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REVIEW ARTICLE

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Electrooculography: Analysis on device control by signal processing

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Abstract: This paper covers a new technology by placing electrodes on forehead of person around the eyes for recording the eye movements, this technique is called Electrooculography (EOG). It is basically focused on the concept of recording down the polarization potential which is also called corneal-retinal potential (CRP), this is resting potential between retina and cornea. The potential is called electrooculogram. This is a tiny electrical potential that can be found out using electrodes that are comparative to eye displacement. Electrooculography is a means of control for allowing the handicapped, mainly people with eye-motor coordination, which allow them live independent lives. This is a very good assistive system for disabled people with less money. This total command control EOG lets users to guide it with a high intensity of comfort ability. Systems which are becoming more popular day by day are HCI (Human Computer Interaction) that are Eye tracking based. To such systems Electrooculogram (EOG) functions as basic source of input. This integral process of analysis of electrooculogram is called Electrooculography. The paper we are presenting gives basic idea on Electrooculography and its use and applications in different HCI systems. In this work we have also included detection of eye blinks from EOG signal. Conclusively it throws light on various issues concerned with Electrooculography.

Keywords: Electrooculography (EOG), eye tracking, eye blinks, Human Computer Interaction (HCI).

I .INTRODUCTION

In 1849, Du Bios-Reymond observed there was a definite relation between electrode potentials from the skin surface and eye movements .Various medical studies conducted that proved the potential difference, which is generally called the resting potential, it emerge from hyper-polarizations and de-hyper polarizations exist between the retina and the cornea. The resting current flows progressively from the retina side to the cornea side, such that an electrical field comes into play with a negative pole at the retina and a positive pole at the cornea. As the eyeball rotates this field changes orientation. Thus, a human eyeball is like a spherical battery where the retina is negative and cornea is positive. It is possible to take it in a way that such battery is embedded in an eye socket and it rotates around the torsional centre of eye. And from the positive pole to the negative pole of the battery the micro current flows radically through the tissue in the orbit called conductive tissue. Here around the eye these currents generate the standing potentials, and from the skin electrodes the micro potentials (EOG) can be detected .Skin electrodes are pasted on the surface of the canthus the rule among the transactions which takes the items within the antecedent of the rule.Electrooculography is a technique for finding out the resting potential of the retina. And resulting signal is known as electrooculogram. A device that calculates the voltage between two electrodes placed on the face of a subject so it can detect eye movement is called Electrooculography. Now a day's benefits of computers are reaching out to all areas. Many sophisticated devices like touch screen, track ball, digitizers solves out this purpose. These techniques are reaching out to everyone. For example: for disable people assistive robotics has improved the quality of life.

