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EOG based Study of Eye Movements and its Application in Drowsiness Detection

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ABSTRACT: This paper presents a method of study of EOG signal for different eye movements and detection of drowsiness using a PIC Microcontroller. Electro-oculography is a technique used to detect the electrical activities generated by eyes. Thesignals generated during eye movements are studied with the help of EOG waveforms. The EOG signal is digitized with the help of PIC microcontroller. Depending on the value of amplitude and frequency of EOG signal, the drowsy and awake conditions are detected. Real time detection of drowsiness is possible due to high speed ADC inbuilt in the microcontroller. Alarm is generated on the onset of drowsy condition.

KEYWORDS: Electro-oculography, EOG, electrodes, EOG waveforms, eye movements.

I.INTRODUCTION

Human body produces many bio-signals, which can be recorded by using electrodes placed on different body parts. These electrodes acquire signals with even small voltages and provide information about physiological activities of body. Signals like ECG, EEG, EMG, EOG etc. represent the electrical activities of heart, brain, muscles, eyes respectively. EOG is electro-oculogram which indicates the electrical activities of eyes.

Human eye represents an electric dipole present between the retina and cornea of eye. The potential difference between the retina and cornea changes along with the change in position of eye ball. The generated signal is called as Electro-oculogram or EOG. The EOG signal is useful in measurement and study of eye movements and thereby can be used in many medical applications.

ANATOMY AND PHYSIOLOGY OF EYE:

Human Eye is the most important sense organ of the body. The Figure 1 shows anatomy of human eye.

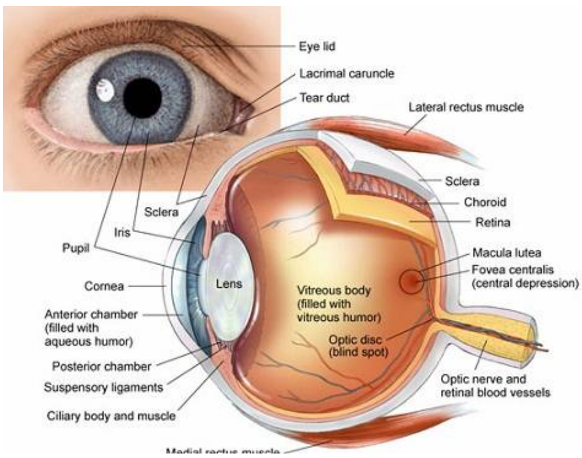

Fig.1: Anatomy of Human Eye

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A pair of eyes is in the sockets known as orbits. The human eyeball is nearly a spherical structure. It measures about 2.5 cm in diameter. The wall of eyeball is formed of three concentric layers such as fibrous, vascular and nervous coats. The outer fibrous layer provides shape to the eyeball and consists of cornea. Cornea is the anterior transparent part of sclera. Cornea functions to allow light to enter into the eyeball and bending of light to form clear image. The middle layer of eyeball is vascularised and differentiated into three regions namely choroid, ciliary body and iris. The lens of human eye is a solid, biconvex and transparent structure. It is suspended behind the cornea and iris. Lens can change its refractive power. The lens divides the cavity of eyeball into anterior and posterior chambers. The anterior chamber is present between cornea and lens. It is called as aqueous chamber and it is filled with a watery fluid called as aqueous humor. The posterior chamber is larger and present between lens and retina. It is called as vitreous chamber and it is filled with transparent gelatinous fluid called as vitreous humor. The vitreous fluid maintains the shape of the eyeball[1]. Retina is the innermost layer of eyeball. The nerve fibres from all over the retina converge and leave through optic disc called blind spot. Blind spot is devoid of rods and cones; hence no image is formed at this point. It shows maximum visual acuity i.e. resolution[1]. Formation of image is a physiochemical process. The inverted image of an object is formed on retina by the principle called refraction. The light rays coming from the object pass the cornea, aqueous humor, pupil, lens, vitreous humor and then fall on the retina. Cornea and lens play an important role in bending of rays. After the rays have fallen on retina an inverted and small image is formed on it. The neural impulse is analysed and the image formed on retina is recognised[1].

