Natural Eye Movement & its application for paralyzed patients

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***Abstract*— The noble aim behind this project is to study and capture the Natural Eye movement detection and trying to apply it as assisting application for paralyzed patients those who cannot speak or use hands such disease as amyotrophic lateral sclerosis (ALS), Guillain-Barre Syndrome, quadriplegia & heniiparesis. Using electrophySiological genereted by the voluntary contradictions of the muscles around the eye. The proposed system which is based on the design and application of an electrooculogram (EOG) based an efficient human–computer interface (HCI). Establishing an alternative channel without speaking and hand movements is important in increasing the quality of life for the handicapped. EOG-based systems are more efficient than electroencephalogram (EEG)-based systems as easy acquisition, higher amplitude, and also easily classified.**

By using a realized virtual keyboard like graphical user interface, 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. [1]

Classifying horizontal and vertical EOG channel signals in an efficient interface is realized in this study. The nearest neighbourhood algorithm will be use to classify the signals. The novel EOG-based HCI system allows people to successfully and economically communicate with their environment by using only eye movements. [2]

An Electrooculography is a method of tracking the ocular movement, based on the voltage changes that occur due to the medications on the special orientation of the eye dipole. The resulting signal has a myriad of possible applications. [2] In this dissertation phase one, the goal was to study the Eye movements and respective signal generation, EOG signal acquisition and also study of a Man-Machine Interface that made use of this signal. As per our goal we studied eye movements and design simple EOG acquisition circuit. We got efficient signal output in oscilloscope.

I sure that result up to present stage will definitely leads us towards designing of novel assisting device for paralyzed patients. Thus, we set out to create an interface will be use by mobility impaired patients, allowing them to use their eyes to call nurse or attended person and some other requests.

***Keywords*— Electro Oculogram, Natural Eye movement Detection, EOG acquisition & signal conditioning, Eye based Computer interface GUI, Paralysed assisting device, Eye movement recognization**

I. INTRODUCTION

As we know that there is different kinds of assisting devices are available for paralyzed patients and more than available under research. Here is an novel attempt to study natural eye movements and its application for design such kind of device that act more assisting role for paralyzed patients.[1]

Recent research attention for the development of assistive technology incorporates direct interfacing of human physiology and computer technology i.e., human-computer interfacing (HCI). The primary function of the HCls is to engender control signals for external devices based on the real time scrutiny of measured biological signals. Since this task can be accomplished while bypassing the spinal cord, an apparent potential of the HCI machinery lies in providing aid to the individuals with severe motor disabilities, such as amyotrophic lateral sclerosis (ALS) and Guillain-Barre Syndrome. While these patients have little or no voluntary muscle control, their cognitive functions might still be intact. Hence, the goal of HCls is to supplement the individuals' residual ability with the surviving functions. With the advancements in sensor technology and embedded technology, various portable and affordable assistive devices have been developed for physically challenged people. Applications utilizing HCI technology includes viz. functional muscle stimulation, virtual reality environments, virtual keyboard, etc. Likewise several research works have been developed for the control of external devices using different physiological signals viz. Photoplethysmography (PPG) and electroencephalography (EEG) based brain computer interface (BCI), electro-oculography (EOG) based eye-gaze tracking, voice control technology, electro-myography (EMG) based cybernetics, etc. However, in addition to the advantages that these systems offer there have been a lot of complications associated with the usage of various biopotential signals.

Epidemiological studies on group of people with disabilities have shown that many of them retain intact their control ability over the oculo-motor system making EOG signals the most prominent signals in the body. Furthermore, since EOG provides a non-invasive method for recording full range of eye movements; it is widely used in ophthalmic research and clinical laboratories for the diagnosis and prognosis of diseases like multiple sclerosis and best's disease.

Besides the clinical and laboratory usage of EOG signal, it has also inspired many researchers to develop practical devices.

However, most of the systems have slow processing speed and some of them have far too complex design and training strategies which makes them unsuitable to be used in the real time environment. Hence, the motivation behind the current study is to develop real time controller that offers improved operation and simple user friendly setup without compromising the performance.

The proposed system incorporates economic and functional flexibility that would assist the severely disabled to live independently. In this study, improvements have been made over the conventional EOG biopotenial amplifiers. The amplification avoids the unnecessary drifts and makes use of active electrodes to enhance the signal quality and reduce the channel and other external noises. Full scale utilization of positive and as well as negative peaks acquired from the EOG signal is made possible by the development of squaring circuit.