II. LITERATURE REVIEW

The author in this paper[1] discussed the application and model of EOG measurement system. This system is based on microcontroller, having CMRR of 88 dB, with an electronic noise of 0.6 µV (p-p), and a sampling rate of 176 Hz.. In this paper, NN technique has been used because of EOG signals are quite distinguishably acquired in time series with lesser noise. It is the duty of EOG classification algorithms to provide eye gaze position. A Rajan, Shivakeshavan R G, and V Ramnath [2] acquired EOG through a dual channel signal acquisition model and processed it for the use in wheelchair control neural networks. The neural network processor unit captures the eye patterns and helps in minimizing the noise. Digitization of the measured EOG signal has been done by means of available ADCs, that has sampling time period of less than 10ms. Now the signal is then transmitted using FSK modulation technique (400MHz to 950MHz) to a control unit. In this paper [3] author proposed an EOG based HCI system. This paper also highlights the feasibility of eye movement related EEG signal to be used in HCI system. According to this paper, EOG has 10-100 µV, light adaptation is kept. In this paper, it has also been tried to predict EEG data according to eye movements. In this paper [4] implemented an EOG based Human Computer Interface model. This paper also provides that the amplitude of the pulse increased with the increment of rolling angle and the width of the positive (negative) pulse is proportional to the duration of eye ball rolling process. The gain of pre-amplifier used for the model is 10 that of main amplifier is 800. For eliminating the base-line higher frequency a band-pass filter of 1-100 Hz has been used. In this paper [5] author discusses the instrumentation for EOG acquisition and signal processing. An AD521 instrumentation amplifier has been used in this model that provides the proper amplification of (25) and bandwidth, high input impedance, high CMRR, low noise, and stability against voltage fluctuations and temperature. Then a non-inverting amplifier of 510 amplification is used. The author introduced a novel embedded eye tracker that was based on (EOG) [6]. It can locally stores the data for long-term recordings or stream processed EOG signals for a remote device over a Bluetooth. The author presented a new model [7] to guide a mobile robot. A neural network is used to detect saccadic eye movements and fixations. A Radial Basis Function Neural Network, that has only hidden layer, is used in this method to detect where one person is looking. The inputs are the present EOG signal and the last nine delayed because a RBF tapped delay network is used. Finally, the network output is the angle of the gaze that is used to control an electric wheelchair by generating different EOG codes. It is necessary to removes the shifting resting potential (mean value) because this value varies with time. An AC differential amplifier with high pass filter is used to avoid the problem of value variation and relatively have long time constant. The author in this paper [8] discussed well improved method for measurement of Electrooculogram (EOG). The method measured the relative potential between the inner canthus (nasal) and outer canthus (temporal) is detailed here. In this method total 6 electrodes instead of 5 are used. Consequently, the waveform of outer canthus potentials reverses against the inner canthus potentials. The EOG was in proportion about ±35° to the amplitude of the eye movement. The small saturation occurs when it was over ±35°. The author implemented an eye-control model in this paper [9] that is based on EOG for developing a system for assisted mobility. Most important features is its modularity, that makes it adaptable to the particular needs of every user according to handicap degree and type. In this research, the final measured EOG signal has been used for controlling wheelchair. It is observed in this analysis that as much as bigger is the degree of freedom and movements that the user can carry out, it becomes easier and more comfortable to guide the wheelchair. The author in this paper [10]discussed a wireless head cap for measuring of EOG and facial EMG signals. The head cap is made up of fabric and that is used to hold the electrodes. The electrodes are created of conducting silver coated fibers by using embroidering. A low gain value is needed because the measured signal contains a DC-component and a high gain could easily saturate the amplifier. DC-measurement is obligatory to estimate the gaze direction. In an AC-measurement only the movement of eyes (change in direction) could be really measured. The problem in DC measurement is that the difference in the half cell potentials of the electrodes will also be amplified. This difference may sometimes be quite high especially with fabric type of electrodes. In this paper [11] author proposed a wireless EOG based human computer interface. It consists of EOG signal acquisition, EOG filter and amplifier, ARM microcontroller and Zigbee wireless module. In this scheme, an embedded microcontroller is adopted to perform a wireless control of a toy car. On the embedded ARM platform, algorithms are programmed to perform the software filtering, feature. A Bulling, D Roggen and G Troster in this paper [12] they represented an eye-based human-computer interaction and for context awareness embedded eye tracker plus the wearable EOG glasses, which consisted with goggles having dry electrodes connected into the frame plus a component small pocket worn which have powerful microcontroller to process EOG signals. These systems are also used for saccadic eye movements. The author found out the limitations of EOG signal and reliability for measuring the angle of eye gaze when controlling a computer [13]. This work included EOG acquisition Nessler Med –Ref 1066, Technin Austria universal Ag-AgCl electrodes. And histograms and Butterworth LP filter of unfiltered and filtered data are then plotted. The author in this paper [14] made aware about a simple plus novel technique for classifying multiple channels of EOG. This classifier was based on DFA or Deterministic Finite Automata. That system had capability for classifying sixteen totally different EOG signals. Here five silicon-rubber electrodes with impedance less than 10K ohm were placed around the eye for obtaining EOG signals. For finding out frequency values present in the EOG signal, FFT was obtained that showed the dominant frequency components are up to 40 Hz on the other hand the maximum frequency components lay around 4 Hz. In this paper author discussed [15] about an algorithm ideal Velocity Shape signal processing for extracting position data where the eyes are focusing on from drift and noisy including EOG signals. With it, an efficient algorithm was suggested for the detection of various eye-lip movements which are wink and blink. In this paper [16] the author implemented a communication support system, eye movements control that which is voluntary eye blinks. And then measurement is done Horizontal and vertical Electrooculograms by making use of two electrodes attached above plus beside the dominant eye which refer to an earlobe electrode also amplified with AC coupling for reducing the not required drift. Then based on threshold setting specific to the individuals, eight directional cursor movements and one selected operation were realized by logically combining the two detected channel signals. The authors talked about the implementation and designing electrooculography system based on gaze-controlled robotic [17]. They consist of pattern recognition, signal acquisition, robot motion modules and control strategy. Then reconstruction of user's eye gaze movements is done from EOG signals, recorded from the face in real time. The authors showed in this paper [18] a new method for eye blink detection which was based on detection function. In it parameters of eye blinks can be extracted from EOG signal for example duration, blink frequency, or eyelid opening level. Then it was reported that blink latency, the time interval between blink onset and stimulus onset, was delayed by cognitive processes**.** This paper [19] discussed the design and application of EOG measurement system it was discussed that the design and application of EOG measurement system. This system is microcontroller based, with CMRR of 88 dB, an electronic noise of 0.6 =V (p-p), and a sampling rate of 176 Hz. There are several signal processing techniques such as analysis of variance, and principal component analysis and classification techniques such as kNN, support vector machines, and neural networks. In this paper [20] author describes common spatial pattern (CSP) to the classification of electrooculography (EOG) signals with four distinct classes, namely, eye blinks (EB), eye rotation clockwise (ERC), vertical eye movement (VEM) and horizontal eye movement (HEM). The author in this paper [21] implemented the various techniques used for eye movement detection are Infrared oculography (IROG), where a light source is focused. The amount of light reflected to the detector differs with respect to the position of the eye balls. Here, the light source is fixed and measuring vertical movement of the eye is difficult since the eyelids occupy more of the surface of the eye.

