the general public, because of the use of the wheelchair that has come to help many people with different illness and injuries. For example, a suitable wheelchair may facilitate the user to be out of sick bed, continuing their life, pick and place things, maneuvers in space and partaking of human experience. The use of wheelchair has becoming very important for mobility among disabled as well as the quadriplegic, which may cause by road accident , falling from high position several diseases. The bio-potential signal also is one of the examples of human machine interface using of nonverbal information such as electrooculography (EOG), electromyography (EMG), electroencephalography (EEG).the overall project idea is to study and implement the EOG signal and transform them into the digital form to operate the motor operated prototype mobility aid (a toy car). A brain–computer interface (BCI), sometimes called a mind-machine interface (MMI), direct neural interface (DNI), synthetic telepathy interface (STI) or brain–machine interface (BMI), is a direct communication pathway between the brain and an external device. BCIs are often directed at assisting, augmenting, or repairing human cognitive or sensory-motor functions. Research on BCIs began in the 1970s at the University of California Los Angeles (UCLA) under a grant from the National Science Foundation, followed by a contract from DARPA. The papers published after this research also mark the first appearance of the expression *brain–computer interface* in scientific literature. The field of BCI research and development has since focused primarily on neuroprosthetics applications that aim at restoring damaged hearing, sight and movement. Faster, more natural, more convenient (and, particularly, more parallel, less sequential) means for users and computers to exchange information are needed to increase the useful bandwidth across that interface. A brain–computer interface (BCI) often called a mind-machine interface (MMI), or sometimes called a direct neural interface or a brain–machine interface (BMI), is a straight communication between the human brain and electronic or electromechanical external devices..Brain computer interface are in many situation directed at boosting, augmenting, or repairing human subjective or sensory-motor functions. A brain-computer interface (BCI is a device that enables acutely disabled bodies to acquaint and collaborate with their environments application their academician waves. [1].

1.1 Electrooculography (EOG) System

This is an inexpensive yet reliable human-computer interface that detects eye movements using electrooculography (EOG), a biomedical technique based on picking up signals from electrodes placed around the eyes. EOG interfaces let users who can’t manipulate a mouse or track pad with their hands move a cursor on a computer screen .An Electrooculogram or EOG is the resulting signal of the potential difference caused by eye movements. The voltage difference is measured between the cornea and the retina. The resting potential ranges from 0.4mV to 1mV and a pair of electrodes are commonly used to detect this signal, but the voltage difference when there an eye movement can be as small as just some micro-volts. Depending on the eyes‟ position, an electrode is more positive or negative with respect to the ground electrode. Therefore, the recorded signal is either negative or positive when moving the eyes[6].such small voltages, an EOG system must amplify those voltages in order to get a readable signal. However, other problems such as unwanted signal (noise) arise, such as the 60Hz signal (if you are in America) caused by the AC electrical devices. Therefore, electronic filters should be used in order to attenuate noise after amplification. The system relies mostly in three important factors: the differential voltage from the electrodes, noise, and offset. In electronics, these three “power sources” can be summed in order to estimate the output voltage. The EOG measures the electrical difference that exists between the cornea and the retina, known as resting or standard potential of the eye. The cornea is almost 6 m positive with respect to the retina, which changes with clashing retinal illumination. The potential of the eye is generated mainly by the transepithelial potential across the pigmented epithelium of the retina. Electro-occulogram change under totally different states of retinal illumination. The EOG is employed to assess the function of the pigment epithelium. In dark adaptation scenario, resting potential drops slightly and reaches a minimum ("dark trough") once many minutes. Once light is switched on, a substantial increase of the resting potential happens ("light peak"), which drops off after many minutes when the retina adapts to the light. The ratio of the voltages is known as the Arden ratio. The measurement is similar to eye movement recordings. Due to the fact that an oscilloscope or a CPU cannot detect. The eye could be a seat of a gentle electric potential field that's quite unrelated to lightweight stimulation. It is also possible that, this field could also be detected with the attention in blackness and or with the eyes closed. It often represented as a stable dipole with positive pole at the cornea layer and negative pole at the retina layer. It's not generated by sensitive tissue however, rather, is attributed to the upper rate within the retina. The polarity of this potential within the eyes of invertebrates is opposite to it of vertebrates. This potential and therefore the rotation of the attention area unit the premise for a symbol measured at a combine of per orbital surface electrodes. The signal is understood because the electrooculogram, (EOG). It's helpful within the study of eye movement.[1]

