Eye movements based Human Computer Interface using Virtual Instrumentation

Vrushali Ratne[1], Dr. M.S.Panse[2]
[1]*M.Tech Student Veermata Jijabai Technological Institute,Mumbai India*
[2]*Professor Veermata Jijabai Technological Institute,Mumbai India*
[1] *vrushaliratne94@gmail.com*

Abstract**—** Persons suffering from peripheral mobility like paraplegia which is paralysis from waist down or quadriplegia which is paralysis from shoulders down have the ability to coordinate eye movements. In such cases biosignal signals such as Electroencephalogram (EEG), Electromyogram (EMG), Electrooculogram (EOG) etc. can be used in Human Machine Interface(HMI). This can improve the quality of the life of differentially abled people and thereby making them minimally dependent on others. EOG signals are used as the control signals for the movement of the prototype motor wheelchair. LABVIEW is used to develop the algorithms to process the acquired EOG signal and generate control commands. The EOG signal will be pre-processed by cacasded stages of filters using Digital Filter Design toolkit, then features extraction is done. The resulting signal is then classified using Support Vector Machine classifier and thresholding algorithm to get control signals. These signals are then programmed using ATmega328P microcontroller for movement of prototype motorized wheelchair.

Keywords**—** *Electrooculogram(EOG), electrodes, LABVIEW, Features Extraction, Human Machine Interface(HMI).*

I. INTRODUCTION

As per Census 2011, in India, out of the 121 Cr population, about 2.68 Cr persons are 'differently abled' which is 2.21% of the total population. Among the disabled population 56% (1.5 Cr) are males and 44% (1.18 Cr) are females. In the total population, the male and female population are 51% and 49% respectively[2]. The country's disabled population has increased by 22.4% between 2001 and 2011, number of disabled, which was 2.19 crore in 2001, rose in 2011 to 2.68 crore. Most of the disabled are those with movement disability. According to the census, 20.3% of the disabled are movement disabled followed by hearing impaired (18.9%) and visually impaired (18.8%)[3]. According to the research conducted in 2013 on the prevalence of paralysis across the U.S., there are nearly 1 in 50 people living with paralysis – approximately 5.4 million people[4]. A huge portion of human society is suffering from severe neurological disorder which makes them paralyzed. Normal functions of their head and eyes, are maintained by many severely paralyzed patients. Persons suffering from peripheral mobility like paraplegia which is paralysis from waist down or quadriplegia which is paralysis from shoulders down usually have the ability to coordinate eye movements. In such cases biosignal signals such as EEG, EMG, EOG etc. can be used in HMIs. The need of the hour is to provide such individuals with assistive technologies which will make them minimally dependent on others and lead a better life. Thus, the motivating factor behind this work is to develop a prototype wheelchair which can help paralyzed individuals regain mobility and HMIs can be used to translate human intentions into wheelchair control commands.

Huang *et al.* developed a system which controlled wheelchair based on EOG signal by detecting one type of eye movement(blink). Single Vertical channel with three wet electrodes was used for EOG acquisition. The System had a sampling rate of 250 Hz. DC level and 50 Hz power line noise was removed using differential approach. Several Features such as the peak value of the sub-segment and the duration of the blink were extracted. Thirteen different commands were generated. Thresholding algorithm was used to process these signals[5]. He *et al.* developed a single-channel EOG-based asynchronous speller. Three electrodes were used for EOG acquisition with 8 healthy subjects. The EOG signals were acquired using a NuAmps device. The data acquisition system had a sampling rate of 250 Hz. The samples were bandpass filtered to remove baseline drift and high-frequency noise. The signal was then differentiated to obtain various features like peak and valley. 73 different characters could be selected using the proposed GUI. Support vector machine (SVM) classification along with waveform detection algorithms was combined to detect the blink[6]. Wu *et al.* developed a wireless EOG-based HCI device. Two channels with 5 wet electrodes were used for EOG acquisition. The System had a sampling rate of 250 Hz. Eight different commands were generated. This system consisted of a wireless acquisition device and thresholding algorithm to classify the EOG signals[7]. Heo et al. developed a Novel Wearable Forehead EOG Measurement System for Human-Computer Interfaces. Ag/AgCl electrodes are used for EOG acquisition. The sampling rate was 256 Hz. These signals were then processed by using thresholding algorithm[8]. Lydia *et al.* developed a LabVIEW based EOG Signal Processing. Ag/AgCl electrodes were used for signal acquisition. Two channels with 4 commands were used[9].

