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RECOGNITION OF EYE MOVEMENT ELECTROOCULOGRAM SIGNALS USING DYNAMIC NEURAL NETWORKS

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Abstract

Human Computer Interaction provides a digital communication between the human and the physical world. This paper concentrates on tracking the eye movements through Electrooculography for HCI with the help of Neural Networks. Two feature extraction algorithms are used to extract the features from raw EOG signals for sixteen eye movements. The signals are classified into sixteen states using two networks namely Feed Forward Neural Network and Elman Neural Network. The performance of the proposed algorithms have an average classification efficiency of 83.36% and 98.50% for Singular Value Decomposition features and 84.60% and 98.46% for band power features using Feed Forward Neural Network and Elman Neural Network respectively. From the results it is observed that Elman Neural Network classifier using band power features outperforms the Feed Forward Neural Network classifier marginally.

Keywords - Electrooculography, Human Computer Interaction, Band power, Feed Forward Network, Singular Value Decomposition, Elman Neural Network.

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I. Introduction

EOG is a technique for measuring the resting potential of the eye [1]. Human Computer Interaction (HCI) is a research field which includes interactions such as communication and control between a user and a computer. HCI is primarily used for accuracy and fast understanding of what the user wants to do [2]. HCI detects the specific pattern activity and translates this pattern into meaningful commands [3]. People make a lot of eye movements that allow them to do several tasks such as look, blink, open, close etc. Eye tracking is a process of electronically locating the point where people look or follow the movement. Eye movements can be used to design an HCI. Recently EOG based HCI has attracted attention due to their non invasiveness and high communication speed.

Depending upon individual capabilities, several HCI have been proposed, such as, speech detection based on voice and surface electromyography [4, 5], lip movement control system [6], vision based multiple gestures [7]. EOG signal is one of the most useful electro-physiological signals, which provides information about activities of the human eye, detecting changes in eye positions.

Eye movements can be classified into eight basic movements namely, up, down, right, left, up-right, up-left, down-right and down-left. Most of the HCI are using the first four directions to develop a device for the elderly and the disabled [8-12]. In this study, eight additional tasks are used to verify the feasibility of developing a sixteen state HCI. The proposed additional eight movements are Open, Close, Winking, Rapid movement, Lateral Movement, Left Blink, Right Blink, and Rapid Blink are proposed. Two feature extraction algorithm based on Singular Value Decomposition (SVD) and Band power to identify the sixteen eye movements through dynamic Neural Networks.

II. Methods

A. *Experimental Protocol and Signal Acquisition*

EOG signals are extracted using AD Instrument bio signal amplifier. Five gold plated, cup shaped electrodes are placed near the eyes of the subject as shown in Fig.1. Eight healthy subjects participated in the experiments. Subjects are given sixteen eye movement tasks to be executed by moving their eyes as per the protocol given for each task. Following is the protocol of the tasks performed by each of the subjects.

Task1 – *Right:* Right movements are binocular movements in which subject is instructed to move both eyes synchronously and symmetrically in the right direction.

Task2 – *Left:* Left movements are binocular movements in which the subject is instructed to move both eyes synchronously and symmetrically in the left direction.

Task3 – *Up Right:* Up right movements are binocular movements in which the subject is instructed to move both eyes synchronously and symmetrically in the upside right direction. .

Task4 – *Down Right:* Down right movements are binocular movements in which the subject is instructed to move both eyes synchronously and symmetrically in the down right direction.

Task5 – *Up Left:* Up left movements are binocular movements in which the subject is instructed to move both eyes synchronously and symmetrically in the upside left direction.

Task6 – *Down Left:* Down Left movements are binocular movements in which the subject is instructed to move both eyes synchronously and symmetrically in the down left direction.

Task7 – *Stare:* Stare is a type of movement in which the subject is instructed to maintain the visual gaze on a single location.

Task8 – *Blink:* The subject is told to open and close both eyes, only once voluntarily.

Task9 – *Right Blink:* The subject is told to open and close the right eye, only once voluntarily.

Task10 – *Left Blink:* The subject is told to open and close the left eye, only once voluntarily.

Task11 – *Rapid Blink:* The subject is told to open and close the eyes, voluntarily and quickly

Task12– *Rapid Movement:* Rapid movements are binocular movements, in which the subject is instructed to move both eyes synchronously and symmetrically within the same direction quickly and repeatedly.

Task13– *Lateral Movement:* Lateral movements are binocular movements, in which the subject is instructed to move both eyes synchronously and symmetrically in the same direction slowly and repeatedly.

Task14 – *Winking:* The subject is told to close the left eye, only once voluntarily.

