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Prospects of Electrooculography in Human-Computer Interface Based Neural Rehabilitation for Neural Repair Patients

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ABSTRACT Disable persons are facing a lot of problems in daily life activities. They need some help from others to fulfil their needs every day. To avoid this condition modern technology help such persons to overcome the problem in a natural way like bio signal based-human–computer interaction. In this paper, we focused to study the performance of male subjects compared with female subjects to analyze the performance to design Electrooculographgy-based HCI using periodogram and neural network. Five male subjects and five female subjects are involved in this experiment. From the experimental analysis, we identified that male performance was maximum compared to female performance. From this paper, we analyzed that subject S4 from male subjects and subject S10 from female subjects performance was marginally high compared with other subjects performance took part in this experiment. From the classification accuracy, we conclude that male subject performance was encouraged with 93.67 % and 92.28% for female subjects. The offline test was conducted in the indoor environment to identify the tasks to confirm the performance of individual subjects. From the offline analysis, we conclude that subject S4 performance was high compared to other subjects take part in this paper. Subject S4 took less time to perform the task as per the protocol. Through this paper, we confirm that scheming HCI is achievable.

INDEX TERMS Electrooculography, periodogram, human-computer interface, probabilistic neural network.

I. INTRODUCTION

Person with neural disorder leads to locked in state (LIS). These types of diseases affect the motor neuron in the brain and spinal cord and make them to inoperative and lose its ability to begin action potentials to manage voluntary body movements. At the early stage it attacks some part of the body, but in the development stage it will not allow them to move and interact with others. Sothe person with LIS needs some other helps to communicate [1]. For such persons Human Computer Interface (HCI) or Brain Computer Interface (BCI) is the only way to improve the interaction between patients and the care takers. This interface convert the control signals in to commands and make communication in more natural and human friendly way in the absence of biological channels [2]. Various physiological signals are available to convey the thoughts with others but Electrooculogram (EOG), Electroencephalogram (EEG) and Electromyogram (EMG) based interfaces are widely used control signals to interact with computer aided hardware devices and playing vital role in communication for neural disorder individuals. From this three interfaces EOG based interfaces are widely used for developing EOG based HCI due to non invasive technique, technically less demanding, user friendly and offered at low-cost [3]–[6].

There are several interfaces are developed with the help of bio signals combined with HCI. They are EOG based Speller [7], EOG based Text Entry System [8],

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Visual Navigation System [9], Remote Control System [10], Television Controller system [11], Virtual Keyboard [12], Wheelchair [13]–[17], [36], [37].In this paper we proposed eye movement based HCI to improve the interaction between the user and the system. The system comprises of three main models they are: Five electrode system with Analog Digital Converter (ADI T26) for collecting signals, Lab chart software applications for displaying the acquired signal, and Graphical User Interface are designed to process the signals to display the classified pattern with the help of neural network classifier related to the eye movements [41]–[43].

II. PREVIOUS STUDY

Some of the previous study based on EOG based HCI plays vital role in converting the control signals to command the external devices to operate in the absence of normal channels. Some of the most important studies are mentioned belowW.Tangsuksant, et.,al developed virtual keyboard controller for Motor Neuron affected individual using voltage threshold algorithm and obtained the accuracy of 95.2%, and the designed keyboard have the capacity to type 25.9 seconds per letter [18]. Zhang *et al.* designed EOG based mouse controller using fast fourier Transform and Learning Vector Quantization. Three subjects were take part in this experiment. Eight tasks were recorded from each subject to move the cursor on the screen and obtain the maximum classification accuracy of 97.8%, 97.6% and 92.7% for all the tasks [19]. López *et al.* [20] designed and developed eye controlled mouse using labview with wavelet transform technique. Hossain *et al.* designed cursor controller from five subjects using Automatic threshold determination technique and vertical, horizontal threshold classification techniques and obtained accuracy of 100%, 97% and 93% for blinks and saccades [21].

Ang *et al.* designed EOG based cursor control devices using eight subjects and verified in the indoor and outdoor environment. From the obtained signal, patterns are analyzed by using Kernal Support Vector Machine and obtained 84.42% for indoor uses and 71.50% for outdoor uses [22]. D'souza and Sriraam designed EOG based HCI to interact with computer system using power spectral density with K nearest neighbor and linear discriminant analysis to classify the obtained signal from healthy subjects for four tasks and obtained an accuracy of 81.87% for K nearest neighbor algorithm. The study proves that K nearest neighbor outperforms three tasks out of four in comparison to linear discriminant analysis used in this study [23], [38].