Establishing a new channel without overt speaking and hand/arm motions makes life easier for patients and therefore improves their life quality. In addition to the patients previously mentioned, giving messages on computer screens and controlling a wheelchair or robot arm without muscular movements are useful for the elderly as well. It is assumed that the population of people aged 60 and beyond will range from one to three in 2030. Considering life span extension and the handicapped, the need for a human–computer interface (HCI) has been increasing. [1][2]

Paralyzed stroke patients are unable to normally communicate with their environment. For these patients, the only part of their body that is under their control, in terms of muscular movement, is their eyeballs. Some research in this area has focused on investigating new efficient communication tools for paralyzed patients for translating their eye movements into appropriate communication messages. Our motivation is to increase the quality of life of these patients using an HCI that provides an efficient communication channel. [1][2]

The ultimate goal of this study is to provide paralyzed patients with an efficient, faster, and accurate means of communication.

- As a review process for this proposed system we refer many reputed journals' papers and also the various conferences papers.

In October 99 S. H. Kwon and H. C. Kim share their view at first joint BMES conference serving huminity-Adavnceing technology, under topic "EOG BASED GLASSES TYPE WIRELESS MOUSE FOR THE DISABLED". They said that "a new EOG based computer input device was developed for disabled, which acquires eye movements and produces output for emulating the PC mouse. Five electrodes were placed on the frame of glasses having good contact with skin and requiring no electrode gel. Wireless radiofrequency was used for transmission media. Virtual lead waveform was reconstructed by a weighted sum of the acquired real lead waveforms. [8]

Though device was convenient to wear but whole system was not so successful because of issues of reconstruction algorithm and transmission loss threats.

In 2009 Zheng , Xiao-xiang X shared their views on "A portable wireless eye movement control computer interface for disabled" at ICME international conference on complex medical engineering.

They used zigbee wireless module for transmission and two channel amplifier and filters for separate eye signals & sat sampling rate 250Hz for eog signal.[9]

There is another literature about EOG based assisting device for disabled people was published by ieee press/ASME transaction on mechatronics on October 2011, named "wireless and portable EOG based interface for assisting disabled people". The authors Andres ubeda & Jose M. Azorin said that "This system interface used five electrode placed around eyes and processing algorithm was developed to detect eye movements in addition system did not need power supply from network as it was work with batteries and USB supply. Interface also tested to control robot arm.[10]

In august 2011, Ali bulent usakli and Serkan gurkan published paper on "Design of novel efficient human-computer interface: an electrooculagram based virtual keyboard" in ieee press transactions on instrumentation and measurement. They mentioned about their attempt and results about establishing an alternative channel without speaking and hand movements to increasing the quality of life for the handicapped. [1]

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 biopotential measurement pitfalls, the novel EOG-based HCI system allows people to successfully communicate with their environment by using only eye movements. [1]

Classifying horizontal and vertical EOG channel signals in an efficient interface is realized in this study. The new system is microcontroller based, with a common-mode rejection ratio of 88 dB, an electronic noise of 0.6 µV (p-p), and a sampling rate of 176 Hz. The nearest neighborhood algorithm is used to classify the signals, and the classification performance is 95%. The novel EOG-based HCI system allows people to successfully and economically communicate with their environment by using only eye movements.[1]

In 2012 at 2nd IEEE international conference on parallel, distributed and grid computing , the authors piyush swami,tapan Gandhi ramandeep singh and sneh anand presented their view , work and results about " Novel embedded approach for the development of wireless Electro-oculogram based human computer interface. They used three different voltages of signals were made available from forced blink, left eye-gaze and right eye-gaze movements. All these signals with set to different thresholds were feed into the microcontroller for the control of two 4.lKgcm servo motors. To segregate the blink signal for the device control from that of the normal involuntary blinks we used forced blink signals for the command generation. The amplitude of the involuntary normal blink is around 1OmV, while that of forced blink which is 400m V thus, this completely avoided the collision of two signals. Precautions were taken to avoid back flow of currents, drifts and motion artefacts.[11]Later, their paper also presented a prosthesis model for upper limb rehabilitation. Additionally, this system provides an extended application of the trend of integrating real-time embedded systems with wireless transmission for diagnostics, making it more practicable to implement on newer and smaller platforms.

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II. Need and Objective of Research

As far as physically disabled person's concern they are deterred from doing their daily life tasks, communicating with people, and dealing with Sophisticated Instruments individually due to their inability to utilize devices. Although lots of assisting devices are available but from which there are only few devices are useful for paralysed patients who can't speak. Establishing a new channel without overt speaking and hand/arm motions makes life easier for patients and therefore improves their life quality.

In recent years, many intuitive interfaces have been developed which make use of minute movements in various parts of the body and translate them into machine commands. However, if directional discrimination of Eye analysed and linked with those devices, then for them it is easy to use such devices. This control technique could be useful in multiple applications of Human Machine Interface (HMI), such as mobility and communication aid for handicapped persons.[2]

Another most important need of this research about cost factor and complexity. As each and every product or plan is popular if it is cheaper. Assisting devices are available for a particular patient is too costly; hence hard to afford by common men. This forces us to design an economic affordable assisting device with less complex algorithm, circuitry and other ancillary requirements.

