Acquisition, Processing and Applications of EOG Signals

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***Abstract*—We are living in the era of a blend of information technology, artificial intelligence, and virtual reality. This rapid transition and development have affected every sphere of life and medical sciences and clinical approaches are not exceptions. This paper discusses the methods of acquisition, processing and applications of Electro Oculography (EOG) signals, a bio signal generated by different eye movements. The use of EOG signals can facilitate a very good Human Machine / Computer interface.**

Keywords—Electro Oculography (EOG) signals, wavelets, pre-processing, Human Computer Interface

I. INTRODUCTION

The eyes are very important sense organs and their movements are very crucial for recognizing stress, emotions, and desires of human being.Our eyes are generating bio signals – Electro Oculography (EOG) signals bymoving continuously during our daily activities[1][2]. These, if properly acquired, can be measured, processed and used as an alternative means of communication for disabled persons.

In the last two decades, tremendous work has been done to find a convenient method of eye tracking to be used in many applications of assistance devices for disabled persons. Applications discussed in this paper include

- Movement and Control of wheel chair.
- Virtual keyboard use.
- Human Computer Interface (HCI) for writing by disabled person.
- Control of daily appliances by patients having motor disabilities.
- Recognizing work done like reading, writing and typing etc.
- Recognizing sleepy or drowsy condition of driver.
- Recognizing neurological problems in patients.

Fig. 1. below shows block diagram of a control system

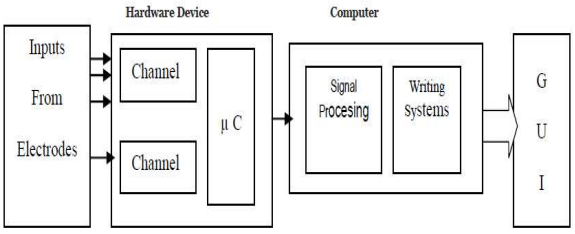

Fig. 1. A Control system based on Eye Movement

For different applications of EOG Signals.

In these applications EOG Techniques are preferred over VOG (Video Oculography) Techniques because of the following –

- Camera placement in VOG near Eye /face which is in convenient as compared to electrodes in EOG.
- Electrodes are simple and cheap as compared to accessories in VOG.
- A wider range of eye tracking is possible as compared to VOG,due to limitation of camera.
- Fast changing EOG signals can be accessed properly by electrodes and can be utilized in real time operations.

In this paper EOG has been considered as technique for generating command signals for Human Computer / Machine Interface. Extensive work has been done in this area, but most of them are either focused only on hardware or only on software in relationship to EOG based human assistant system. Now a day's focus is on small, inexpensive and portable wireless systems for acquiring, processing, transmitting, controlling and generating command signals from EOG Signals. Most of such devices developed are available for research work and not for commercial purpose.

Charging of the battery is done when not in use to keep the safety of person /patients in mind.

II. EOG

Eye movements generate bio signals. Electro-oculography is a technique that enables the detection of eye movement with help of these generated signals. This is becausethe eye can be modeled as a dipole, with the cornea and the retina being the positive and the negativepotentials, respectively. Movement of eye ball generates electric field, which can be measured as shown in Fig.2. The EOG amplitude varies from 50 to 3500 µV and its frequency ranges from DC to50 Hz. However, an EOG signal is not deterministic. This signal is dependent on many factors, some of which are - skin-electrode contacts,the placement of electrodes, environmental conditions, other biopotentials, etc. Robust results can be obtained by adequate acquisition and processing modules.

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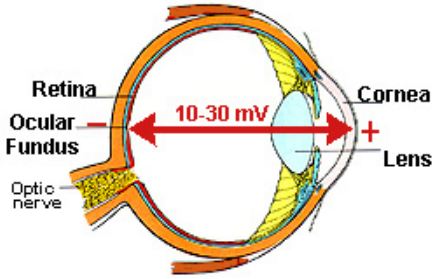

Fig. 2. Voltage Difference between cornea and Retina

A. Acquiring electro optical signals

Measuring and acquiring setup for these bio potentials involve proper sensors suitable for applications, design of appropriate amplifiers and techniques to mitigate the artifacts and noises. These signals are acquired by placing electrodes at five different positions on the face - two for horizontal movement of eyes, two for vertical movements of eyes and one as a reference node. Reference electrode is placed on fore head of the person. From these captured EOG signals, three basic movements can be recognized like saccade, fixation and blinks.EOG signal is acquired at a sampling frequency of 256 Hz using 5 Ag-AgCl disposable electrodes, two for the horizontal channel, two for the vertical channel and one as reference. Some EOG signals are represented in Fig 3.