Chang *et al.* developed EOG based eye tracking system for individuals with ALS using eighteen healthy subjects and three ALS patients by using continuous wavelet transform-saccade detection algorithm and classified with dynamic time warping (DTW), dynamic positional warping (DPW), a combination of DTW with support vector machine (SVM), and a combination of DPW with SVM and obtain 95.93% for healthy participants and 95.00%, 66.67%, and 93.33 for ALS patients [24].Ramkumar *et al.* designed EOG based interface for ALS patients for six subjects using nine movements. Statistical method and Time delay neural network (TDNN) were applied to extort the features and classify the obtained features. Obtained features were compared with Feed Forward Neural Network to analyze the performance. The result proves that TDNN model was higher than the other network model used in this study [25]. Hossain *et al.* [26] developed eye controlled cursor movements using Support Vector machine and Linear Discriminant Analysis.

Fang and Shinozaki proposed new techniques in the eye writing system for the language Japanese Katakana from six subjects using deep neural network based Hidden Markov Model. Finally through the study they obtained recognizing accuracy of 95% with error rate of 5% for Japanese Katakana characters [27]. Huang *et al.* created EOG based wheelchair control for spinal cord injury persons using blink detection algorithm and decision making used to analyzed the acquired data from four subjects in indoor and outdoor environment and obtained the average accuracy of 96.7% and 91.7% for indoor and outdoor environment [28].

From the previous study we identified that compared with other existing indoor systems, our system performance was highly appreciated due to user friendliness, cheap, easy to use and need less training for the LIS individuals with proper eye condition. In this study we analyzed the offline study to identify the tasks performed by the subject in indoor environment and also we make a comparison study between the male subjects and female subjects to identify the performance for creating HCI [39]–[41].

III. METHODOLOGY

Ten subjects participated in this study. All the subjects take part in this study are healthy and signals are recorded for two seconds and sampled at 100MHZ and divided in the range of 2Hz from 0.1 to 16 Hz per trail per task with five electrode system using ADT26 bio amplifier. Experiment setup, data collection and pre- processing were previously enlightened by same authors in his earlier work [29]. Raw Signal acquired from subject S4 was shown in the fig.1.

FEATURE EXTRACTION

Features were extracted from cleaned signal using Periodogram method. Periodogram states that it is a mathematical tool to calculate the differences in the periodic signals. It calculates the significance of different frequencies in time-series data to recognize any essential periodic signals. The feature extraction method contains the following steps.

Step 1: S = Sample data of two channel EOG signal for 2 seconds.
Step 2: S was partitioned into 0.1 seconds windows.
Step 3: Bandpass filters were applied to extract eight frequency bands from S.
Step 4: Apply Fourier Transform to the frequency band signal to extract the Features.