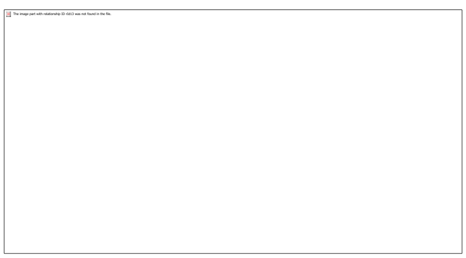

Figure 1: *Different electrode placement*

2. RELATED WORK

With improvement in the technology, there is a vast development in the field of rehabilitation techniques. Researches are going on to develop reliable, low cost and easy to use device.

Min Lin , Bin Li (2010)designed scheme of a wireless EOG-based Human Computer Interface.It consist of a EOG signals acquisition, EOG filter and amplifier,ARM microcontroller and Zigbee Wireless Module.[2]

Watcharin Tangsuksant, Chittaphon Aekmunkh ongpaisal, Patthiya cambua ,Theekapun Charoenpong, Theerasak Chanwimalueang (2012) developed a EOG based system For Typing Words via virtual keyboard by using voltage threshold algorithm.Typing rate on Virtual Keyboard 25.94 sec/letter and its accuracy is 95.2%.[3]

Anwesha Banerjee, Sumantra Chakraborty, Pratyusha Das, Shounak Datta, Amit Konar, D.M.Tibarewala, R.Janarthan(2012) Designed a system using EOG. Using different combination of eye movement in a right and left direction a simple control strategy has been developed to drive a motors of a small prototype mobility aid.[4]

Dong Ming, Yuhuan Zhu, Hongzhi Qi, Baikun Wan , Yong Hu, KDK Luk (2009).worked on EEG based system by using brain –computer interface to move a cursor on a computer display.Relevant experiment results showed that this system achived 80%accuracy for IHM task/free pattern classification.The EEg Based mouse system is feasible to drive the cursor'sfour direction movement and may provide a new communication and control option for patients with server motor disabilities.[5]

Patterson Casmir D'Mello, Sandra D'Souza (2012) developed a LabVIEW based EOG classification system. Ag/AgCl electrodes were used for EOG signal acquisition. To overcome the poor conductivity of skin, they used an electrolytic gel based up on Sodium Chloride. EOG signals were then amplified and filtered by using a high pass filter of 0.5Hz and low pass filter of 30Hz. M Series USB-6221 was used as a data acquisition interface. They used amplitude based EOG classification algorithm. They used the fact that amplitude of blink signal is higher than other eye movement. They compared the peak amplitude with a threshold value and if the amplitude was greater than threshold, then it was considered as a blink.