EYE MOVEMENTS:

To generate an eye movement along any axis, there are three antagonistic pairs of muscles which are attached to the eyeball. These muscles assist to move the eyes in different ways such as; horizontal, vertical and rotational. The eye movements are generally described in terms of angles that the eye is rotated (degrees). There are four different types of conjugate eye movements. These eye movements fall into two categories; such as to stabilize the eye during head movement and to follow a moving target. The eye muscles work individually or in synchrony to provide the overall motion of the eyeballs which position the eye in the direction of vision.
Saccadic eye movements (saccades) are generated to move the eye rapidly to a specific target of interest in visual space. Saccades are the voluntary eye movements. Eyes move from target to target like jerks. They can be produced even when the eyes are closed or in darkness. These movements are produced while scanning the surroundings and reading the text. The Figure 2 shows the saccades during reading[2].

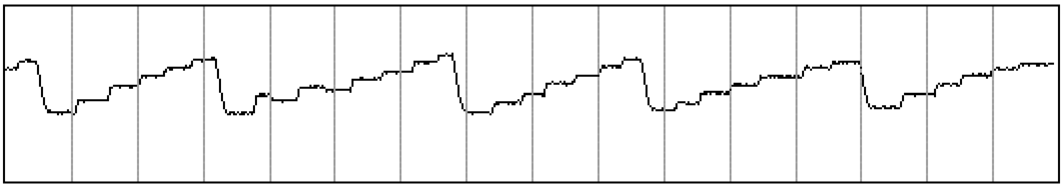

Fig. 2: Saccades during reading

Smooth pursuit eye movements are generated when the human eyes follow a moving object. These movements are only produced while following any moving target, hence cannot be produced by closed eyes or in darkness.Figure 3 shows waveform for the horizontal smooth pursuit eye movement[3].

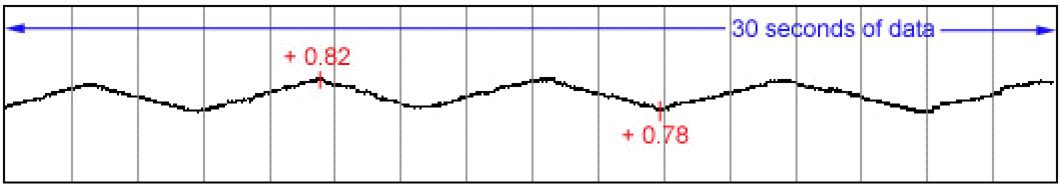

Fig. 3: Horizontal smooth pursuit

Vestibule-ocular eye movements help in providing unblurred vision during head movements[4]. These are stabilizing movements of the eye with respect to the movement of the head. These movements prevent in keeping the object under

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the circle of vision even while the head is moving. These are also called as compensatory movements, which are related to pursuit movements. They act to compensate for movement of the head or body so as partially to stabilize an object on the retina. The figure 4 shows VOR eye movement[4].

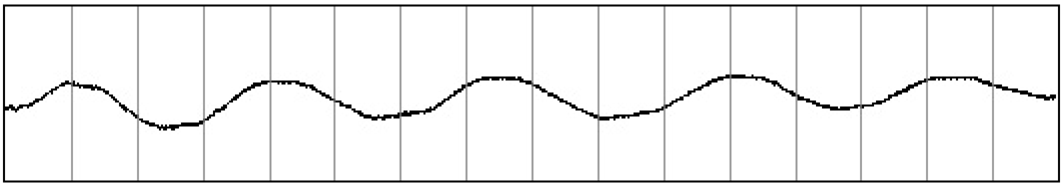

Fig. 4: Vestibulo-ocular eye movement

Nystagmus eye movement is a regular form of eye movement, comprising two alternating components – a slow and fast phase. The best example is in a train where looking out of the window you look at a tree and follow it as it moves past (slow phase) then make a rapid movement back (fast phase) and fixate on the next object which again moves past you. There are several different types of nystagmus[5]. The following waveform represents the Nystagmus eye movement.