III. SIGNAL ANALYSIS

A. Block diagram

Signals from the placed electrodes at five positions around the eyes are captured. Bio-potential signals that obtained are in the range of 0.05-3.5 mV are then amplified with help of an instrumentation amplifier. The signal has a useful frequency range from 0to16 Hz and filtered to remove noise. The output is displayed and recorded using a digital storage oscilloscope. The block diagram of EOG signal analysis is shown below in fig 1.

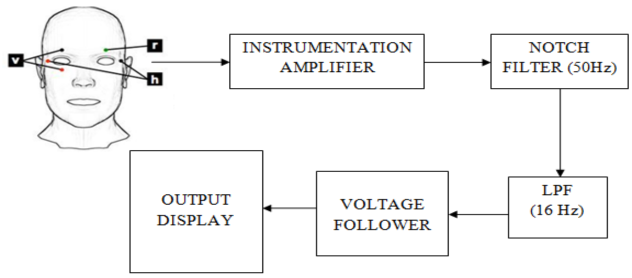

Fig.1 block diagram

B. Electrodes

Electrodes transfer the ionic form of energy into electrical one in the body. Then the currents can be amplified and used for diagnosing various diseases. The several types of electrodes that are used wet, dry and insulating type of electrodes. They can be sub-divided as Fetal scalp electrodes, Pacemaker electrodes, pH electrodes, Electro surgical electrodes, Nasopharyngeal electrodes and ion-sensitive electrodes. Conductive gel is used to record electrical activity on the surface of the skin. Ag-AgCl Electrode: It is a reference electrode. The electrode used is a silver wire that is coated with a thin layer of silver chloride. They are inexpensive to manufacture, are simple construction and have stable potential. Metal disk electrode: They are generally made of high purity gold, silver, tin or even. Application area is near the eye region. Diameter ranges from 4 to 10mm.

C. Electrodes placement

The EOG signal properties varies accordingly on the electrode placement. The various configurations such as 3/4, 4/5, 7/8 are used for different applications. Here, the first number denotes the number of active electrodes placed and the second number denotes the total number of electrodes including the reference electrode. The 4/5 electrode configuration is used here as it is a compromise between the other two configurations. The wires used in the 7/8 configuration area disadvantage. The different measurements are as shown in Fig.2.