II. PHYSIOLOGY OF ELECTROOCULOGRAPHY

Eye movement and blinking can be detected using several methods such as scleral search coils, EOG, infrared oculography and image-based methods. The EOG based methods are relatively more convenient, cost-effective and non-invasive. EOG signal finds application in the fields related to the estimation of drowsiness level to prevent an accident, as a communication aid by means of a virtual mouse, keyboard control, electric power wheelchair, Industrial assistive Robot or neuroprostheses and in the Ophthalmological diagnosis. EOG signal gives information about eye movements. The eye has a resting potential and acts as a dipole in which the front of the eye(cornea) is positive and the back of the eye (retina) is negative. The magnitude of EOG signal lies in the range of few millivolts and frequency range is dc to 50 Hz. Physiological signals suffer from interference such as power-line noise, motion artifacts, DC offset etc[1].

III. METHODOLOGY

The EOG analysis system is developed in LabVIEW platform. LabVIEW(Laboratory Virtual Instrument Engineering Workbench) is a graphical programming environment developed by National Instruments (NI), which allows high-level or system-level designs. LabVIEW constitutes a graphical programming environment that allows one to design and analyze a DSP system in a shorter time as compared to text-based programming environment[13].

A. Implemented Block Schematic

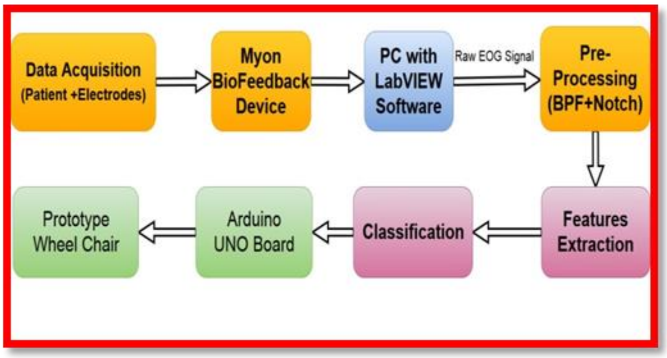


Fig. 1.Block Schematic of the EOG System

The implemented system consists of stages of Data acquisition, Signal Conditioning, Feature Extraction, Classification and rehablilitation aid as shown above.

B. Data Acquisition

Recordings of all EOG signals were carried out using a Myon biofeedback device. Disposable pre-gelled Ag/AgCl electrodes were used for EOG signal acquisition. The sampling frequency of the device is 2000Hz. Figure 1 shows placement of electrodes.

Data is collected from 18 Subjects for a given set of eye movements. A pair of electrodes was placed above and below the right Eye(anyone eye can be deployed). The subjects were asked to perform each eye movement those included Up, Down, Blink Once, Blink Twice for a duration of 10seconds. Also, the subjects were asked to follow the commands like Up, Down, Blink Once, Blink Twice, Rest etc. with a gap of 3seconds each. Such 3 sets of Readings were taken.

Fig. 2.Electrode Placement

C. Signal Conditioning

Acquired EOG signal was then passed through cascaded stages of filters. EOG signal is of low frequency. To remove 50Hz power-line noise, the signal is initially passed through the notch filter. Further, the signal is band-limited from 0.5-35Hz using band pass filter .

D. Features Extraction

After filtering, Feature extraction is undertaken to acquire the most significant information from the original data in-order to easily classify the eye movements. Some of them are : Mean, Median, Mode, Kurtosis, Entropy, Maximum, Minimum, Number of Peaks, Number of Valleys etc.

E. Classification of Eye Movements

The classification of signal is done using Thresholding and Support Machine Vector classifier.