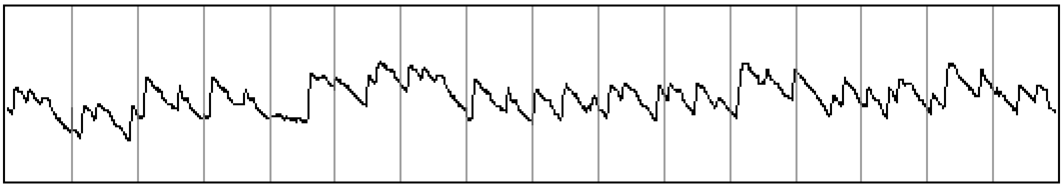

Fig. 5: Nystagmus eye movement

CONCEPT OF DROWSINESS:

Drowsiness is a general term for a condition in which a person feels a sensation of sleepiness, tiredness, fatigue, weariness, lethargy, or exhaustion. Drowsiness refers to feeling sleepy or tired, or being unable to keep your eyes open. Even though most people feel drowsy at some point or another, persistent sleepiness or fatigue, especially at inappropriate times, can indicate a sleep disorder or other medical problem. Drowsiness can be normal, such as at the end of the day before bedtime, or drowsiness can be a symptom of a wide variety of mild to serious diseases, disorders and conditions[6]. People working in shifts have major disturbances in sleep and circadian rhythms. The disturbed circadian rhythm can upset physiological factors such as, motor activity, body temperature, sleep/wakefulness, hormonal secretions, blood pressures and work performance. Drowsiness also affects various work environments such as mining industry, transportation industry, factory workers, executives, managers and industrial engineers. To avoid the unwanted circumstances, the drowsy or fatigued states must be identified well before time, to alert the person, who otherwise may face a life-threatening situation.

II. METHODOLOGY

To study the different eye movements the technique used here is Electro-oculography. It acquires the electric potentials generated by eyeball movements and provides information related to the eye movement.
This method can also be used to study the physiological condition of a person.

PRINCIPLE OF ELECTRO-OCULOGRAPHY(EOG):

Electro-oculography is a technique used to measure the corneo-retinal standing potential present between the front and the back of the eye. A steady electric potential is present between the positively charged cornea and negatively charged retina of eye. The magnitude of this corneo-retinal potential is in the range 0.4-1.0 mV[7]. This potential is generated due to the occurrence of higher metabolic activity in the retina. The signal is known as the Electro-oculogram (EOG)[8].

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A set of three electrodes is used to measure the EOG signal from the person. The position of electrodes is as shown in the Figure 7. A potential difference between measuring electrode and a reference electrode is acquired and then processed to get the readable form of it. These electrodes measure horizontal eye movements and vertical eye movements. The principle is represented in the Figure 6.

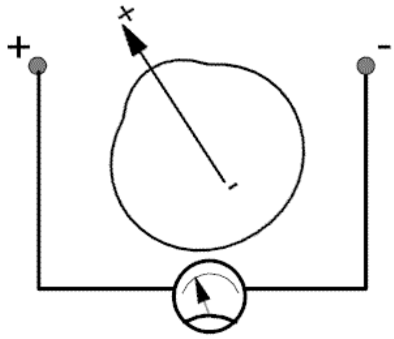

Fig. 6: Principle of EOG

MEASUREMENT OF EOG:

The EOG signal is measured by placing a set of three Ag/AgCl surface electrodes on the forehead. The potential difference between a measuring electrode and a reference electrode gives the value of voltages generated by movements of eyes. The electrode position is as shown in the figure 7. To enhance the contact between skin and the electrode surface a conducting gel is used. It also helps in reducing artefacts due to noise. An adjustable band containing the conducting electrodes is placed on the forehead of the subject. The central electrode is connected to ground. The left and right electrodes are connected to Vcc and reference respectively. The signal captured by electrodes is provided to EOG amplifier for further processing.

