EEG SIGNALS DURING EYES-OPEN & EYES-CLOSED STATE

Manpreet Kaur[1], Neelam Rup Prakash[2], Parveen Kalra[3], Goverdhan Dutt Puri[4]
[1]Research Scholar, Centre of Excellence (Industrial & Product Design)
[2]Professor, Electronics & Communication Engineering Department
[3]Professor, Production & Industrial Engineering Department
PEC University of Technology, Chandigarh, India
[4]Professor, Department of Anaesthesia & Intensive Care, PGIMER Chandigarh

Abstract
Analysis of electroencephalogram (EEG) signal is a popular method for brain activity tracing. This includes the eyes state whether to be in a closed or open position based on the experiment requirement. In this study, we have demonstrated that there is significant difference between eyes open and eyes closed state in terms of a total of 7 features. Also, there is no significant change in beta and gamma waves. The significant criterion is determined when p-value is less than 0.05 for paired t-test. We concluded that it is possible to discriminate between eyes open and eyes closed state on the basis of features derived from EEG signal.

Index Terms: ECoG, EEG, MLP, PSD.

I. INTRODUCTION

Human Electroencephalogram (EEG) signals were discovered by Hans Berger in 1924. EEG known as Electroencephalogram is a measurement of currents that flow during synaptic excitations of the dendrites of many pyramidal neurons in the cerebral cortex. When neurons are activated, the synaptic currents are produced within the dendrites. This current generates a magnetic field measurable by EMG (Electromyogram) machines and secondary electrical field over the scalp measurable by EEG systems [2]. It is the non-invasive method of recording electrode potentials generated from million of neurons. An invasive method of recording electrode potentials is known as Electrocorticogram (ECoG) or Intracranial Electroencephalogram.

As shown in figure I, the human brain comprises of five planes which are frontal polar, frontal plane, central plane, parietal plane and occipital pole [3].

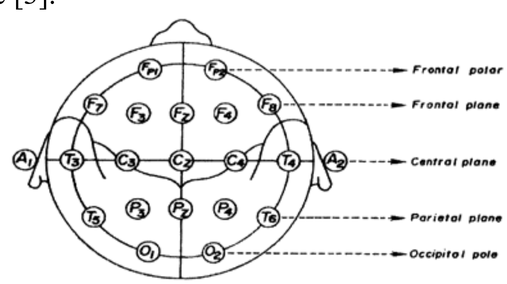

Figure I: Different planes of human brain

The electrodes can be connected as two different montages i.e. bipolar and monopolar montage. In bipolar recording, the difference between the pair of active electrodes is measured. In monopolar recording, the potential at an active electrode is recorded with respect to inactive electrode. The brain waves can be classified as delta, theta, alpha, beta and gamma waves.

In this paper, two different EEG dataset consists of Eyes Closed and Eyes Open are processed and analyzed by extracting different features to identify the significance of these two states. This paper emphasizes the importance to maintain specific eye condition during EEG recording.

II. DATA ACQUISITION AND METHODS

A. Data Acquisition

The EEG data was acquired from physionet.org [5]. This database comprises of 14 different records out of which two records are of baseline with eyes open and eyes closed and the remaining 12 records are of different motor/imagery tasks. Raw EEG signal was sampled at 160 Hz.

B. Pre-processing

In this study, the raw EEG data is firstly filtered using notch filter to remove the noise due to A.C. mains supply. Then the data is segmented into an epochs of 2 second duration.

C. Feature Extraction

The occipital lobe was selected for the analysis because the EEG signals changes in the occipital lobe when the eyes are open or closed. When the eyes are closed, then alpha appears in the occipital lobe and when the eyes are open then alpha disappears. That's why alpha RMS was also selected for the analysis. It is very difficult to understand the raw EEG signal. So, different features i.e. Alpha RMS mean, Median Frequency, 95% Spectral Edge frequency, approximate entropy; Relative power in different bands, Bispectrum and bicoherence were derived from the raw EEG signal.

1. Approximate Entropy:-

Approximate entropy is a measure of signal irregularity, so it can be used for EEG signals. It is a measure which quantifies the signal predictability or its randomness. Its origin is from non-linear dynamics but unlike most measures, it does not require the use of limit. It is more suitable for signals of finite length. The approximate entropy is calculated as:

Let us consider a signal's' of finite length N. Fix a positive integer m and a positive real number r. Then, from signal s the N-m+1 vectors $x_m(i)=\{s(i),s(i+1),\_\ \_\ \_\ \_,s(i+m-1)\}$ are formed. After that for each i, 1< i < N-m+1, the quantity $C_i^m(r)$ is calculated using:

$$C_i^m(r)=\frac{\text{Number of such } j \text{ that } d[x_m(i), x_m(j)] \le r}{N-m+1} \quad (1)$$

where distance d between the vectors $x_m(i)$ and $x_m(j)$ is defined as:

$$d[x_m(i), x_m(j)] = \max (|s(i+k-1)-s(j+k-1)|)$$

$$k=1,2,3,\_\ \_\ \_, m$$

Next, the quantity $\phi_m(r)$ is calculated as

$$\phi_m(r)=\frac{1}{N-m+1}\sum_{i=1}^{N-m+1}\log C_i^m(r) \quad (2)$$

Finally, the approximate entropy is defined as follow:

$$ApEn(m,r,N)=\phi^m(r)-\phi^{m+1}(r) \quad (3)$$

The parameter r corresponds to the maximum allowable distance between the neighbouring trajectory points; therefore r can be viewed as filtering level. The parameter m is the embedding dimension and it determines the dimension of the phase space.