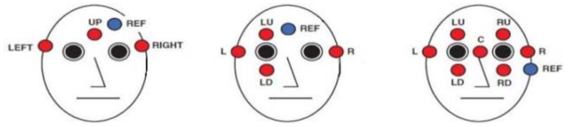

Fig.2 Different measurement systems

IV. ANALOG SIGNAL PROCESSING

A. Instrumentation amplifier

This INA118 is a low power, amplifier that offers high gain. It provides a high CMRR of about 110 dB at G=1000. The block diagram of the instrumentation amplifier is as shown in Fig.3.

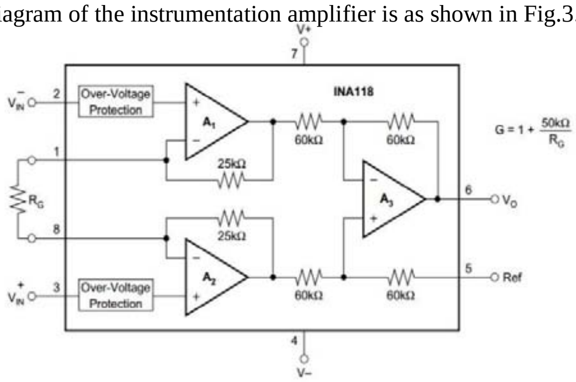

Fig.3 Instrumentation amplifier

C. Notch filter

Filters are that electronic circuits which are used to remove unwanted frequency components that is noise from the signal, to enhance the wanted signal. In this we requires a filter of high gain and twin T notch filter is used that can tune up to 100dB. Here, the required frequency for filtering is 50Hz for that the resistance and capacitance values are chosen appropriately. The notch filter is shown in Fig.4.

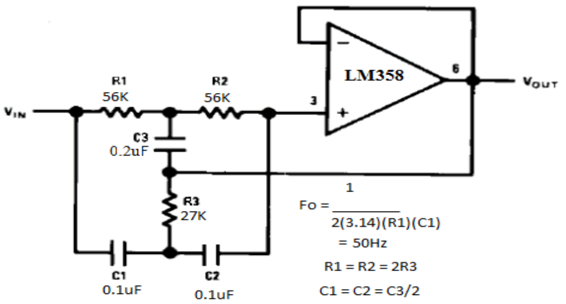

Fig.4 Notch filter

C. Low pass filter

The noises and other artefacts come under high frequencies and they have to be removed. For that, a low pass filter with the frequency range 0-16Hz is implemented and the corresponding resistor, capacitors are chosen accordingly.

D. Voltage follower

A voltage follower (buffer) is the one that provide the transformation of electrical impedance from one circuit to another. And this is designed to have an amplifier gain of 1. Buffers are used in impedance matching for maximizing energy transfer between circuits.

E. DC bias removal

The resting potential between the eyes varies that depending upon several parameters such as nature of the skin, conductivity, lighting of the type of electrodes used and electrodes placement. After the process of amplification, the resting potential is then amplified, but it is not desired in the EOG signal. A differentiator circuit is used to remove the DC drifts for providing better high frequency responses.

V. CONCLUTION

The EOG used is an inexpensive eye reliable human-computer medium that detects eye movements, sensing the signals by placing electrodes around five positions of the eyes. The EOG signals obtained were amplified by using an instrumentation amplifier in order to provide correct measurement for the study. Further changes in the analysis were made by using filter for filtering the high frequency components and eliminating the power line noise. The resulting EOG signals were in the digital storage oscilloscope and the eye movement directions were differentiated that is based on the time and the amplitude. Thus the analysis of EOG signals lets people who are unable to manipulate an object with their hands provides more options in controlling many appliances. This all shows that control system can be applied to a non-industrial level, for automation and easy channelize. However, even this describes the method by which disabled people can commute, there are obviously so many applications of such a system, for example, a fork-lift operator working at a harbor, Pilots can navigate easier in clear conditions using such a technique. Hence the paper concludes, proving that control engineering and neural processing, can simplify both industrial and non-industrial tasks to a great extent. Many improvements can be made in placing the electrodes around the eyes.

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