1) SVM Classifier

An SVM uses a discriminant hyperplane to identify classes. The basic idea is to find a hyperplane which separates the d-dimensional data perfectly into its two classes. In SVM, the selected hyper plane is the one that maximizes the margins, i.e., the distance from the nearest training points[10]. However, there are situations where a nonlinear region can separate the groups more efficiently.SVM handles this by using a kernel function (nonlinear) to map the data into a different space where a hyperplane (linear) cannot be used to do the separation [11]. In SVM, it is easy to have a linear hyperplane between classes. There are functions which takes low dimensional input space and transform it to a higher dimensional space i.e. it converts not separable problem to separable problem, these functions are called kernels. It is mostly useful in non-linear separation problem. Out of 37 features, 20 best features were selected using Principal component Analysis.

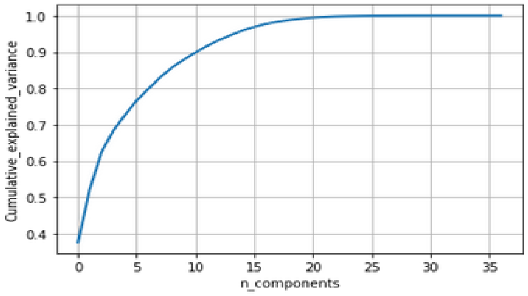


Fig.3.Graph showing selection of 20 features

2) Thresholding Algorithm

A window size of 3000 samples is considered. This algorithm is developed in labVIEW using Structures like while loops, case structures etc., comparators, string indicators, LED's for showing all 4 movements. Features such as positive peak, negative peak, peak to peak value which are considered while setting thresholds. The flow charts for eye movements are as shown :