Manuel Merino, Octavio Rivera, Isabel Gómez, Alberto Molina, Enrique Dorronzoro (2010) developed a system to detect eye movement based on the EOG signal. They used Ag/AgCl sensors and BCI2000 and the amplifier gUSB amp for EOG acquisition. Since EOG signal information is mainly contained in low frequencies, band pass filter with a range between 0.1 and 30Hz and sample rate of 128 wasused. Noise was further removed by an averaging filter. Developed algorithm for EOG classification depends on derivative and amplitude level of EOG signal. Derivative of EOG signal was used to detect the edges of the signal. This algorithm found out initial edge, final edge, and area between edges. For an up movement and blink, initial edge is positive and final edge is negative. A timer calculated width of area between edges. A pulse was classified as a blink if the width of this area was smaller than 250ms. The EOG measures the electrical difference that exists between the cornea and the retina, known as resting or standard potential of the eye. The cornea is almost 6 m positive with respect to the retina, which changes with clashing retinal illumination. The potential of the eye is generated mainly by the transepithelial potential across the pigmented epithelium of the retina. Electrooculogram change under totally different states of retinal illumination. The EOG is employed to assess the function of the pigment epithelium. In dark adaptation scenario, resting potential drops slightly and reaches a minimum ("dark trough") once many minutes. Once light is switched on, a substantial increase of the resting potential happens ("light peak"), which drops off after many minutes when the retina adapts to the light. The ratio of the voltages is known as the Arden ratio. The measurement is similar to eye movement recordings. The patient is asked to modify eye position repeatedly between two points. Since these positions are static, a amendment in recorded potential

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originates from a change within the resting potential. EOGs are most appropriate when diseases that affect the retinal pigment epithelium may be present. Fishman (1990) outlines those dystrophies of the pigment epithelium that may give rise to EOG abnormalities. The only one disease that consistently associated with abnormal EOGs, however, is Best (vitelliform) macular dystrophy. Autosomal-dominant macular degeneration is a best disease that may be congenital or may have an onset of up to 7 years of age.[1]

3. PROPOSED SYSTEM

EOG-based systems are more efficient than electroencephalogram (EEG)-based systems in some cases. By using a realized virtual keyboard, it is possible to notify in writing the needs of the patient in a relatively short time. Considering the bio potential measurement pitfalls, the novel EOG-based HCI system allows people to successfully communicate with their environment by using only eye movements. The System implements a human-computer interface based on electrooculography (EOG) that permits interaction with a computer using eye movement. The EOG stores the movement of the eye by measuring activity, through electrodes, and therefore the difference of potential between the cornea and the retina. A motorized vehicle is a part of control parameter in proposed system where user can control the vehicle in multiple direction using facial motions near eye area. The main objective in system is to detection of electric signal near eye area and using electrodes system will try to identify the changes in electric pulse in order to conclude the motion to be taken. Proposed system includes the wireless robotic vehicle which can be controlled in 4 different directions. User can have access to this vehicle using Radio Controlled enabled circuitry through brain signals generated using eye motion. Likewise user can control the computer cursor and the applications using electric signals. This will enable disabled patients to have good access over computer system. To implement this there will be a microcontroller to USB interfacing circuitry which will convert microcontroller signals in to computer understandable signals which will then get processed by software program.