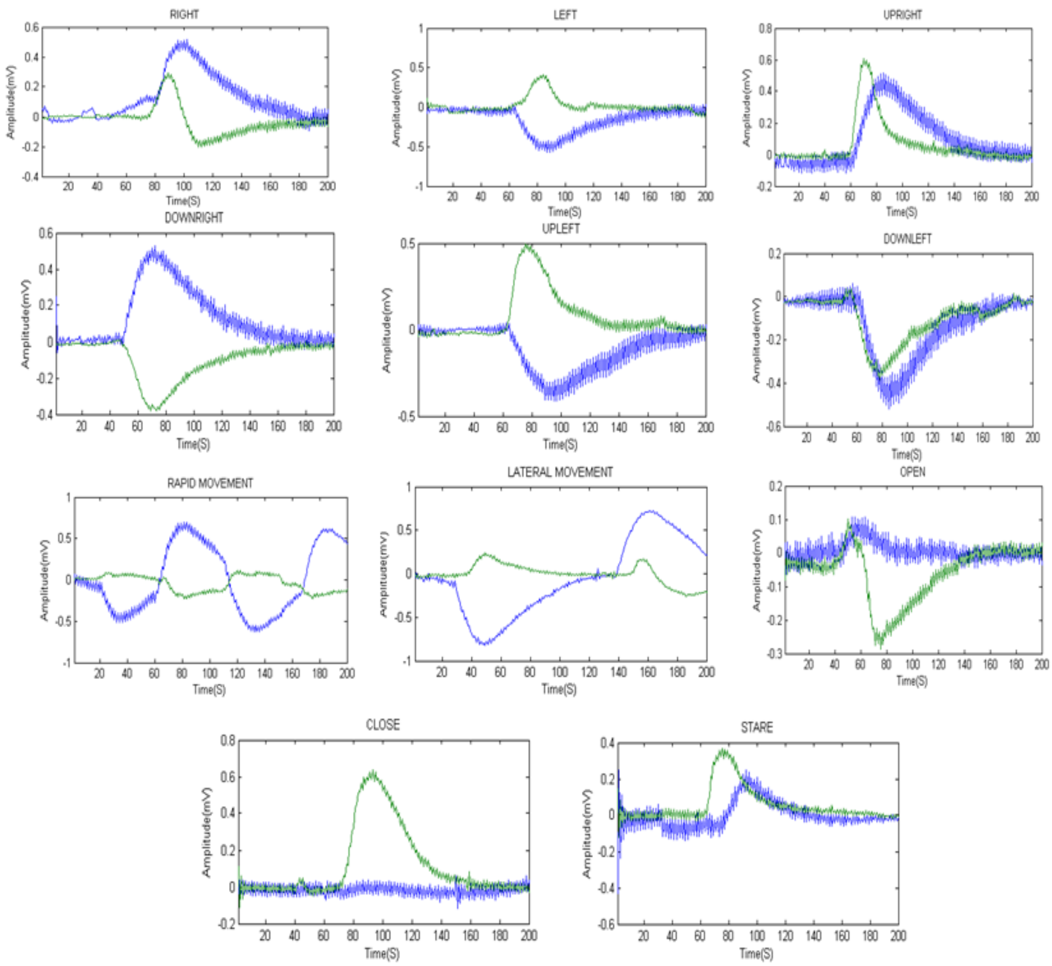

FIGURE 1. **Raw EOG signal acquired from subject S4 for eleven tasks.**

Step 5: Extract the absolute values and sum of the power values are extracted

Step 6: Take the average values from each frequency band.

Step 7: Repeat steps 1 to 6 for each trial for all tasks and for ten subjects.

Step 8: Sixteen features were obtained for each one tasks per trial shown in fig.2 and repeat for ten such trials for eleven tasks.

Step 9: 110 data samples were obtained from each subject individually to train and test the neural network.

Step 10: Repeat the steps 1 to 9 for ten subjects to collect master dataset.

IV. CLASSIFICATION METHOD

Prominent features selected from above mentioned steps were applied to Neural Network to categorize the signals. In this study we focused Probabilistic Neural Network (PNN). PNN was based on statistical principles derived from Bayes decision strategy and Gaussian kernel based estimators of Probability Density Function (PDF). Every input neuron communicates to an element of an input vector and is fully coupled to the n hidden layer neurons. Again, each of the hidden neuron is fully connected to the output neurons. Input layer simply feed the inputs into the classifier. Hidden layer will be able to compute the distance between the input vector and the training input vectors using bayes decision strategy and Gaussian kernel function, and produce PDF features whose elements show the closeness between the input data points and the training vector points. As the last step, output layer will pick the summing output of the hidden layer with weight and apply bayes decision learning; it will select the most of the probabilities on the hidden layer and also supply a one for that class and a zero for the other classes [30]–[35]. The network design used during this experiment was shown in fig.3.

V. OUTCOME OF THE STUDY

Master Dataset was collected from ten subjects for eleven tasks by executing each task for two seconds by using five electrode system with two channels T26 AD Instrument and labchart. Totally ten subjects (5 male, 5 Female) was take part in this whole study and assured that free from poor health which is shown in Table.1.