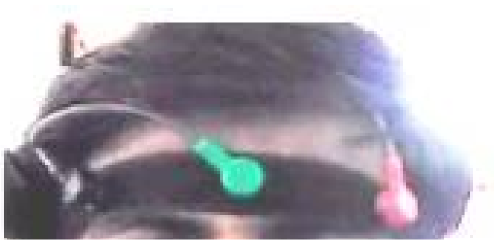

Fig. 7: Position of electrodes

The eye movements are generally measured in terms of angles of rotation of eyes. The EOG signal provides the corresponding voltage generated by the eye movement. It can be used to study the eye movement pattern and related aspects. These measurements are useful in studying the physiology of human. EOG signal obtained is in analog form and can be digitized to be used for various applications.

ADVANTAGES OF EOG:

- Detection and measurement of eye movement.
- Recording techniques are simple and cheap and can be done with minimal discomfort.
- Recording eye movement patterns.
- EOG readings can be measured even when eye is closed
- EOG can be utilized as an aid to detect the neurological disorders

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- EOG can be employed in modelling ophthalmic instruments which are capable of accompanying in disease diagnosis as well as for therapeutic purposes[8].

Aid to assist fully or partially differentially abled persons through human-machine interfacing..

III.SYSTEM DESIGN

The EOG signal acquisition system consists of different components. The block diagram is shown in Figure 8.

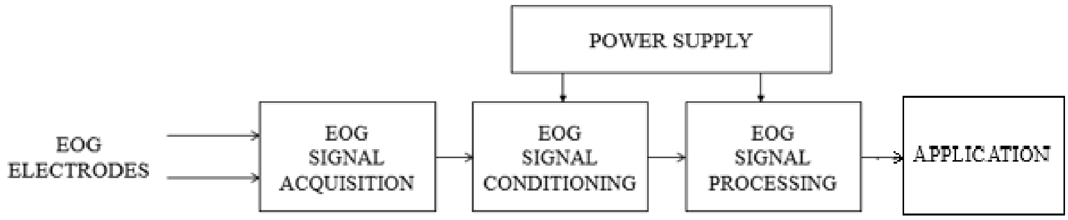

Fig. 8: Block diagram of EOG acquisition system

The potentials generated by eyes are acquired by the EOG electrodes. The signal obtained is an EOG signal. As the signal is of low frequency and low voltage, it should be amplified and processed. The EOG signal acquisition block consists of an instrumentation amplifier, which measures the potential difference between the two electrodes. It further amplifies the signal and passes it to the next block. The signal conditioning block mainly consists of filter circuitry. A low pass filter and a high pass filter is set with their cutoff frequencies to match window in which the EOG signal frequencies fall. It is followed by a notch filter to eliminate the powerline noise and eliminate the signal artifacts. The block also consists of set of amplifiers to amplify the signal further. The amplified signal is then fed to a processing unit. The processing unit carries digitization of the signal and converts the analog signal to a digital signal. The digitized signal can be utilized to detect the physiological condition of person or can be fed to the display system.

To acquire the signal from person, Ag/AgCl surface electrodes are used[9]. A conduction gel is applied between the skin and electrodes to improve the contact and conduction of the signal. Different types of Ag/AgCl electrodes are used for the acquisition purpose. These electrodes used are either disposable type or wearable type. The disposable electrodes are pre-gelled and attached to a snap type leads. The wearable electrodes ae attached to a headband at specific positions and can be attached to a snap type leads. The captured signals are then amplified and filtered to get the readable form.
As the amplitude of the EOG signal is in microvolts, it should be amplified further. The amplifier circuit uses an instrumentation amplifier to provide the desired gain to acquire small signals like EOG. Instrumentation amplifier IC INA114 is used as a pre-amplifier due to its characteristics like low cost, low offset voltage, high CMRR and wide range of gain. Gain of INA114 can be adjusted by a single external amplifier. The frequency of the signal is also very low. A combination of low pass filter and a high pass filter is selected to get the signal in a desired range. The LPF and HPF together work as a band pass filter and provide the signal in a specific range of frequencies. LPF with cutoff frequency 30 Hz and HPF with cutoff frequency 0.1 Hz is typically used. Further a notch filter can be added to reject the 50 Hz powerline noise, which otherwise may distort or suppress the original signal. A set of amplifiers are used to set desired gain. Instrumentation amplifier is the best choice for bio-signal acquisition system.