Task15 – *Open:* The subject is told to open the eyes slowly together to focus on the markers.

Task16 – *Close:* The subject is told to close the eyes slowly to cut off from the focus.

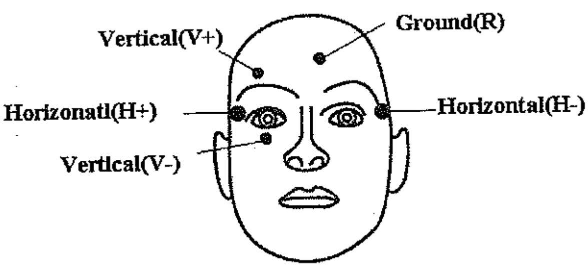

Figure 1 : Electrode Placement

Each EOG signal recording lasts for two seconds per task. Signals are taken in ten trials per task from each subject. In between tasks the subject is given a break of five minutes. Data is collected for two sessions. The EOG signals are sampled at 100Hz. All the subjects who participated in the experiments are university students and staff aged between 21 and 44 years. The raw signals are preprocessed by notch filter to remove the power line artifacts. Eight frequency bands are extracted using chebyshev filter to split the signal in the range of two Hz. The eight frequency ranges are (0.1-2) Hz, (2-4) Hz, (4-6) Hz, (6-8) Hz, (8-10) Hz, (10-12) Hz, (12-14) Hz, (14-16) Hz.

B. Feature Extraction

From the filtered signals, features are extracted using SVD and band power algorithm. The feature extraction algorithms use the following procedure

(i). Singular Value Decomposition Features

A) Band pass filters are applied to extract the eight frequency band signals

B) Apply Singular Value Decomposition (SVD) function to frequency band signals to extract the features

C) Repeat A and B for each trial.

Sixteen features are extracted for each task per trial. The features are extracted for ten such trials for each task. 160 data samples for one subject were obtained to train and test the neural network.

(ii). Band Power Features

A. Band pass filters are applied to extract the eight frequency band signals

B. Sum of the power values are extracted

C. A logarithmic transform is performed on the summed power value

D. Repeat A to C for each trial.

Sixteen features are extracted for each task per trial. The features are extracted for ten such trials for each task. 160 data samples for one subject are obtained to train and test the neural network.

C. Signal Classification

To classify the EOG signal extracted from the eye movements two neural network models are designed to identify the sixteen eye movements. The band power and the SVD features are given as input to the neural network. Two classical network namely the Feed Forward Neural Network and Elman Neural Networks are used in this study. The networks have sixteen input neurons and five output neurons. Neurons in the hidden layer are chosen experimentally and fixed as 5 and 7 depending on the subject data.

Forty-eight neural network models are modeled to verify and indentify the sixteen task signals collected from eight subjects. Each network is tested with 160 data samples collected from single subjects for the sixteen eye movement task. 75% of the data is used in the training of the network and 100% of the data is used in the testing the network. The FFNN is trained using Levenberg back propagation training algorithm and ENN is trained with gradient descent back propagation algorithm. The training error tolerance is fixed as 0.001 and testing error tolerance is fixed as 0.5.

III. Result and Discussion

The signal recognition performance result obtained from Forty-eight neural network models are listed in Table I, II, III, IV for SVD features and band power features using FFNN and ENN respectively. The result of the SVD features using FFNN and ENN classification is shown in Table I. The Table I shows the number of the hidden neuron, the mean training time, testing time and classification percentage with max, min, mean and standard deviation. From Table I it is observed that the mean training 11.84 sec. The mean testing time is 1.24 sec the standard deviation of 1.81 to 4.82 was seen and the mean recognition accuracy of 87.63% were obtained for subject7 with five hidden neurons using SVD features.

The result of the SVD features using ENN classification is shown in Table II. The Table I shows the number of the hidden neuron, the mean training time, testing time and classification percentage with max, min, mean and standard deviation. From Table II it is observed that the mean training 5.52 sec. The mean testing time is 1.31 sec the standard deviation of 0.44 to 1.70 was seen and the mean recognition accuracy of 99.37% were obtained for subject2 with five hidden neurons using band power features. The best results are obtained for subject 2 with five hidden neurons.

The result of the Band power features using FNNN classification is shown in Table III. The Table III shows the number of the hidden neuron, the mean training time, testing time and classification percentage with max, min, mean and standard deviation. From Table II it is observed that the mean training 11.22 sec. The mean testing time is 0.97 sec the standard deviation of 2.87 to 4.78 was seen and the mean recognition accuracy of 86.33% were obtained for subject2 with seven hidden neurons using band power features.