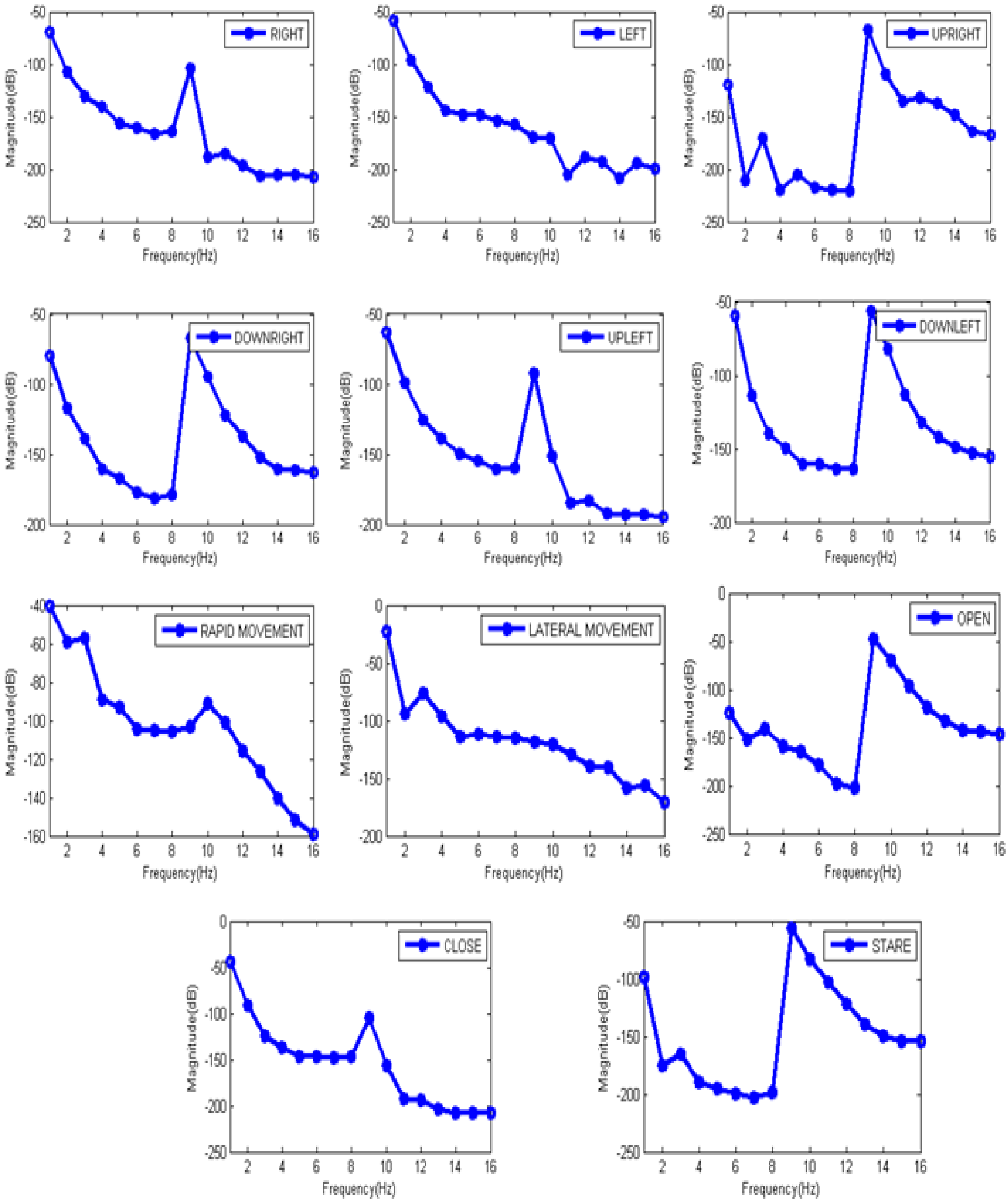

FIGURE 2. Feature extracted signal for eleven different eye movements for subject S4 using periodogram.

A. CLASSIFICATION ACCURACY

Performance of the each individual subjects was analyzed by Periodogram and Probabilistic Neural Network. Table.2 shows the average classification performance of male subjects using periodogram features with PNN model. Table.2 particularly shows the result of mean, minimum, maximum, testing time and training time to determine the performance of the male subjects participated in this study. From the Table.2 we identify that subject S4 performance was marginally high compared with other male subjects participated in this experiment with an maximum classification accuracy of 95.90% and minimum classification accuracy

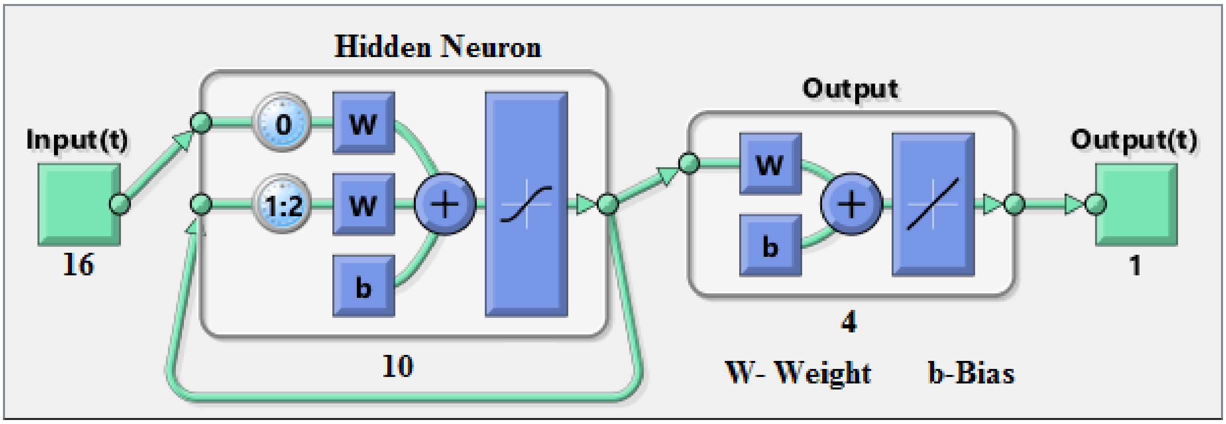

FIGURE 3. Probabilistic neural network.

TABLE 1. List of different subjects participated in the study.

Subjects	Male Subjects	Female Subjects
	S1, S2, S3, S4 and S5	S6, S7, S8, S9 and S10

TABLE 2. Average performance accuracy for male subjects using periodogram and PNN.