The objective behind this to study of natural eye movements and its application for paralysed patients, that helps to build up a Prototype of EOG Operated assistive device which may give them some short of communicating strength and help people to interact with the world at least helps to tell their need to attendants.

Our objective is dividing in to two tasks. Firstly to acquire and investigate different eye Movement using Electrooculography and secondly to design of a assisting device using Electrooculography-based Human- Machine-Interface, which allows a user to guide his/her attendant about his/her need of activity using selecting activity from computer/machine by his eye movements

- EOG acquisition system.
- Set a Human-Computer/machine Interface; EOG based graphical user interface.

III. Electro Oculogram(E.O.G.)

The human visual system embraces a group of organs responsible for gathering information from the surrounding, whose main structures - the eyes - react to the light, being able of focusing, in a balance between refraction and refraction, converting stimuli to signals. Their message is transported through neurons and other optical pathways until the forebrain, where is decoded; accessory structures, as eyebrows, palpebrae, eyelids and lacrimal apparatus, supporting the visual function. Eye has three main layers or tunics: 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.[14]

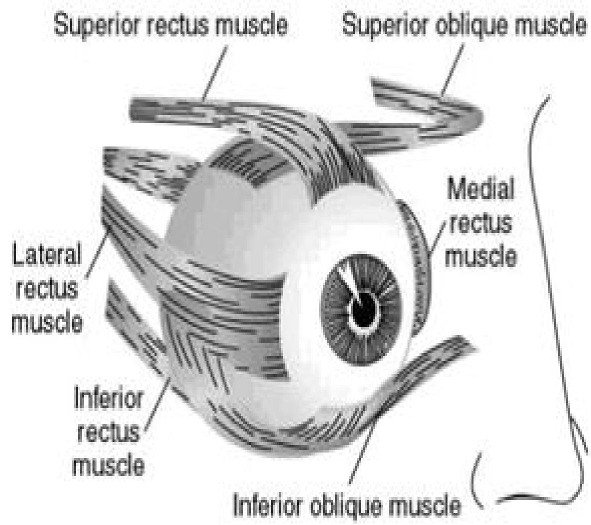

Fig. 1. The muscles controlling the eye movements

An eye movement is controlled by six muscles as shown in figure 1. The extra ocular or extrinsic eye muscles, considering their relatively small size, are incredibly strong and efficient. There are the six extra ocular muscles, which act to turn or rotate an eye about its vertical, horizontal, and anterior-posterior axes. [14] Medial rectus (MR), Lateral rectus (LR), Superior rectus (SR), Inferior rectus (IR), Superior oblique (SO), and Inferior oblique (IO).

Electrooculography 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 a negative pole in the retina. Changes in the position of the eyeball cause changes in potential at the skin. Plot of Eye Potential referred as an **Electrooculogram [EOG].**

It can be described as a fixed dipole with positive pole at the cornea and negative pole at the retina. The magnitude of this potential is in the range 0.4-1.0 mV and frequency ranges from 0 H_Z to 40 H_Z .[12]

One of the most basic requirements of this assisting device is to develop an EOG acquisition system. Generally basic biological signal acquisition system contains pre amplifier, High gain instrumentation amplifier and band pass as well as notch filter. Below figure 2 shows the block diagram for eog signal. We have to design separate circuitry

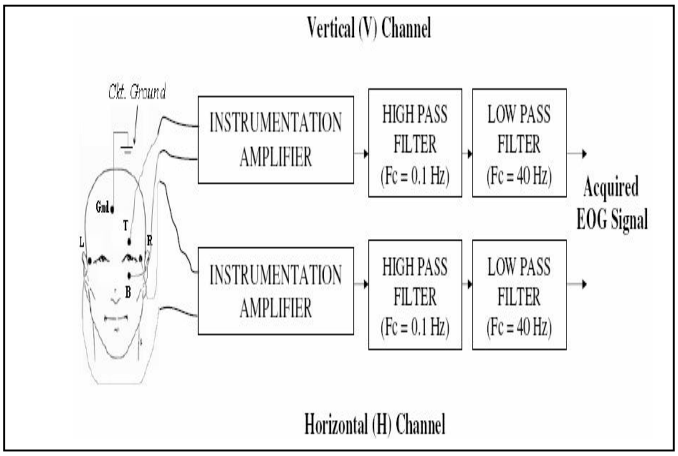

Figure 2. Acquisition block diagram and electrode position

for horizontal and vertical eye movements.[3]

Below figure 3 shows generalized block diagram for proposed system and figure 4 shows EOG signal acquisition block diagram.