The amplified signal is then digitized by using analog to digital converter. The sampling frequency must be at least five times greater than the signal frequency. The EOG signal sampling frequency is usually small (100-400 Hz typically). This is appropriate for modern microcontrollers to have enough computation power for signal processing, recommended are DSPs (Digital Signal Processors)[10]. Sampling frequency of 200 Hz gives reliable results. PIC microcontroller is the best choice for digitization as it contains inbuilt ADC. This microcontroller requires ±5V DC supply. The digitized data can be used for different applications. Figure 9 shows the system setup.

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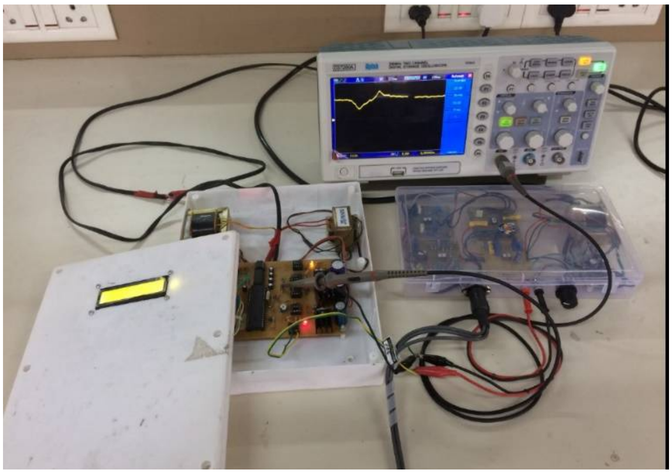

Fig. 9: Set up of EOG acquisition system.

IV.RESULTS AND DISCUSSION

SYSTEM OUTPUT:

There are different values of amplitude and frequency during different eye movements. The Table 1 shows the results of amplitude ad frequency during different eye conditions.

Condition of eyes	Amplitude (V)	Frequency (Hz)
Eyes open	0.64	0.39
Leftward movement	3.84	4.58
Rightward movement	3.92	3.42
Normal blink	2.48	0.41
Prolonged(drowsy) blink	2.72	1.29
Consecutive blinks	4.06	1.06
Eyes half closed	0.64	0.17
Eyes closed without movement	0.64	0.42
Eyes closed with movement	7.36	1.73

Table 1: readings of EOG in different eye conditions

The measurements are acquired from a subject wearing the EOG electrodes connected to the signal acquisition system. The system is applied to ten different people and the individual readings are measured. The Table 1 shows the values of amplitude and frequency of EOG signal obtained in different eye conditions measured from a person. the value varies from person to person depending on the actin potentials generated by that individual eyes. The signals obtained from a fully awake person and a drowsy person show different values of amplitude and frequency. These are used to program the microcontroller to capture the desired signal and produce an alarming signal when the drowsy conditions arrive.

The EOG signals are displayed on DSO as a waveform representing the respective conditions of eyes. These waveforms are useful in studying the pattern of change of signal during different eye conditions. Figure 9 shows the waveforms for different eye conditions.