Subjects	Mean Training Time (sec)	Mean Testing Time (sec)	Average Performance (%)			
			SD	*MAX*	*MIN*	*MEAN*
S1	18.20	0.71	1.46	95.32	89.90	93.87
S2	18.89	0.72	1.52	95.25	90.10	92.86
S3	18.84	0.70	1.66	95.44	89.70	93.60
S4	18.95	0.73	1.40	95.90	90.40	94.90
S5	18.73	0.70	1.58	94.77	89.90	93.12

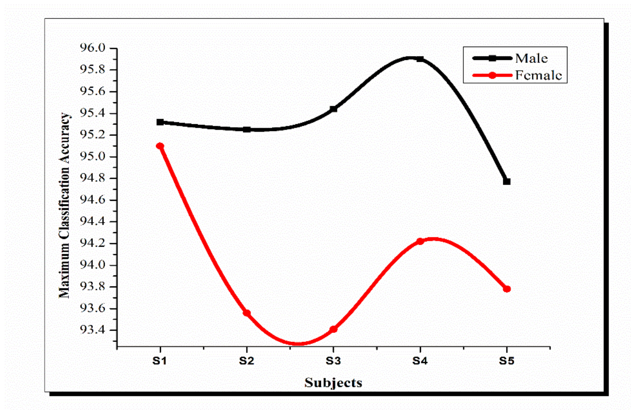

FIGURE 4. Maximum classification.

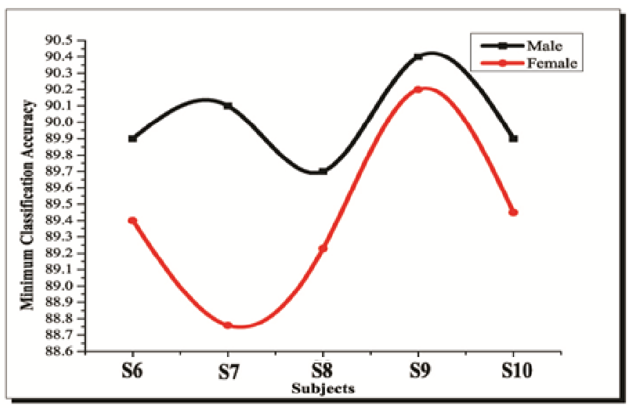

FIGURE 5. Minimum classification.

of 90.40% with a training and testing time of 18.95 and 0.73 seconds for ten trials per tasks and average classification accuracy of 94.90%. Next maximum classification accuracy was obtained for Subject S1 with maximum classification accuracy of 95.32% and minimum classification accuracy of 89.90% and average classification accuracy of 93.87% with a training and testing time of 18.20 and 0.72 seconds for ten trials per tasks. The minimum classification accuracy for male subject was obtained for Subject S2 with maximum classification accuracy of 95.25% and minimum classification accuracy of 90.10% and average classification accuracy of 92.86% with a training and testing time of 18.89 and 0.72 seconds for ten trials per tasks. Maxiumu and Minimumclassification accuracy obtained from this experiment for both male and female subjects are shown in fig.4. and fig.5.

From the Table.3 we identify that subject S10 performance was marginally high compared with other female subjects participated in this experiment with an maximum classification accuracy of 93.78% and minimum classification accuracy of 89.45% with a training and testing time of 19.65and 0.76 seconds for ten trials per tasks and average classification accuracy of 92.55%. Second maximum classification accuracy was obtained for Subject S6 with maximum classification accuracy of 95.10% and minimum classification accuracy of 89.40% and average classification accuracy of

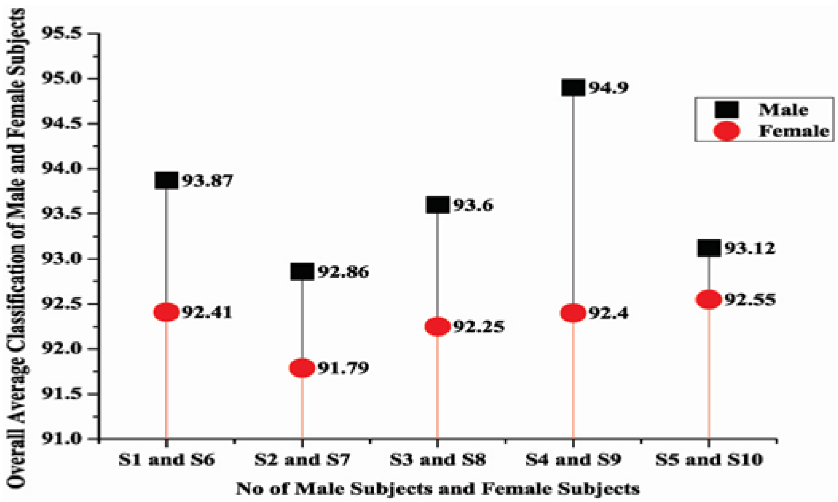

FIGURE 6. Overall average classification accuracy.

TABLE 3. Average performance accuracy for female subjects using periodogram and PNN.