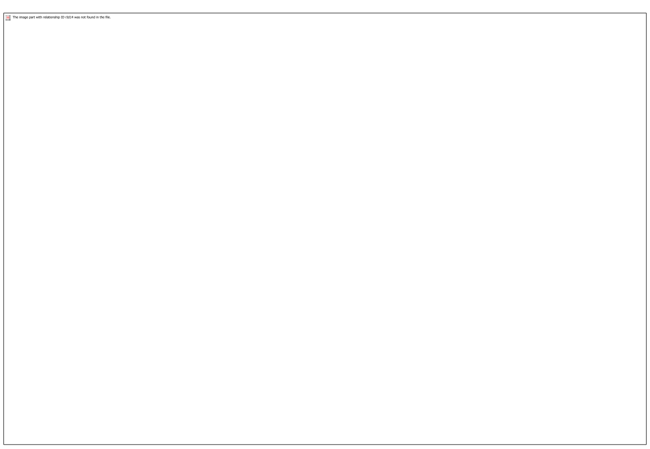

Fig2. *Showing EOG system*

4. PROPOSED METHODOLOGY

Electroencephalography (EEG) is the most studied potential non-invasive interface, due to fine temporal resolution, ease of usability, portability and low set-up cost. But as well as the technology responsibility to noise, another substantial barrier to using EEG as a brain–computer interface is the extensive training required before users can work the technology. For example, in experiments trained severely paralyzed people to self-regulate the slow cortical potentials in their EEG to such an extent that these signals could be used as a binary signal to control a computer cursor. Rehabilitation devices are increasingly being used to improve the quality of the life of differentially able people. Human Machine Interface (HMI) have been studied extensively to control electromechanical rehabilitation aids using bio signals such as EEG, EOG and EMG etc. among the various bio signals, EOG signals have been studied in depth due to the occurrence of a definite signal pattern. Persons suffering from extremely limited peripheral mobility like paraplegia or quadriplegia usually have the ability to coordinate eye movements. The entire project focuses on the design and development of a EOG amplification circuit and prototype model for DC motor driven prototype toy car controlled by EOG signals EOG signals were used to generate control signals for the movement of the toy car. As a part of this work an EOG signal acquisition system was developed. The acquired EOG signal was then processed to generate various control signals depending upon the amplitude and duration of signal components. These control signals were then used to control the movements of the prototype DC motor driven toycar model[7].

4.1.EOG Amplifier Circuit

The Electrooculogram (EOG) is the electrical signal that corresponds to the potential difference between the retina and the cornea of the eye. The generation of the electrooculogram (EOG) signal can be understood by envisaging dipoles located in the eyes with the cornea having relatively positive potential with respect to the retina. This EOG signal is picked up by a two channel signal acquisition system consisting of the Horizontal (H) and Vertical (V) channels. Here the disposable ECG electrodes are used for our experimental setup due to availability and the low price. The acquisition system employs Ag - AgCl surface electrodes for signal pickup which requires application of sufficient electrolyte gel to reduce the skin impedance .The EOG signal has a frequency range between DC and 38Hz and amplitude between 10 to 100mV. Current literature states that the EOG signal amplitude is merely dependent upon the position of the eyeballs relative to the conductive environment of the skull, though the signal has been found to be dependent on a few other factors in recently conducted research. The EOG signal, like the other bio-signals is corrupted by environmental interferences and biological artifacts. Therefore the primary design considerations that have been kept in mind during the design of the EOG bio-potential amplifier are proper amplification, sufficient bandwidth, high input impedance, low noise, stability against temperature and voltage fluctuations, elimination of DC drifts and power-line interference.

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Fig3. *block diagram of instrumentation amplifier circuit*

An instrumentation amplifier is a type of differential amplifier that has been outfitted with input buffer, which eliminate the need for input impedance matching and thus make the amplifier particularly suitable for use in measurement and test equipment. A high pass filter is an electronic filter that passes high-frequency signals but attenuates signals with frequencies lower than the cutoff frequency. A low pass filter is a filter that passes low frequency signals with frequencies higher than the cutoff frequency. The actual amount of attenuation varies depending on specific filter design.

4.2.The Eye

The retina of the eye is not uniform. Rather, one small portion near its center contains many densely-packed receptors and thus permits sharp vision, while the rest of the retina permits only much blurrier vision. That central portion (the fovea) covers a field of view approximately one degree in diameter (the width of one word in a book held at normal reading distance or slightly less than the width of your thumb held at the end of your extended arm). Anything outside that area is seen only with „„peripheral vision,"" with 15 to 50 percent of the acuity of the fovea. It follows that , to see an objectclearly, it is necessary to move the eye so that the object appears on the fovea. Conversely, because peripheral vision is so poor relative to foveal vision and the fovea so small, a person‟s eye position gives a rather good indication (to within the one-degree width of the fovea) of what specific portion of the scene before the person is being examined.

Fig4.*Electro-oculogram Schematic*

The eye can be considered a dipole with the anterior part relatively more positive than the posterior pole. EOG electrodes have become fixed for the outer and inner canthi of the left eye. On the left of the diagram as the eye moves to the left, the outer canthal electrode (being closer to the positive pole of the eye) becomes more positive than the inner canthal electrode. This change in potential can then be recorded on a voltage meter. When the eye moves to the right side direction, the inner canthal electrode then becomes positive and again a change in potential can be recorded but with opposite polarity.