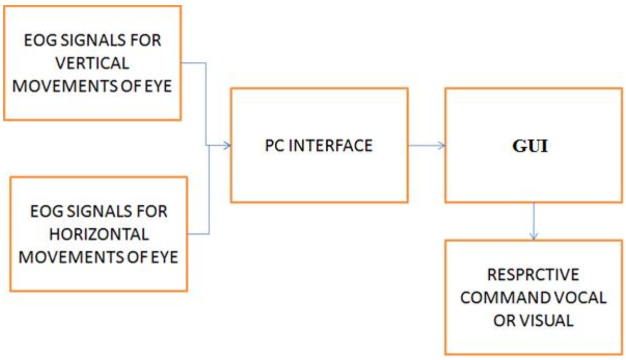

Figure 3: Generalized block diagram for proposed system

Figure 4: Block diagram for EOG acquisition system [9]

INSTRUMENTATION AMPLIFIER is use to amplify the low level signal up to enough voltage level. As discussed earlier like all biological signals the EOG has very low amplitude of around 0.05 mV to 3.5 mV. So in order to process the signal, our first task is to amplify it to a level where we can use it to drive other processing circuits. [12] We've used IC INA128, differential amplifier. Analog Butterworth filters are generally used to filter out the other than frequency related noise from the original or required signal. As we know that EOG signals' frequency from 0 to 40 Hz; and generally as discussed filter of band 0.01 to 50Hz is designed.[12] To remove power line noise notch filter of 50Hz frequency is designed.[13].

We are using only low pass filter as we can also remove noise in PC instead of circuitry filtering; in addition there is some threat of filter out useful signal strength also via circuitry filtering.

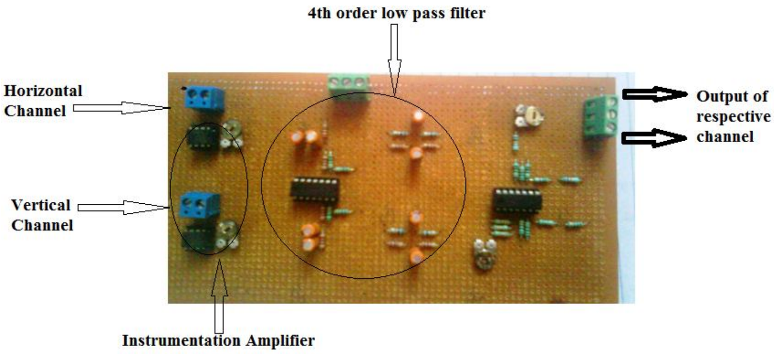

Figure 5: Hardware of EOG signal acquisition

We are using IC TL084 which contains four operational amplifiers to design two 4^{th} orders LPF for each channel. Above figure 11 shows the hardware for EOG signal acquisition of horizontal and vertical channel both.

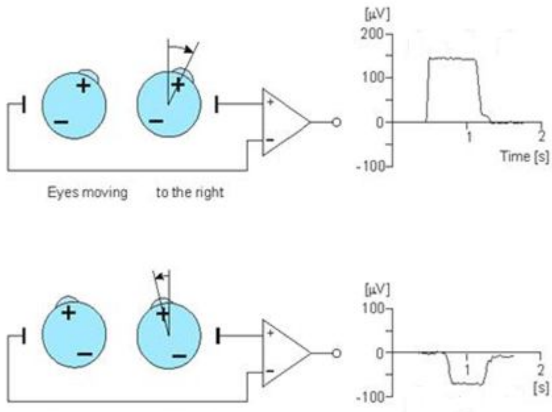

Figure 6 Eye ball movements and respective output

Now discussion about **Electrode placement and respective output of signal**. As there is no effect have been seen into vertical channel output while eye's horizontal movements occurs, & vice-versa we have to use separate circuit for horizontal and vertical movements of EOG and each type of movements can only seen in respective channel. But blink can be seen into both channels we don't have two separate circuits. Following discussion is about the output of response of EOG with respect to terminal of amplifier connected to electrode at particular position. Signal goes positive side followed by negative if eye moves towards respective electrode which is connected to positive terminal of amplifier and it goes negative side followed by positive if eye moves towards respective electrode which is connected to positive terminal. There is no effect have been seen into vertical channel output while eye's horizontal movements occurs, & vice-versa. [7]