Frequently, r is chosen according to signal s standard deviation, it has been suggested that initial value for r be .2 SD. A common value for m in EEG analysis is 2.

2. Power Spectral Features:-

Power contents at different frequency will be obtained from PSD curve. From the PSD curve, median frequency, Spectral Edge Frequency, Relative delta power, power in different bands like alpha, theta, beta bands and alpha RMS are calculated. Median frequency is defined as the spectral frequency below which contains 50% of total power in EEG. It is the frequency that divides the power equally in the power spectrum. Spectral Edge frequency is defined as the spectral frequency below which contains 95% of total power in EEG. Relative delta power describes the percentage of EEG power in the delta band range relative to the power over the entire EEG frequency spectrum. Alpha RMS is the root mean square value of the alpha signal.

3. Bispectral features:

The main drawback of power spectral variables is that these don't contain the information regarding phase. So, in order to extract the phase information, bispectrum is calculated. Bispectrum measure phase correlation of waves obtained by Fourier analysis among different frequencies. It is calculated by multiplying three complex spectral values where each complex spectral value includes frequency, phase and amplitude information. It is expressed in micro volts raised to the third power as it is the product of three sign waves [4].

From the bispectrum, the absolute value of bispectrum is calculated. Feature of the signal can be extracted by selecting the eigenvector whose corresponding eigen value's module is the largest as the template of recognition. Knowledge of the bispectrum in the triangular region f1, f2>0, and f2> f1 is enough for a complete description of the continuous bispectrum. There are in fact 12 regions of symmetry in the continuous bispectrum. As the discrete Fourier transform is periodic, the discrete bispectrum is also periodic which means that there are added symmetries for the discrete bispectrum, and it can be shown that it is only necessary to estimate the discrete bispectrum in the region 0< f2< f1, and f1+ f2< fs/2. This region is known as the principal domain and can be further subdivided into two regions. In order to extract the feature of signal, eigenvalue and eigenvector will be calculated [10]. The eigenvalue equation can be defined as follow

$$| \lambda E - B | = 0$$

Where E is a unit matrix whose size is the same as the matrix B and B is a Bispectral matrix whose size is 128×128. After doing a large numbers of experiments, we unexpectedly find that the eigenvalue of the matrix B has an interesting property that most of the eigenvalues are much smaller than the rest of the eigen values. Through large number of experiment, we find that there are only a few eigen values which are comparatively very large while the rest eigen values are close to zero.

III. RESULTS & DISCUSSION

A. Feature Classification

The records having baseline with eyes open and eyes closed were used for the analysis. So, in total 30 EEG records were analysed out of which 15 records were with eyes open and the remaining 15 with eyes closed. Analysis of Variance with P<0.05 was used to reduce the number of features. 7 features meeting this criteria were selected and used for further analysis.

B. State Classification

In this research Multilayer perceptron was used for classification. A hyperbolic tangent function was used as activation function for hidden layer and softmax function for output layer. Cross-entropy was used as error function for output layer. Scaled conjugate gradient algorithm was used as optimization algorithm for estimation of synaptic weights.

7 features derived from the EEG signal were used as input matrix to network. Input matrix was rescaled by standardized method. An output of 0 and 1 for eyes open and eyes closed was supplied to network. Network architecture is shown in fig.II.

70.9 % of cases were randomly assigned to training, remaining 29.1 were used for testing. Accuracy of network for classifying eyes open and eyes closed was 79.9 % during training, 80.9% during testing. Classification matrix of network is shown in table I.

ROC (Receiver Operating Characteristic) curve of sensitivity vs specificity (true vs false rate) of network is shown in fig. III.

Area under curve (AUC) of RoC was .862 which indicates high accuracy of classifier.

Figure II: Neural Network Architecture

Classification

Sample	Observed	Predicted		
		0	1	Percent Correct
Training	0	245	80	75.4%
	1	48	265	84.7%
	Overall Percent	45.9%	54.1%	79.9%
Testing	0	91	34	72.8%
	1	16	121	88.3%
	Overall Percent	40.8%	59.2%	80.9%

Dependent Variable: VAR00001

Table I: Classification Matrix

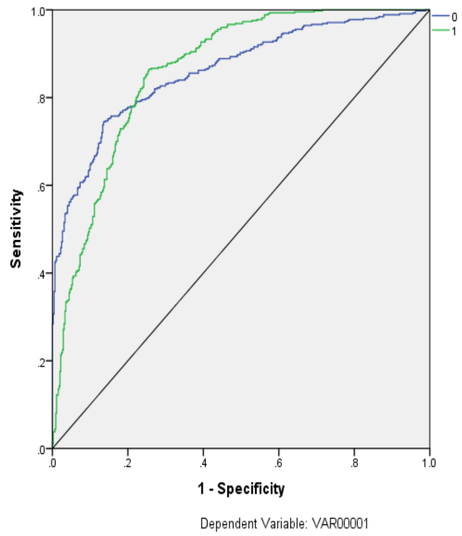

Figure III: Sensitivity Vs Specificity

IV. CONCLUSION

This study concluded that the features extracted from EEG signal can be used for the classification of different states. The analysis of variance can reduce the number of features selected from EEG signal. The multilayer perceptron was able to classify different states with accuracy of 79.9 % during training, 80.9 % during testing. The area under curve of ROC was .862 which indicates high accuracy of classifier. Further this technique needs to be cross-validated.

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