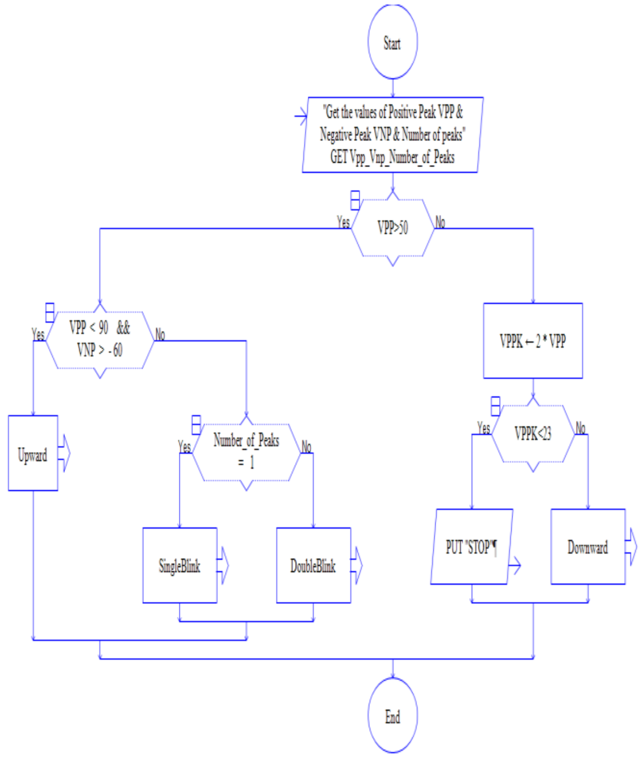


Fig. 4.Flow chart consisting of all Procedures of eye movements

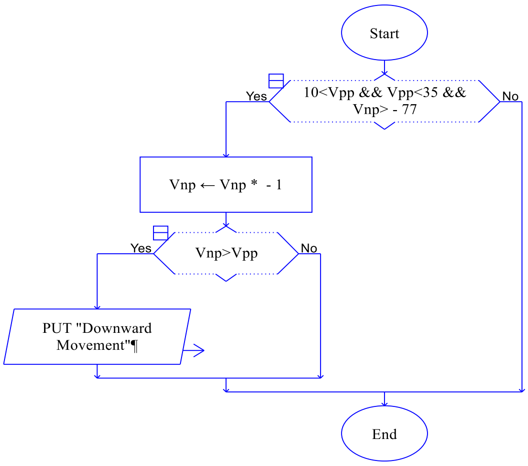


Fig.5. Flow chart Procedure for Downward Movement

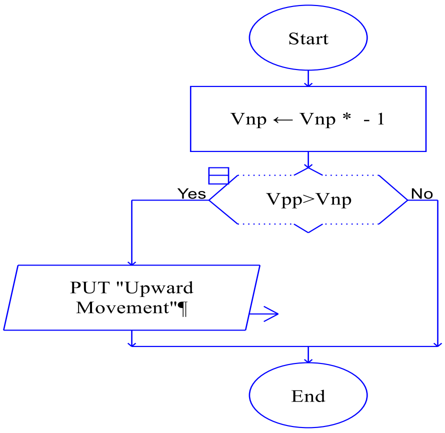


Fig. 6.Flow chart Procedure for Upward Movement

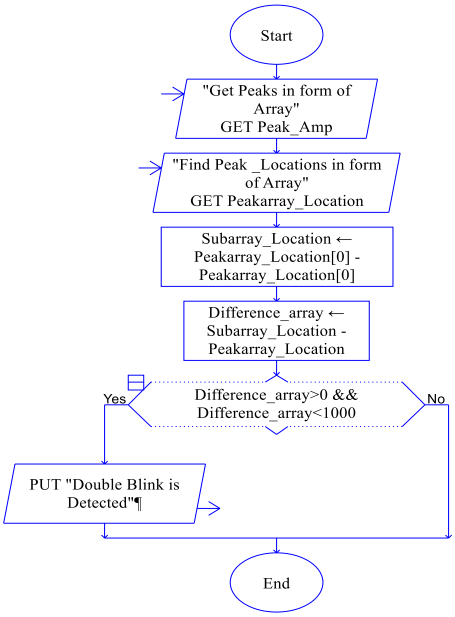


Fig. 7.Flow chart Procedure for Double Blinks

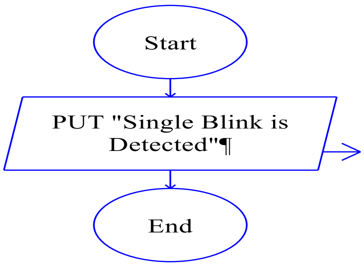
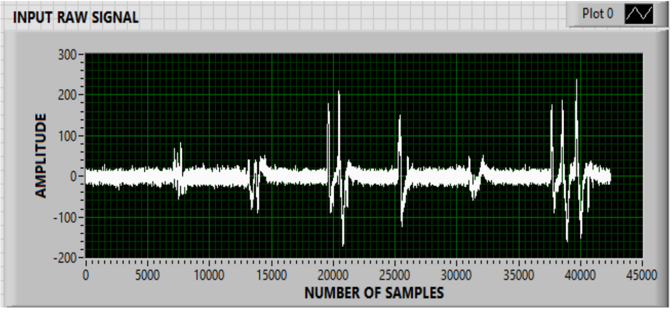


Fig. 8.Flow chart Procedure for Single Blink

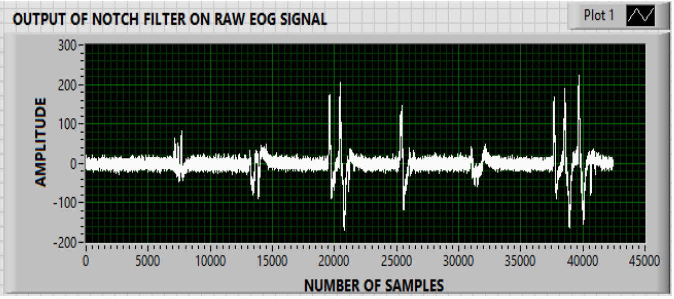
IV. RESULTS

Figures A-I shows Acquired Raw EOG signal and its Processing using Notch and BandPass Filter and

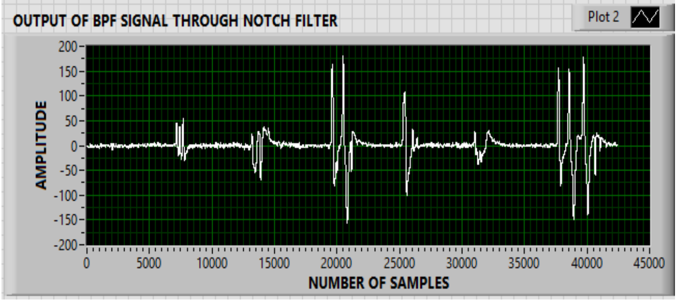
(A)