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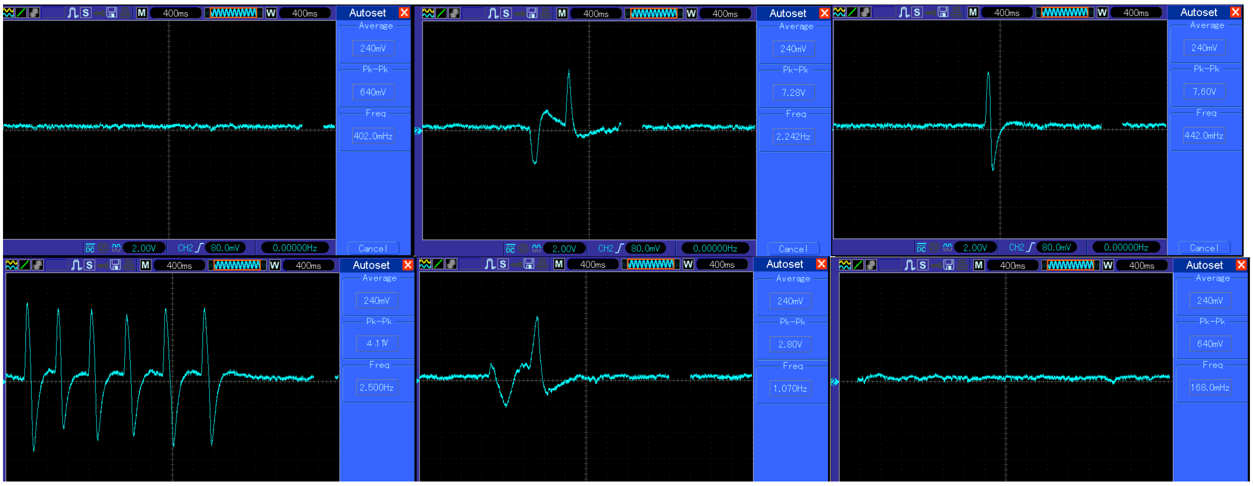

Fig. 10: waveforms showing Eye Movements:-
open eyes, left then right, blink, consecutive blink, drowsy blink, closed eyes respectively

The drowsy conditions are detected based on pattern of blinks. A threshold value is set in the microcontroller, above which the system detects the drowsy blink. If such 5 consecutive blinks arrive, then the system generated al alarm to detect the drowsy condition of person. The system is also connected to the LCD display system to mention the real-time condition of the person. This displays the count of drowsy blinks and shows drowsy condition when the threshold is crossed. Figure 11 shows the different conditions displayed on LCD. When a person is not drowsy he generates normal blinks and the system displays ‘B’, which represents Blink. When the person generates drowsy blinks, the system starts counting them and it is displayed on the screen as ‘PB’, which represents Prolonged Blink. Even the count is displayed as shown in the figure 11.

Fig. 11: LCD display showing different conditions of person

APPLICATIONS OF ELECTRO-OCULOGRAPHY:

The electro-oculography has a wide range of applications in variety of fields mentioned as follows:
Medical diagnosis: The EOG signal parameter changes according to the physical, mental as well as environmental conditions. The changing nature of EOG signal can be used as a tool to diagnose the medical condition of a person. The saccadic eye movement pattern in disorders like schizophrenia, paralysis, epilepsy, amyotrophic lateral sclerosis, Guillain -Barr syndrome, down’s syndrome, quadriplegia etc[11].

Study of different eye movements: Human eyes produce different eye movements like saccades, smooth pursuit, vergence, vestibule-ocular, nystagmus etc. These different eye movements generate different EOG signals. Eye movements are closely related to the activity we perform.

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Human Computer Interfacing: The concept of HCI provides facility to establish communication between humans and digital world. An eye movement controlled wheelchair is one of the most beneficiary application of electrooculography.

Driver Drowsiness Detection: the changed pattern of EOG signal is used to detect the drowsy condition.

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V.CONCLUSION

An overview of Electrooculography and its applications has been presented in this paper. Development of system which includes such bio-signals obtained from human body is possible due to optimizations of components, recent advances and cost reductions. Now Electrooculography is extensively used in many Human Computer Interfacing systems. The future of Electrooculography is very promising.

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