Subjects	Mean Training Time (sec)	Mean Testing Time (sec)	Average Performance (%)			
			SD	*MAX*	*MIN*	*MEAN*
S6	19.19	0.73	1.70	95.10	89.40	92.41
S7	19.29	0.74	1.68	93.56	88.76	91.79
S8	19.67	0.77	1.84	93.41	89.23	92.25
S9	19.71	0.78	1.90	94.22	90.20	92.40
S10	19.65	0.76	1.87	93.78	89.45	92.55

92.41% with a training and testing time of 19.19 seconds and 0.73 seconds for ten trials per tasks. The minimum classification accuracy for female subject was obtained for Subject S7 with maximum classification accuracy of 93.56% and minimum classification accuracy of 88.76% and average classification accuracy of 91.79% with a training and testing time of 19.29 and 0.74 seconds for ten trials per tasks.

From the Table.2 and Table.3 we analysed that Subject S4 from male subjects and subjectS10 from female subjects performance was marginally high compared with other subjects performance took part in this experiment. From the individual performance stated in the Table.2 and Table.3 we found that Subject S4 performance was appreciable compared with other male subjects and female subjects participated in this study which is shown in the fig.6.Finally classification accuracy proves that performance of all male subjects was high compared to all female subjects. From the study we concluded that female subjects get tired easily compared to male subjects and also during the training phase female subjects showed less interest than that of male subjects and also some of the tasks like upleft, open and close are difficult to performed by the female subjects.

TABLE 4. Offline analysis for male subjects using PNN with periodogram features.

Tasks	Single Trail Analysis											
	Events								*Non Events*			
	R	*L*	*UR*	*DR*	*UL*	*DL*	*RM*	*LM*	*O*	*C*	*S*	*Unknown*
S1	8	8	8	7	8	9	8	8	8	8	8	4
S2	7	10	6	7	7	7	9	8	6	7	7	8
S3	8	9	8	8	8	9	8	9	7	7	8	4
S4	**10**	**10**	**10**	**9**	**8**	**8**	**10**	**9**	**9**	**9**	**9**	3
S5	8	8	8	8	7	8	8	7	7	8	8	9

TABLE 5. Offline analysis for female subjects using PNN with periodogram features.

Tasks	Single Trail Analysis											
	Events								Non-Events			
	R	L	UR	DR	UL	DL	RM	LM	O	C	S	Unknown
S6	8	8	7	7	8	8	8	8	8	7	8	4
S7	7	10	6	7	7	7	9	8	6	6	7	8
S8	7	7	7	8	7	8	8	9	7	7	7	5
S9	7	8	8	7	6	7	8	8	7	7	7	5
S10	**9**	**9**	**10**	**9**	**8**	**8**	**9**	**9**	**8**	**8**	**9**	**4**

B. SINGLE TRAIL ANALYSIS

Single trail analysis was conducted to analysis the recognition accuracy of the individual subjects. The recognizing accuracy of the HCI systems was analyzed through offline analysis to determine the performance of the HCI system using the GUI, it was demonstrated in fig.7. The recognition accuracy of the individual subjects for both male and female subjects using periodogram features with PNN network models were shown in Table.4 and Table.5, Fig.8 and fig.9 respectively.

From the Table.4 we investigated the recognizing accuracy of the male subjects was illustraed in the fig.8. Table.4