4.3 Atmega16 Microcontroller

Microcontroller can be termed as a single on chip computer which includes number of peripherals like RAM, EEPROM, Timers etc., required to perform some predefined task. For experimental setup, we are using Atmega16 AVR Microcontroller SMD development board which is a single side low cost development board designed for robotics applications. Board can work on 5v DC power supply. It has built-in reverse polarity protection and compatible with 16x2 alphanumeric LCD. AVR is an 8-bit microcontroller belonging to the family of Reduced Instruction Set Computer (RISC). In RISC architecture the instruction set of the computer are not only fewer in number but also simpler and faster in operation. The AVR microcontrollers are based on the advanced RISC architecture and consist of 32 x 8-bit general purpose working registers. Within one single clock cycle, AVR can take inputs from two general purpose registers and put them to ALU for carrying out the requested operation, and transfer back the result to an arbitrary register. The ALU can perform arithmetic as well as logical operations over the inputs from the register or between the register and a constant. Single register operations like taking a complement can also be executed in ALU. AVR follows Harvard Architecture format in which the processor is equipped with separate memories and buses for Program and the Data information. Here while an instruction is being executed, the next instruction is pre-fetched from the program memory.

Fig5. *ATmega-16 AVR Architecture*

Since AVR can perform single cycle execution, it means that AVR can execute 1 million instructions per second if cycle frequency is 1MHz. The higher is the operating frequency of the controller, the higher will be its processing speed. We need to optimize the power consumption with processing speed and hence need to select the operating frequency accordingly.

4.4 Analog to Digital Conversion

Most real world data is analog. Whether it is temperature, pressure, voltage, etc their variation is always analog in nature. For example, the temperature inside a boiler is around 800°C. During its light-up, the emperature never approaches directly to 800°C. If the ambient temperature is 400°C, it will start increasing gradually to 450°C, 500°C and thus reaches 800°C over a period of time. This is an analog data. Now, we must process the data that we have received. But analog signal processing is quite inefficient in terms of accuracy, speed and desired output. Hence, we convert them to digital form using an Analog to Digital

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Converter (ADC). ATmega16 has an inbuilt 10 bit, 8-channel ADC system. Some of the basic features of Armega16 ADC are:

- 8 Channels
- 10-bit Resolution
- Input voltage range of 0 to Vcc
- Selectable 2.56V of internal Reference voltage source
- AREF pin for External Reference voltage.
- ADC Conversion Complete Interrupt

5. RESULT ANALYSIS

Body consists of static electricity in the form of analog signal. This static energy changes when the body parts movement occurs. When we move the body part then the variation occur in the form of analog signal.AD620 amplifies this analog signal. For converting this analog signal into digital signal Microsoft provides various API‟s. Here we are using Windows Sound API. Fig. explains the input signals received from the eye movement. High pass filter of 0.1 Hz is used to remove the noise from the signal. After removing noise, if the range of the signal decreases, then the second amplifier is used to amplify the signal to the desired range. Active Low Pass Filter is used to improve the efficiency by checking if there is any kind of noise persisting in the system. Finally, the Analog to Digital converter i.e. the Windows Sound API, is used to convert the analog signal received from Active Low Pass Filter to digital signal as the output. Figure.6. is the circuit diagram of signal detection showing the electrodes input, instrumentation amplifier, high pass filter, ope-amp, low pass filter and AD620.