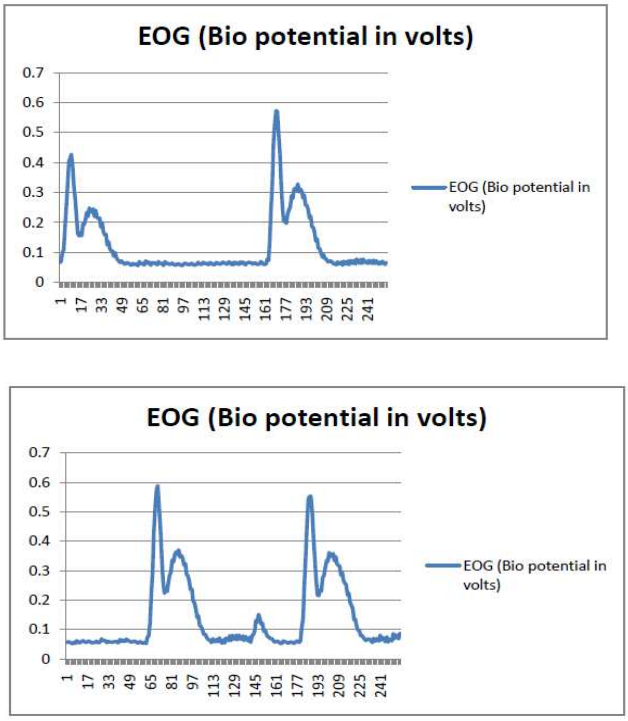

Fig. 3. EOG (bio potentials in volts)

There is a critical requirement of biomedical sensors due to tremendous increase of medical devices for improved health care. Biomedical sensors are mostly used to check/measure temperature, oxygen level, heart rate, blood pressure,breathing rhythm and daily exercise activities etc. [3]-[7].

Optical sensing technology is booming now a days, because ofsensors small size, light weight, non-electrical connections to the patients, Biocompatibility with MRI (Magnetic Resonance Imaging) and CT (Computer Tomography).

It is fast as light is used, also it is used in minimal noninvasive techniques in medical procedures due to inherent penetrating property of light. In future optical sensors are going to be leaders.

B. Pre Processing

Noises and the baseline drift cannot be suppressed in the hardware stage. EOG signal requires pre-processing to reduce noise and eliminate base drift to prepare the signal for further steps. De noising is accomplished in wavelet domain.

The EOG signal is non-stationary (its statistical characteristics varies over time) and cannot be properly analyzed with the Fourier transform. Wavelet transform (WT) is better tool in such cases. In this work, reduction of noise in EOG signals is done by using WT. Some mathematical preliminaries are presented before using Wavelet Transform. Wavelet transform of a function f(t) is decomposition of f(t) in terms of basis function $\psi_{s,\tau}(t)$ and defined as eq. 1. Where s is scale factor and τ is translation factor and mother wavelet are defined in eq. 2.

$$W(\tau,s) = \int f(t)\,\frac{1}{\sqrt{s}}\,\psi\left(\frac{t-\tau}{s}\right)dt \quad (1)$$

$$\psi_{\tau,s}(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-\tau}{s}\right) \quad (2)$$

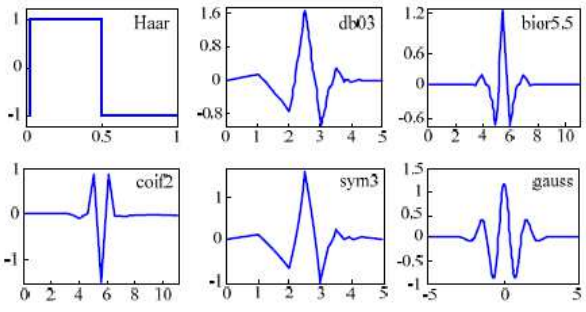

Fig.4. Some wavelet families

Fig.4. shows some families of wavelet functions, on x axis time is represented and on y axis normalized magnitude is represented.

When the scale factor and translation factor are discretized, the above equations are known as DWT.

DWT of a signal x[n]can be implemented through iterative decomposition of the signals in low pass filter and high pass filter as shown in Fig. 5.