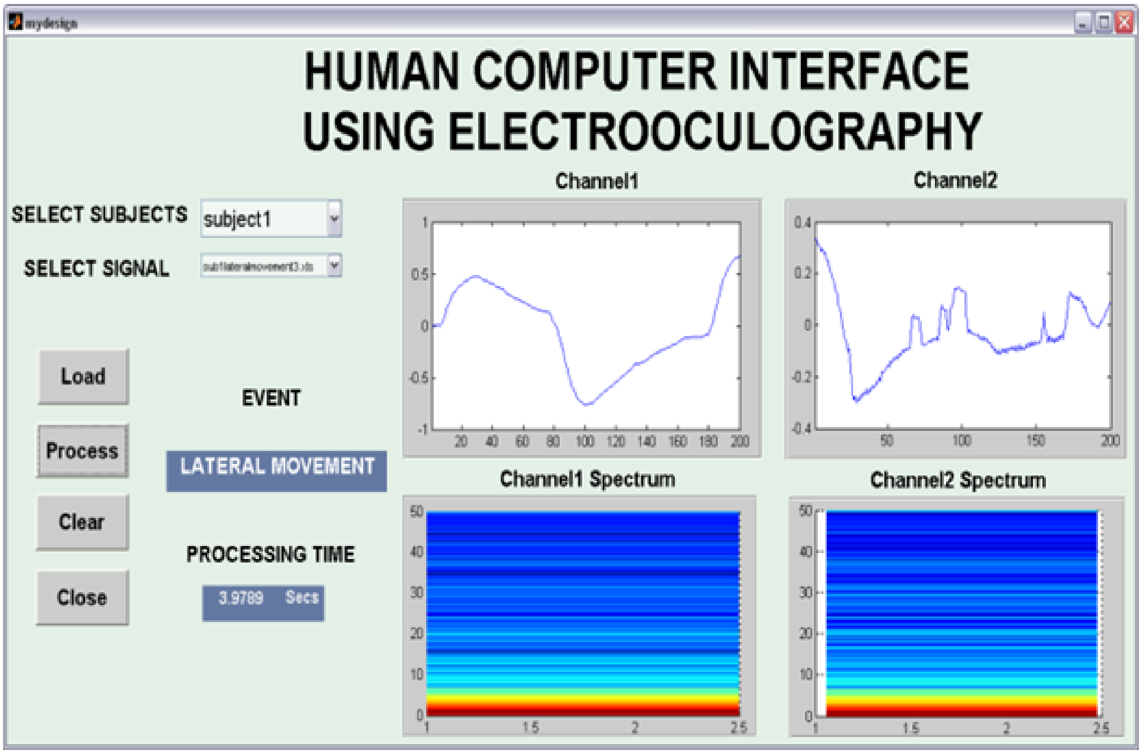

FIGURE 7. GUI for single trail analysis.

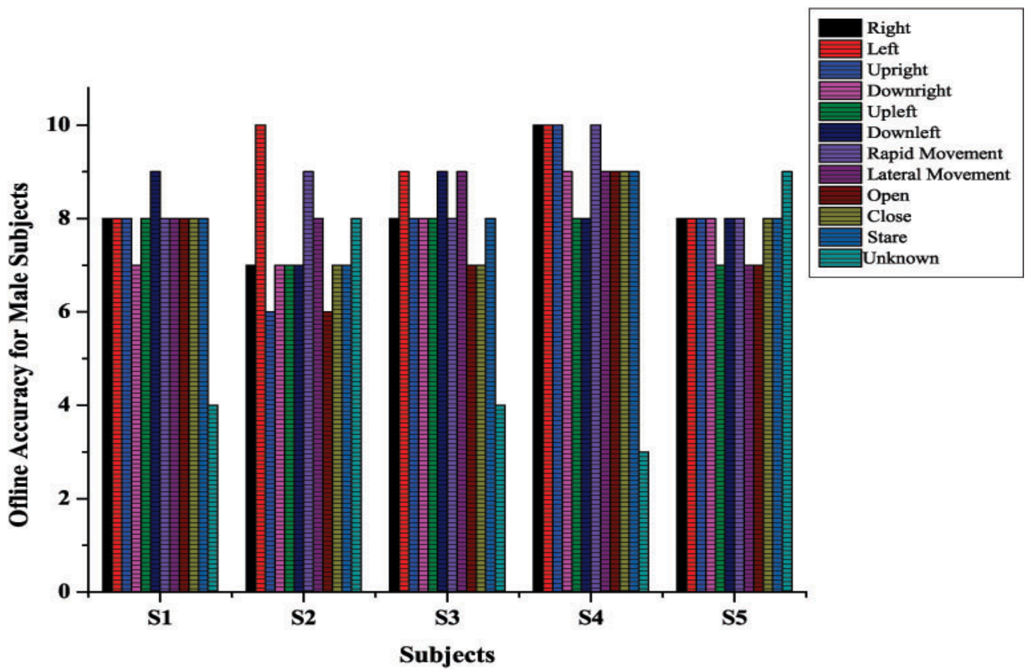

FIGURE 8. Offline analysis for male subjects.

interpret that first maximum recognition accuracy was obtained for subject S4 with 91.81% and 100% acuracy for the individual tasks like right, left, upright and rapid movement. Second maximum recognition accuracy was obtained for subject S3 with 80.90%. Minimum recognition accuracy was obtained for subject S3 with 77.27%. From the table.5 we concluded that recognizing accuracy varies from 91.81% to 77.27% for male subjects.