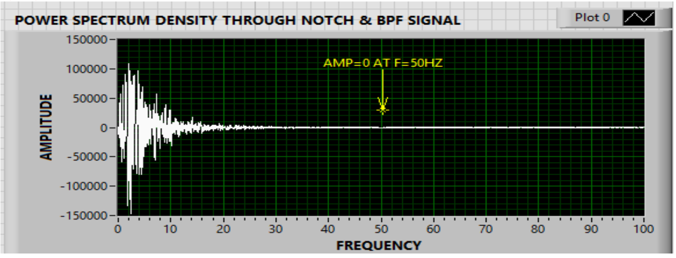
(B)



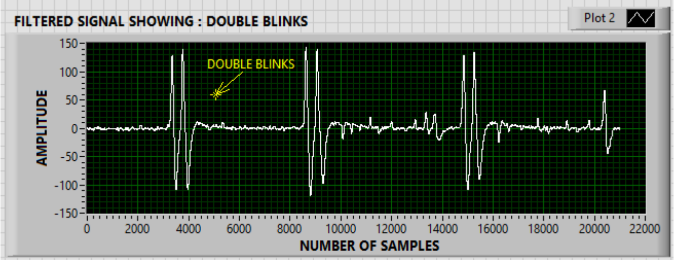
(C)



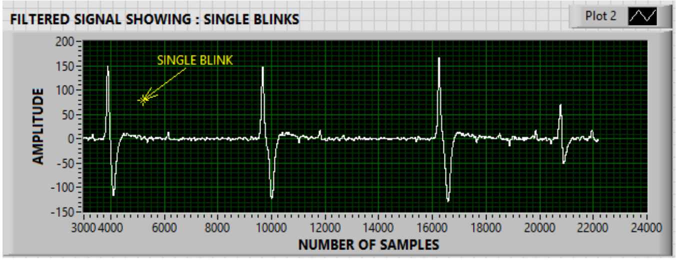
(D)



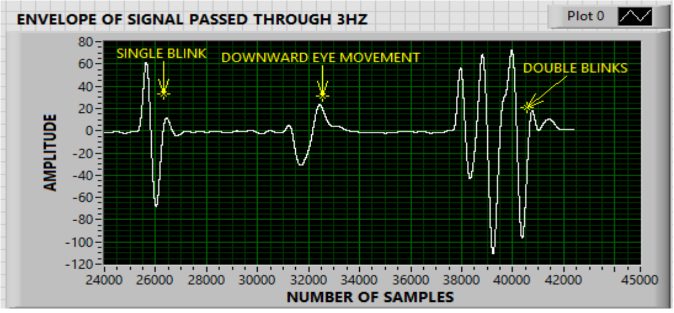
(E)



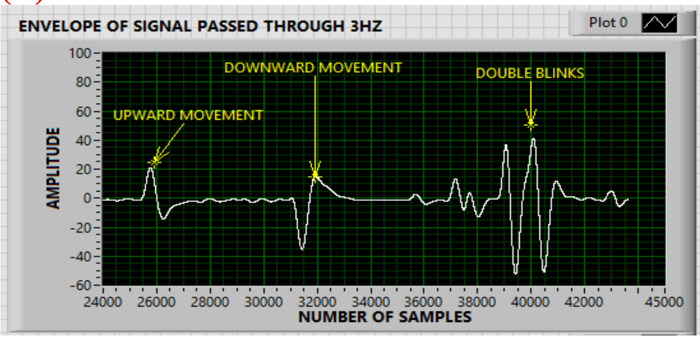
(F)



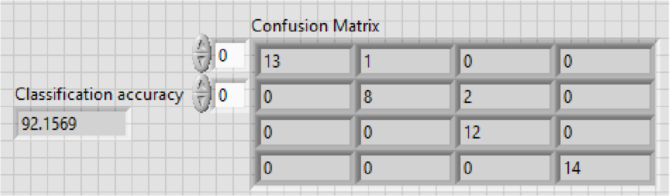
(G)



(H)



Upward or Downward movement of an eye corresponds to Vertical Movement. As seen from the result (H), Upward Movement initially has as a positive peak, which is then accompanied by a negative peak. The amplitude of initial positive peak is higher than that of the negative peak. For the downward movement, the case is exactly the opposite. If the subject looks straight then dc level appears. Blink EOG signal is also attainable from vertical channel. Blink signal in comparison with up movement has the highest peak but time span is short which makes them distinguishable. Result(D) shows that maximum information content is present at lower frequencies. These characteristics of upward and downward eye movements are used for its classification using thresholding technique.