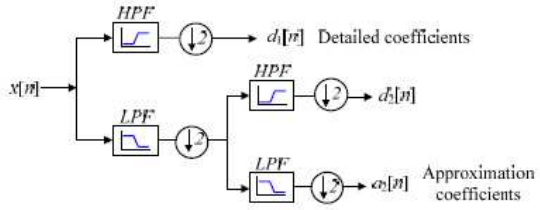

Fig.5. Decomposition of Image [25]

Denoising involves three steps -

- Decompose noisy signal in to wavelet coefficients using different wavelet transform as (Discrete Wavelet Transform –DWT) and Stationary Wavelet Transform-SWT).
- Estimate the threshold and thresholding of the wavelet coefficient using either Universal Thresholding (UT) orSoft Thresholding (ST).
- Reconstruction of denoised signal from thresholded wavelet coefficients.

Different thresholding methods available in the literature are used in this work as universal and soft thresholding. Signal to noise ratio and Mean Square error are the parameters on the basis of which the Denoising methods are compared. Best results will be obtained when nature of the signal matches with mother wavelet which is somewhat true for wavelets of bi orthogonal family and EOG signal [17].

TABLE 1. SNR (dB) in UT and ST Thresholds with SWT and DWT Methods

WT and Threshold	**Sym3**	**haar**	**Coif3**	**Bior4**
SWT,UT	23.2	14.0	24.0	24.4
SWT, ST	28.1	26.8	30.3	33.8
DWT,UT	22.8	25.3	31.1	33.8
DWT,ST	25.3	26.8	27.9	29.8

$$SNR_{dB} = 10\log\left[\frac{\sum_{n=1}^{N}(x[n])^2}{\sum_{n=1}^{N}(x[n]-x_R[n])^2}\right] \quad (3)$$

$$MSE = \frac{1}{N}\sum_{n=1}^{N}(x[n]-x_R[n])^2 \quad (4)$$

Where n is the length of the EOG signal, x[n] is the original signal, and $x_R[n]$ is the reconstructed signal. After getting a de noised signal it has to be treated for base drift which is basically due to power line interference. EOG signal has frequency range of dc to 10 Hz that's why it is very susceptible for power line interference. To remove this instrumentation amplifier with high Common Mode Rejection Ratio has to be used.

III. APPLICATIONS OF EOG SIGNALS

A. Alarm Systems in Hospitals

EOG signals are used to activate hospital alarm system in the case of severely paralyzed patients admitted in hospitals. By tracking their eye movements and respective EOG signals generated, these signals can be used to start an alarm scheme in the control room of hospitals as well as to the patient's attendant. This helps in quick actions in case of clinical emergencies [8] – [11].

B. Control of Wheel Chair and daily appliances by patients having motor disabilities

A simple micro controller-based system can be designed and used with the command signals generated from EOG, for wheel chair movements. Upward, downwards, right and left movements of the eyes can be encoded as forward motion, backward motion, turning left and turning right the wheel chair.

For on and off of daily appliances in the same way it can be coded. A particular graphical user interface has to be placed along with these systems so that a suitable eye movement and EOG can be recorded. Wireless communication of control signal has to be facilitated for the ease of use of these gadgets by patients [13]-[16].

C. HCI for writing by disabled person and Virtual Keyboard

Focusing on a virtual keyboard as graphical user interface,EOG signals can be acquired and are properly mapped on the position of the Keyboard to identify the English Alphabets, focused by disabled patients and then appropriate keys are pressed for typing the text. For the help of disabled persons, the text to speech can be also added in the output and command signals generated[23].

D. Eye based activity recognition

Similar Concept as explained in above application can be used for activity recognition of a person used for spying or keeping control on the activities of an employee.

E. Detecting sleepy or drowsy condition of driver

With the help of EOG recordings saccades, fixations and blinking speeds of eyes can be detected with fairly good

accuracy. In the form of head gears or goggles these systems are used by drivers and continuously measured by traffic control units on highways. Wherever blinking speeds becomes high than normal eye blinking, an alarm in the car is activated and on the next nearest traffic control point car / driver is stopped for safety reasons [12].

F. Detecting Neurodegenerative Diseases by EOG Signals

EOG signalsare used in the detection and monitoring ofdiseases such as dyslexia, autism, attention-deficit hyperactivity disorder epilepsy and Alzheimer[18–22],

Deep learning algorithms have been popular due to their better performance and used in usedmany machinelearning applications such as classification ofphysiological signals and early diagnosis of diseases.Convolution neural network (CNN) is a popular Machinelearning algorithm model for the supervised learning task [24].

IV. CONCLUSION

In the medical world, accuracy being the most important parameter, variouspreprocesseshas been applied to get the most optimized result. The application discussed can be commercialized for better life of mankind.

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