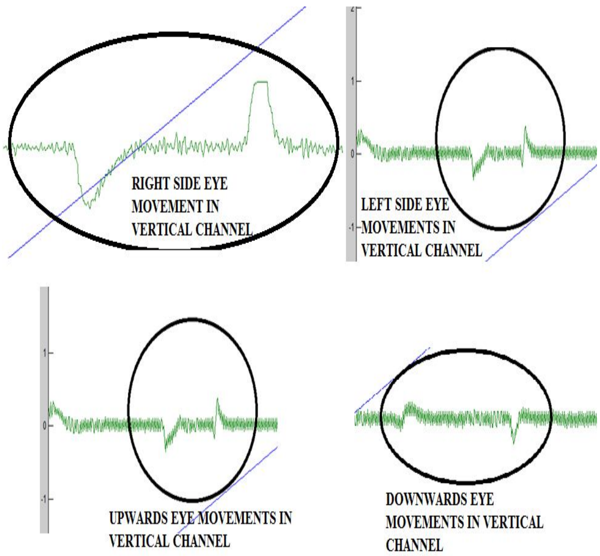

Figure 7. Horizontal & vertical channel outputs for right, left, top & bottom side eye movements

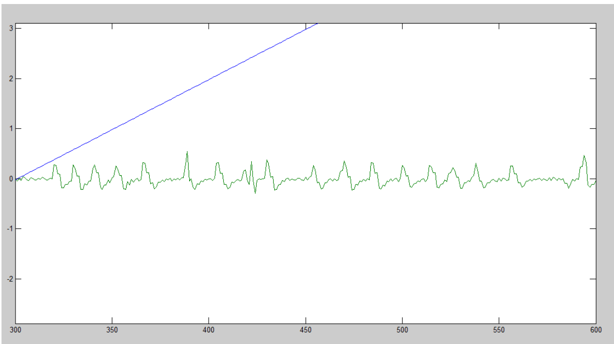

Figure.8 continuous blink detection in Horizontal channel

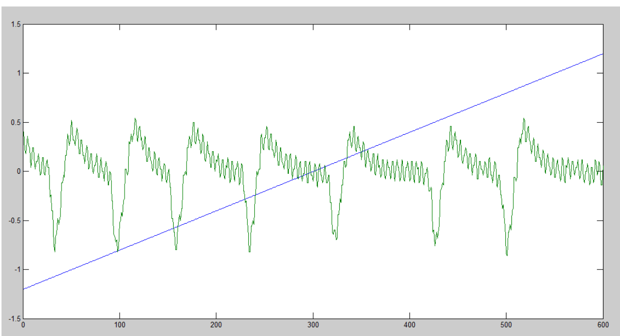

Figure.9 continuous blink detection in Vertical channel

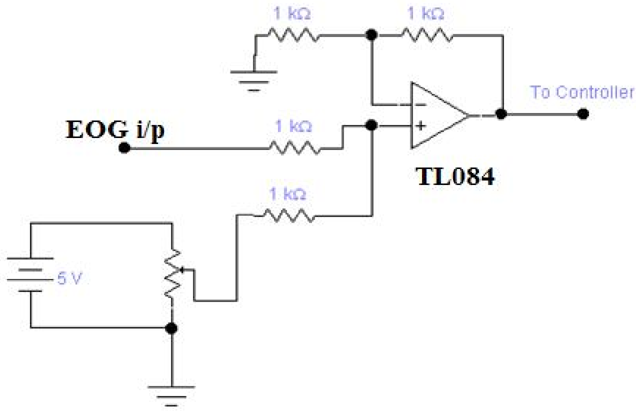

Figure 10: Summing Amplifier to Shift DC level

As per our application we have to recognize this EOG signal using signal processing technique for this purpose we have to transmit this signal into PC.

The signal must be brought into the range of zero to five volts to enable the analog to digital converter to perform analysis on it. The summing amplifier is depicted in Figure 7. Using Kirchhoff's law, it is seen that the output voltage is the sum of the input voltages. After amplifying, the signal is around 330mvolt peak-to-peak, so the best way to make the signal reside only in the positive domain is to add 1 to 2 volt DC voltage. After summing amplifier, the base line of the ECG signal has been brought to an offset of 1 or 2 volt depending upon how much DC voltage has been summed with the signal. For our convenience we used potentiometer (variable resistance), for generating 1V DC from a voltage divider circuit. The output of the summing amplifier is then directly fed to the analog input ADC channel of the Atmegha-16 controller.

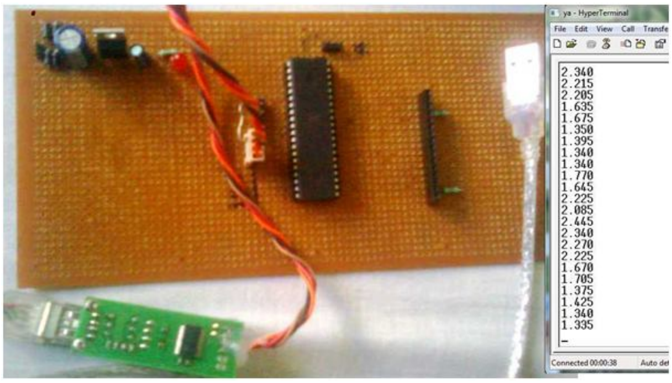

Figure 11: Microcontroller unit with USB port & random data received at hyper terminal of PC

EOG from patient is in the analogue form, which must be converted into digital form to interface it to PC. The purpose of the microcontroller is to acquire analogue signals ranging from 0 to 5V and sending them by standard serial protocol. Data acquisition system is designed using Atmegha-16 microcontroller. Analogue ECG signal is converted into digital form by built-in ADC of microcontroller. We get digital EOG signal with no loss of original details.