Confusion Matrix

Classification accuracy

92.1569

0		13	1	0	0
0		0	8	2	0
		0	0	12	0
		0	0	0	14

Fig.9. Confusion Matrix and Accuracy Obtained by SVM classifier

As per confusion Matrix, the dataset was fed to SVM classifier in a manner such that first row corresponds to double blinks, second row corresponds to single blink, third row to upward movement, and fourth row to downward movement. As per the Confusion Matrix obtained, it is observed that out of 14 double blinks, 13 are correctly classified by SVM classifier as double blinks whereas 1 is misclassified as single blink. Out of 10 single blink, 8 are correctly classified by SVM classifier as single blink whereas 2 are misclassified as upward movement. Out of 12 upward movements, all 12 are correctly classified as upward movements. Out of 14 downward movements, all 14 are correctly classified as downward movements.

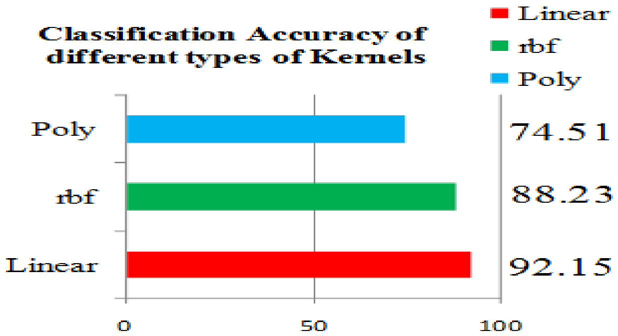


Fig. 10.Classification accuracy of different types of SVM classifiers

The Eye movements are classified using various kernels like Linear, Polynomial, radial basis function. It is found that linear kernel gives highest accuracy of 92.15%.
dial basis

CORRESPONDING EYE MOVEMENT
DOUBLE BLINK

CONTROL SIGNAL GENERATED
C

Fig. 11.Detection of Corresponding Eye Movement by flashing of Respective LED

The Acquired Data was analysed and threshold values were chosen to distinguish between each eye movements. The above figure shows the Graphical User Interface built in LabVIEW consisting of 5 LED's indicating each eye movements those are Upward, Downward, Single Blink, Double Blink and No movement(Stop). One of the string indicator displays message as which eye movement was captured and other string indicator named as the "control signal generator" is given to 8-bit ATmega328P microcontroller via Bluetooth module for driving the motors. The waveform graph shows the captured eye movement.

Each Eye movement generates corresponding control signal like A, B, C, D, E as shown in Fig.11 These control signals are transmitted to USB to serial converter, which is then wirelessly transmitted via bluetooth to ATmega328P microcontroller. This microcontroller then decides the type of eye movement and drives the motors.

TABLE I
DIRECTION OF LEFT AND RIGHT MOTORS FOR VARIOUS MICROCONTROLLER OUTPUTS

Eye Movement	Microcontroller Output				Motor Direction
	A	B	C	D	
Up	High	Low	High	Low	Forward
Down	Low	High	Low	High	Backward
Double Blink	High	Low	Low	Low	Right
Single Blinks	Low	Low	High	Low	Left
Straight	Low	Low	Low	Low	Stop