Module Explanation

The below given figure shows the Signal detection system in its ideal state. This figure shows the normal i.e. the default working of the system when no eye movements take place. It shows the trigger value settings where there is a upper left positive value bar, upper right negative value bar, lower left positive bar and lower right negative value bar respectively. The start and stop eye detection tab is used to start and stop the eye detection system respectively. Close tab is used to close this default system. The green waves show the electric impulse generated from the brain. As every human body generates different impulse values, so the values shown on the L.H.S varies accordingly. When the device is not worn by the any person, the readings on the left side shows the values of the surrounding environment. Otherwise it shows the values generated by the electric impulse. The below given figure is showing the values generated by the electric impulse of the range 4441 and 621 respectively.

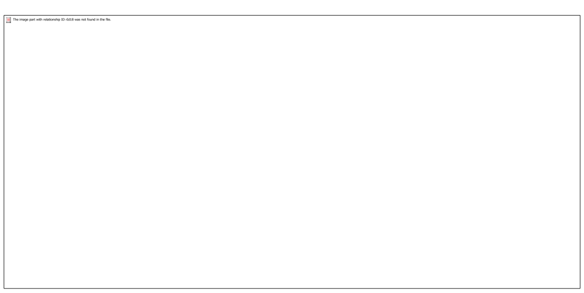

Fig6. *Signal Detection System In Its Ideal State*

The below given Figure, Explains the condition when the movement of the human eye is in the right side. When the impulse reading generated by this right movement of the eye exceeds the average noise value

Fig 7. *Signal Detection System Showing Right Eye Movement*

The below given Figure, Explains the condition when the movement of the human eye is in the left side. When the impulse reading generated by this left movement of the eye exceeds the average noise value

Fig8. *Signal Detection System Showing Left Eye Movement*

The below given figure, Explains the condition when the movement of the human eye is upward. When the impulse reading generated by this upper movement of the eye exceeds the average noise value.

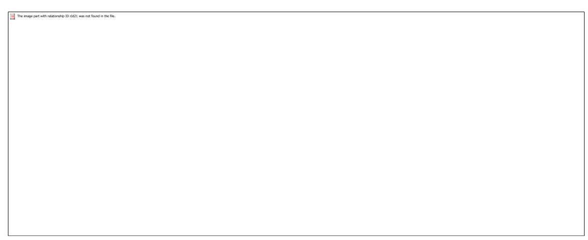

Fig 9 .*Signal Detection System Showing Up Eye Movement*

The below figure, Explains the condition when the movement of the human eye is downward. When the impulse reading generated by this down movement of the eye exceeds the average noise value

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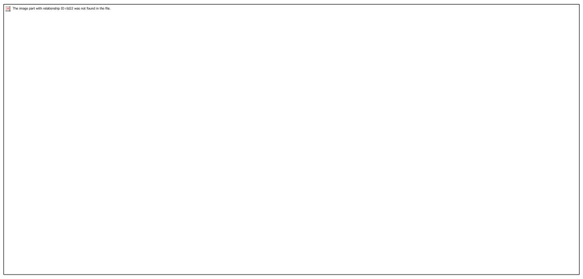

Fig10. *Signal Detection System Showing Down Eye Movement*

6. CONCLUSION

In order to build a detecting system for eye movements which will use electronic signals originating from the eyes it's crucial to understand the eye structure and the source of the signals which are measured by the system. Understanding these signals and their nature will help to design a suitable system that will function properly and will simplify its use. Vision is one of our most valued senses and during the course of each day our eyes are constantly moving. Attached to the globe of the eye, there are three antagonistic muscle pairs, which relax and contract in order to induce eye movement. These pairs of muscles are responsible for horizontal, vertical and tensional (clockwise and counter clockwise) movement. Due to the fact that an oscilloscope or a CPU cannot detect such small voltages,an EOG system must amplify those voltages in order to get a readable signal. However,other problems such as unwanted signal (noise) arise, such as the 60Hz signal (if you are in America) caused by the AC electrical devices. Therefore, electronic filters should be used in order to attenuate noise after amplification. The system relies mostly in three important factors: the differential voltage from the electrodes, noise, and offset. In electronics, these three “power sources” can be summed in order to estimate the output voltage.

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