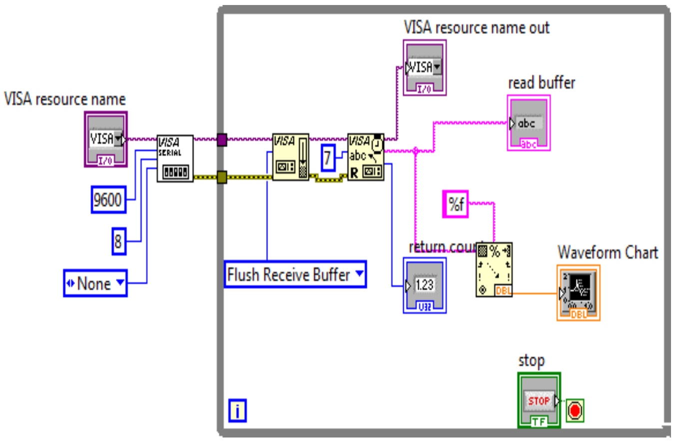

Figure 12 VI file for serial Data receive

Digital data is brought into microcontroller then it is transmitted to PC using standard serial protocol. Baud rate for serial transmission is set to 9600bps, which will give about 5000 samples per 6.04 seconds. We are using USB port for transmission. Above figure 8 shows the microcontroller unit mounted on GPB with output data USB port and the random data received at hyperterminal of the PC.

A. Advantages of EOG over other methods

The visual systems mentioned above in this section other robust methods of eye tracking, usually with very good accuracy. While in certain circumstances, visual methods may be more appropriate, some of the reasons for favouring the EOG over other options for measuring eye movements are presented here.[2]

The EOG typically has a larger range than visual methods, which are constrained, for large vertical rotations where the cornea and iris tend to disappear behind the eyelid. Estimated that since visualization of the eye is not necessary for EOG recordings, angular deviations of up to 80 can be recorded along both the horizontal and vertical planes of rotation using electrooculography. [1]

The EOG has the advantage that the signal recorded is the actual eyeball position with respect to the head. Thus for systems designed to measure relative eyeball position to control switches (e.g. looking up, down, left and right could translate to four separate switch presses) head movements will not hinder accurate recording. Devices for restraining the head or sensing head movement are only necessary when the absolute eye position is required.[2]

Even visual methods that compensate for head movements by tracking relative movement of two points in the eye require that the eyes be kept within the line of sight of the camera and thus often use a head rest any way to keep the head in position. The criterion that the head must be kept in front of a camera may not be possible in certain circumstances where it is conceivable that the user may not be in front of a computer screen or in instances where the user has uncontrolled head spasms, as may be the case for users with cerebral palsy.

In visual methods, measurements may be interfered with by scratches on the cornea or by contact lenses. Bifocal glasses and hard contact lenses seem to cause particular problems for these systems. EOG measurements are not affected by these obstacles.

EOG based recordings are typically cheaper than visual methods, as they can be made with some relatively inexpensive electrodes, some form of data acquisition card and appropriate software. Any method using infrared light requires an infrared transmitter and camera for operation, plus ex- pensive software to calculate the eye position from the captured image. Software to convert EOG recordings into absolute eye position is considerably more straightforward than video based techniques that require complicated computations to analyse video frames and convert this into an estimate of eye position, and thus EOG software should be less expensive.[2]

The EOG is commonly used to record eye movement patterns when the eye is closed, for example during sleep. Visual methods require the eye to remain open to know where the eye is positioned relative to the head, whereas an attenuated version of the EOG signal is still present when the eye is closed. The EOG can be used in real-time as the EOG signal responds instantaneously to a change in eye position and the eye position can be quickly inferred from the change.

B. Limitations of EOG-Based system

The EOG recording technique requires electrodes to be placed on both sides of the eyes, and this may cause some problems. Firstly, it requires that a helper is present who has been taught how to correctly position the electrodes.[2]

Secondly, electrodes placed around the eyes may draw attention to the user's disability and compromise the user's feelings of dignity. For horizontal EOG recordings, a possible solution is to use a pair of glasses or sunglasses. The two electrodes are placed on the inside of the temple arm of the glasses so that the electrodes make contact with the skin when the glasses are worn. Many people who are disabled already wear sunglasses, even indoors, due to photosensitivity.