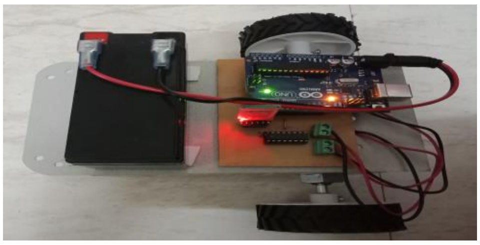


Fig.12.Prototype wheelchair Model controlled by control Commands from LabVIEW

V. CONCLUSION

The EOG Data is acquired using disposable electrodes, from the surrounding region of eye. These signals were pre-processed for noise using cascaded stages of filter. Time Domain features are extracted from the filtered EOG signal. These features are used to classify the eye movement directions. Support vector machine with different kernel functions such as 'linear', 'radial basis function', 'polynomial' have been used for classification. Observing the results it can be said that the linear kernel SVM classifier shows the best performance. Additionally, a new Thresholding algorithm for EOG classification and control signal generation was also developed. These control signals were used to control a wireless prototype motorized wheelchair model by various eye movements and blink using Bluetooth module. This meets the objective of this work which aimed at utilizing a biomedical signal for Human Machine Interface targeted for differently abled individuals.

REFERENCES

[1] Vrushali Ratne and Dr.M.S.Panse, "Single Channel EOG Signal Processing and Features Extraction using Virtual Instrumentation," International Journal of Research and Scientific Innovation, vol. V, issue IV, pp. 287-290, April 2018.

[2] http://mospi.nic.in/sites/default/files/publication_reports/Disabled_persons_in_India_2016.pdf

[3] https://timesofindia.indiatimes.com/india/Disabledpopulation-up-by-22-4-in-2001-11/articleshow/28072371.cms

[4] https://www.christopherreeve.org/living-with-paralysis/stats-about-paralysis

[5] Huang Qiyun, Shenghong He, Qihong Wang, Zhenghui Gu, Nengneng Peng, Kai Li, Yuandong Zhang, Ming Shao, and Yuanqing Li, "An EOG-Based Human-Machine Interface for Wheelchair Control", IEEE Transactions on Biomedical Engineering vol. pp., no. 99, pp. 1-1, July 2017.

[6] He Shenghong and Yuanqing Li, "A Single-channel EOG-based Speller", IEEE Transactions on Neural Systems and Rehabilitation Engineering vol. PP, no.99, pp. 1-1, June 2017.

[7] Wu, Shang-Lin, Lun-De Liao, Shao-Wei Lu, Wei-Ling Jiang, Shi-An Chen, and Chin-Teng Lin, "Controlling a human–computer interface system with a novel classification method that uses electrooculography signals", IEEE Transactions on Biomedical Engineering 60, no.8, pp.2133-2141, February 2013.

[8] Heo, Jeong, Heenam Yoon, and Kwang Suk Park, "A Novel Wearable Forehead EOG Measurement System for Human-Computer Interfaces", Sensors vol.17, no. 7, pp. 1485, July 2017.

[9] Lydia Yuhlung, Hemashree Bordoloi, Khomdram Jolson Singh, Irengbam Vengkat Mangangcha and Laishram Richard, "LabVIEW Based EOG Signal Processing", International Journal for Research in Emerging Science & Technology, vol. 2, no. 3, March 2015.

[10] Lotte, F., Congedo, M., Lecuyer, A., Lamarche, F., Arnaldi, B.: A review of classification algorithms for EEG based Brain-computer Interface. Journal of Neural Engineering 4 (2007)

[11] Banerjee A., Konar A., Janarthana R., Tibarewala D.N., "Electro-oculogram Based Classification of Eye Movement Direction", In: Meghanathan N., Nagamalai D., Chaki N. (eds) Advances in Computing and Information Technology. Advances in Intelligent Systems and Computing, vol 178. Springer, Berlin, Heidelberg 2013

[12] Andreas Bullingy, Jamie A. Wardz, Hans Gellersenz and Gerhard Trostery., "Eye Movement Analysis for Activity Recognition using Electrooculography", IEEE Transactions on Pattern Analysis And Machine Intelligence, vol. 33, no. 4, April 2011.

[13] Umashankar and Dr. M. S. Panse, "Electroretinogram (ERG) Signal Processing & Analysis in LabVIEW", Advances in Medical Informatics Volume I, Issue I, pp-01-05, 2011.

[14] Champaty, Biswajeet, Jobin Jose, Kunal Pal, Thirugnanam A, "Development of eog based human machine interface control system for motorized wheelchair", Emerging Research Areas: Magnetics, Machines Drives (AICERA/iCMMD), 2014 Annual International Conference on. IEEE, 2014.

[15] https://www.ni.com