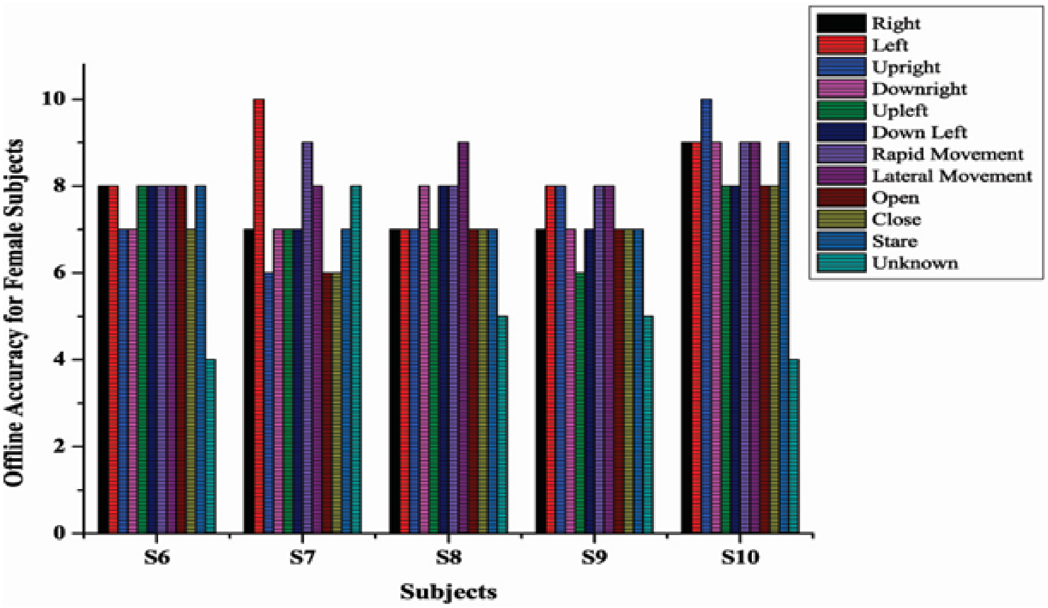

FIGURE 9. Offline analysis for female subjects.

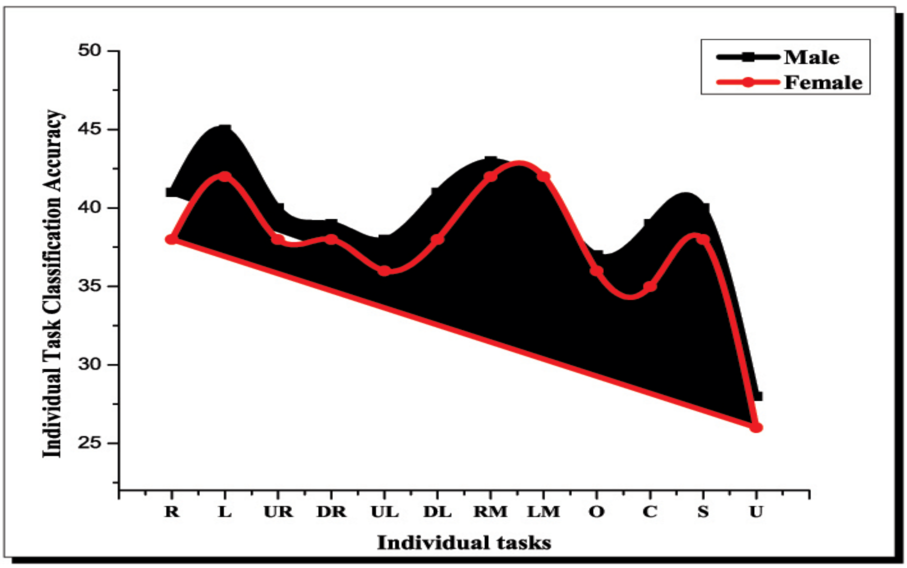

FIGURE 10. Offline individual task recognition accuracy for male and female subjects.

From the Table.5 we investigated the recognizing accuracy of the female subjects was illustraed in the fig.9. Table.5 interpret that first maximum recognition accuracy was obtained for subject S10 with 87.27% and 100% acuracy for the individual task upright. Second maximum recognition accuracy was obtained for subject S6 with 77.27%. Minimum recognition accuracy was obtained for subject S9 with 77.73%. From the table.5 we concluded that recognizing accuracy varies from 87.27% to 77.73% for male subjects.

From the Table.4 and Table.5 we calculated the overall individual task performance for male subjects and female subjects was shown in fig.10. From the Table.4 we inspect that maximum recognizing accuracy of 90%, 86% and 74% was obtained for the left, Rapid Movement and open respectively. From the Table.5 we interpret that maximum recognizing accuracy of 84% and 70% was obtained for the left, Rapid Movement, lateral movement and close respectively. From the single trail analysis test we concluded that performance of the male subjects using PNN model with periodogram features were maximum compared with female subjects using same feature extraction and classification technique.

VI. CONCLUSION

Experiment was conducted with ten subjects (5Male, 5Female) using five electrode system by executing eleven different eye movements. Signals were record using Analog Digital Instrument T26 with lab chart using periodogram and PNN network model to analyze the performance of the subjects participated in the study. The study proves that classification performance of all male subjects was high compared to all female subjects.

From the study we found that Subject S4 performance was appreciable compared with other male subjects and female subjects. Recognizing accuracy was calculated using single trail analysis. From the single trail analysis test we concluded that performance of the male subjects was maximum compared with female subjects. Through this experiment we concluded performance of all the male subject was maximum compared to all female subjects.In future we are planned to conduct this experiment in online phase with more number of subjects and enhanced hybrid classification algorithm to check the possibility of designing HCI.

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