Another large problem faced by EOG-based gaze tracking systems using DC coupled amplifiers is the problem of baseline drift. This problem may be troubleshoot by using an AC coupled amplifier but then the signal recorded will only react changes in the eye position rather than expressing the absolute eye position. If eye position is to be used for any sort of continuous control then a DC coupled amplifier is usually necessary. The measured EOG voltage varies for two reasons. Either the eye moves (which we want to record), or baseline drift occurs (which we want to ignore). Baseline drift occurs due to the following factors [2]

Lighting Conditions: The DC level of the EOG signal varies with lighting conditions over long periods of time. When the source of the light entering the eye changes from dark conditions to room lighting,

Electrode contact: The baseline may vary due to the spontaneous movement of ions between the skin and the electrode used to pick up the EOG voltage. The mostly commonly used electrode type is silver-silver chloride (Ag-AgCl). Large DC potentials of up to 50mV can develop across a pair of Ag-AgCl electrodes in the absence of any bioelectric event, due to deference in the properties of the two electrode surfaces with respect to the electrolytic Conduction gel. The extent of the ion movement is related to a number of variables including the state of the electrode gel used, variables in the subject's skin and the strength of the contact between the skin and the electrode. Proper preparation of the skin is necessary to maximise conduction between the skin and the conduction gel, usually by brushing the skin with alcohol to remove facial oils.

Artefacts due to EMG or Changes in Skin Potential: The baseline signal may change due to interference from other bioelectrical signals in the body, such as the electromyogram (EMG) or the skin potential. EMG activity arises from movement of the muscles close to the eyes, for example if the subject frowns or speaks. These signals may be effectively rejected by careful positioning of the electrodes and through low pass filtering the signal. Skin potential changes due to sweating or emotional anxiety pose a more serious problem.

C. Current work and Future Work Plan

As far as final goal is concern result up to this is though motivational but not enough. To provide excellent example of man-machine interface we have to set proper EOG detection algorithm and on which we can set its application to paralysed patients. Currently I am working on serial transmission of signal using Atmegha-16 micro controller through USB port. As a trial I transmit random data through it and also checked on HyperTerminal of PC. Also make simple GUI having choice buttons/matrix using asp.net and checked by manually cursor clicking. I also store my EOG signal of various up, down, left, right and blink movements of eye in csv file.
With the help of differentiation of signal i got total change in peak to peak and also set the threshold for each movement with the help of various data from different persons

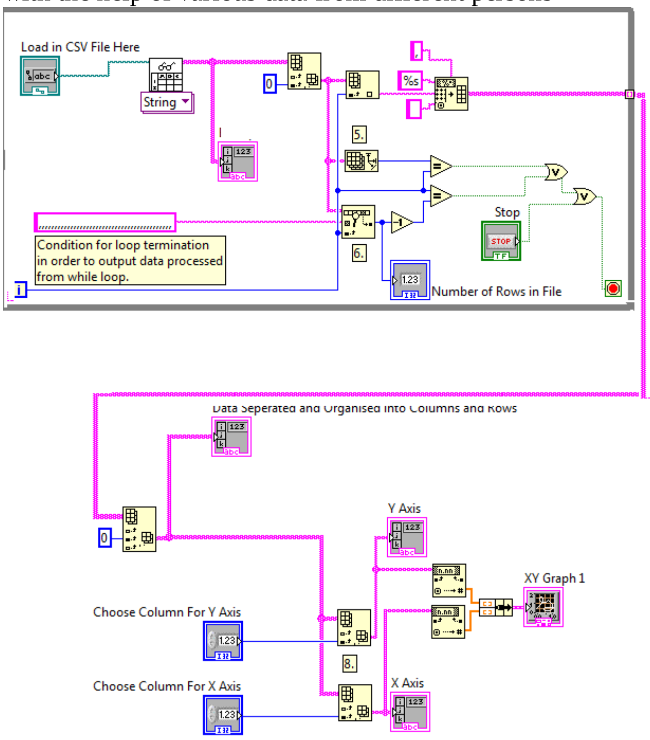

Figure 13: CSV file load and display with help of LAB-view

Now I have to set signal detection statically and also GUI operation statically by applying these signals. For signal detection first, the signal is to be filtered and then, the derivative is calculated to obtain the abrupt changes of the signal. Finally, using specific thresholds for each user, the direction is obtained. The processing algorithm is executed for each channel. The result will be −1, 0, or 1 that corresponds to left, nothing, or right for the horizontal channel, and down, nothing, or up for the vertical channel.