The result of the Band power features using ENN classification is shown in Table IV. The Table IV shows the number of the hidden neuron, the mean training time, testing time and classification percentage with max, min, mean and standard deviation. From Table I it is observed that the mean training 5.41sec. The mean testing time is 1.11 sec the standard deviation of 0.16 to 1.51 was seen and the mean recognition accuracy of 99.90% were obtained for subject2 with five hidden neurons using band power features.

From the results obtained in recognizing the sixteen eye movement it is seen that the performance of ENN models using band power features is higher compared to the FNN models. The results obtained validate the feasibility of identifying the sixteen eye movement through EOG signals. However further validation is required to identify individual state through single trail analysis is the focus of the future work

IV. Conclusion

In this study EOG signals recorded from eight subjects were used for sixteen eye movements. Eight new movements were proposed to develop sixteen states HCI. The feasibility of employing sixteen states HCI and recognizing the same using two neural network models was studied. One is the static network and other is the dynamic network were employed. Two feature extraction algorithm namely the SVD and band power were used to train and test the network model. From the result it is observed that the network model using Elman model and band power features is suitable for recognizing all the sixteen eye movements with the recognizing performance of 99.90%. However further study is required to access the performance of the network for online recognition of the EOG signals.

TABLE I

Classification Performance of FFNN Using SVD Features

S.no	Sub	Hidden Neuron	Mean Training Time	Mean Testing Time	Classification Performance for FFNN			
					Max	Min	Mean	SD
1	S1	5	9.83	0.95	95	76.88	84.23	4.72
2	S2	5	17.83	1.65	95	80.00	85.19	4.75
3	S3	5	9.99	0.98	87.5	76.38	80.94	2.88
4	S4	5	9.75	0.98	83.75	77.5	80.92	1.81
5	S5	5	17.93	2.48	88.75	78.13	83.53	3.28
6	S6	5	9.82	1.04	89.37	78.13	83.24	3.85
7	S7	5	9.81	0.95	93.13	81.87	87.63	3.78
8	S8	5	9.82	0.95	92.5	77.00	81.23	3.48

TABLE II

Classification Performance of ENN Using SVD Features

S.no	Sub	Hidden Neuron	Mean Training Time	Mean Testing Time	Classification Performance for ENN			
					Max	Min	Mean	SD
1	S1	5	5.97	1.74	99.8	97.5	98.63	0.85
2	S2	5	5.52	1.02	99.63	98.00	99.37	1.02
3	S3	5	5.39	1.08	99.38	97.5	98.88	0.56
4	S4	5	5.61	1.11	99.38	93.75	95.78	1.7
5	S5	5	5.46	1.65	99.38	96.88	99.16	0.65
6	S6	5	5.42	1.07	99.38	97.5	99.13	0.81
7	S7	5	5.36	1.20	98.22	96.88	98.87	0.64
8	S8	5	5.46	1.65	99.8	97.5	98.16	0.86

TABLE III

Classification Performance of FNNN Using Band Power Features

S.no	Sub	Hidden Neuron	Mean Training Time	Mean Testing Time	Classification Performance for FFNN			
					Max	Min	Mean	SD
1	S1	7	11.26	0.94	88.75	80.00	84.26	2.90
2	S2	7	11.24	0.98	92.00	81.25	86.33	3.04
3	S3	7	11.02	1.00	91.13	78.13	82.96	3.66
4	S4	7	11.24	0.96	89.37	78.13	84.66	3.28
5	S5	7	11.14	0.97	89.38	79.37	82.81	3.14
6	S6	7	11.14	0.96	92.5	81.25	85.88	2.92
7	S7	7	11.39	0.97	89.37	77.50	84.35	3.74
8	S8	7	11.40	0.99	90.00	82.00	85.50	3.50

TABLE IV

Classification Performance of ENN Using Band Power Features

S.no	Sub	Hidden Neuron	Mean Training Time	Mean Testing Time	Classification Performance for ENN			
					Max	Min	Mean	SD
1	S1	5	5.41	1.21	99.38	96.25	97.34	0.78
2	S2	5	5.58	1.11	99.75	99.38	99.90	0.14
3	S3	5	5.24	1.16	99.38	98.12	99.25	0.33
4	S4	5	5.53	0.94	99.38	96.25	97.87	0.74
5	S5	5	5.37	1.08	99.38	96.88	98.47	0.59
6	S6	5	5.43	1.18	99.38	96.88	98.28	0.70
7	S7	5	5.42	1.16	99.38	96.25	98.19	0.16
8	S8	5	5.42	1.16	98.75	96.25	98.39	0.16

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