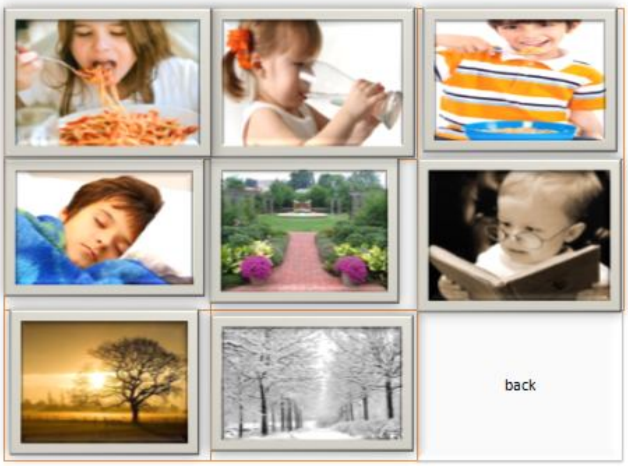

Figure 13 GUI of Different activities

Figure 13 shows the matrix of GUI having matrix of button; upon click it gives respective audio output which uses to inform attend person of patient. For future scope this algorithm could be implemented on real time EOG also. We can also set various functions like entertainment, general activity and virtual keyboard etc in GUI which will be controlled by patient's EOG.

IV. CONCLUSION

The main thing is to set threshold for eye movements for this purpose we record EOG from different persons for exact threshold value.

Following are main factors are to consider that electrode position as varying in position is seen in change output voltage so for proper application electrode position must follow the standard position.And for the real time application we have to consider difference between involuntary as well as voluntary blink signals to remove effect of such false trigger (for select block event).For real application for paralysed patients the block matrix of various activity should increase and so also precisely movement detection and respective selection of block event should occur.

At current stage we got efficient result of button matrix having audio output upon click event of respective block.

V. REFERENCES

1. Ali Bulent Usakli and Serkan Gurkan," Design of a Novel Efficient Human Computer Interface: An Electrooculagram Based Virtual Keyboard", Ieee transactions on instrumentation and measurement, vol. 59, no. 8, august 2010
2. Joo Martins N, Ana Leal N., Joana Loureno N., Jonathan Ribeiro N.,Miguel Almeida N., Miguel Castro N., Joana Paulo N., "Man Machine Interface",instrumentation and signal acquisition in bioengineering-2011,lisbon, Portugal
3. Shubhodeep Roy Choudhury, S.Venkataramanan, Harshal B. Nemade, J.S. Sahambi, "Design and Development of a Novel EOG Biopotential Amplifier", IJBEM-Vol. 7, No. 1, 2005
4. Joseph J. Teccea, James Gipsb, Peter Olivierib," Eye movement control of computer functions", International Journal of Psychophysiology 29 _1998. [319-325]
5. D. Borghetti, A. Bruni, M. Fabbrini," A low-cost interface for control of computer functions by means of eyemovements", Computers in Biology and Medicine 37 (2007) 1765 – 1770, www.intl.elsevierhealth.com/journals/cobm
6. S. Aungsakul, A. Phinyomark, P. Phukpattaranont, C. Limsakul," Evaluating Feature Extraction Methods of Electrooculography (EOG) Signal for Human-Computer Interface", I-SEEC2011, Procedia Engineering 32 (2012) 246 – 252, http://www.elsevier.com/locate/procedia
7. Siriwadee Aungsakun, Angkoon Phinyomark, Pornchai Phukpattaranont,Chusak Limsakul," Development of robust electrooculography (EOG)-based human computer interface controlled by eight-directional eye movements",International Journal of Physical Sciences Vol. 7(14), pp. 2196 - 2208, 30 March, 2012, http://www.academicjournals.org/IJPS
8. S. H. Kwon & H. C. Kim,"EOG based glasses type wireless mouse for disabled", Proceedings of The first joint BMES/EMBS conference- serving Humantiy,Advancing Technology, Oct 13-16 '99,Atlanta,GA, USA
9. Zheng , Xiao-xiang X "A portable wireless eye movement control computer interface for disabled"at ICME international conference on complex medical engineering, 2009.
10. Andres ubeda & Jose M. Azorin "wireless and portable EOG based interface for assisting disabled people". The authors, ieee press/ASME transaction on mechatronics on October 2011
11. Piyush swami, Tapan Gandhi, Ramandeep singh and sneh anand " Novel embedded approach for the development of wireless Electro-oculogram based human computer interface, 2nd IEEE international conference on parallel, distributed and grid computing, 2012

Books:-

12. R S Khandpur,"Handbook of Biomedical Instrumentation", twelfth reprient 2008-Tata Mc grew hill company Ltd
13. Op-amps and linear integrated circuits,Ramakant A. Gayakwad, Prentice Hall, 2000
14. Text book of medical Physiology",John hall, Elsevier Health Sciences, Jul-2010