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Review of Techniques for Predicting Epileptic Seizure using EEG Signals

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Abstract— Epilepsy is a disorder that is characterized by seizures. Seizures are caused due to unusual electrical activity in the brain. Electroencephalogram (EEG) is used to read brain signal in form of 5 sub-bands viz. Alpha, Beta, Gamma, Theta and Delta. The features within each of theses sub-bands can be analysed and processed upon to predict the onset of a seizure. By accurate prediction of seizures, we can take preventive measures such as providing medication to reduce the severity of suffering of the patient. This pape r reviews the different techniques by which we can predict the onset of epileptic seizure using EEG signals. Each method utilizes one or more sub-bands of the EEG signal and classifies the patient records based on the features extracted through that set of sub-bands. Every method uses a different way to extract the sub bands. Also different classification algorithms are used in every method. We compare t e performance of each technique and analyse their efficacy.

Keywords*-Epilepsy, Electroencephalogram, seizure, Discrete Wavelet Transform , classification.*

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I. INTRODUCTION

Epilepsy is the fourth most common neurological disease next to only, migraine, stroke and Alzheimer's disease and about 1% of the people worldwide have epilepsy. Epileptic seizures can be controlled effectively by use of appropriate medications but about 30% of the epilepsy patients do not have sizure control at the proper time. Seizure is sudden , intensive and uncontrolled neurological activity in the brain. In Epilepsy there are spontaneous seizures which may last for few seconds upto 2 minutes. The different frequency band act as the source for the feature extraction which is used in different methods. The frequency bands in the brain primarily can be classified into 5 types of waves:

i) Delta Waves(0. 5 to 3 Hz):

Delta brainwaves are slow , loud , of low frequency and deeply penetrating. They are source of empathy and suspend external awareness and are generated in dreamless sleep. [1]

ii)Theta waves(3 to 8 Hz):

Theta brainwaves act as our gateway to memory and learning and thus occur often during sleep and deep meditation. They are made up of our senses withdrawn from the external world. [1]

iii)Alpha waves(8 to 12 Hz):

Alpha waves aid overall alertness, calmness, mind/body integration, mental coordination, and learning. Thus they are more dominant in some meditative states and during quietly flowing thoughts. [1]

iv)Beta Waves(12 to 38 Hz):

Beta brain waves controls our of consciousness. It is responsible for performing cognitive tasks which require concentration. Beta waves are most active when we are alert, attentive, solving a problem, making a judgment or decision [1]

v)Gamma waves(38 to 42 Hz):

Gamma brainwaves are the fastest of brain waves as they are able to process information from multiple brain areas at the same time. One can access gamma waves when his mind is calm. [1]

Seizure forecasting systems help in improving the quality of life for patients suffering with epilepsy. Due to prediction of epileptic seizure at such an early stage the effects of medication can be increased and more patients can be treated accordingly. Most forecasting systems are based on feature extraction from EEG signal bands and their analysis to find changes between the behaviour during preictal(seizure hasn't occurred) and interictal(during a seizure) periods. All bands are not related to seizures. Only some features of bands are related to seizures.

One method by Aarti Sharma suggests a method by calculating power in the beta band of the EEG signal. By dividing the brain into zones power is calculated in each zone[2]. The zone in which there is highest change in power is held responsible for the seizure. Section II talks about this method. Another method by M. Z. Parvez and M. Paul proposes using two features viz. frequency and amplitude through DWT decomposition technique and classification using LS-SVM. This method uses the gamma band of brain waves for prediction of epilepsy [3]. Section III of this paper explains this in brief.Another method by Tahar Haddad et al. proposes to extract Delta frequencies from the EEG signal and prediction by observing voltage peaks and correlation between electrodes [4]. Section IV of this paper describes this method in detail.The method proposed by A. Kumar and M.H. Kolekar uses only 3 sub-bands viz. alpha,beta and theta band. Information from features like energy, variance, zero crossing rate etc. are fed to a classification algorithm that separates seizure signals from seizure free ones [5]. Section V of the paper will discuss the method in details. The final section compares the accuracy and performance of all algorithms.

II. EPILEPSY PREDICTION USING POWER ANALYSIS OF BETA BAND

A. *Basis of Method*

Beta frequency band is extracted using a bandpass filter that obtains frequencies in the range 14-30 Hz.The power of beta band is calculated from the different regions of the brain using the formula given in equation (1).

$$P_x = 1/N \sum_{N=0}^{N-1} [x(n)]^2 \qquad (1)$$

In the above equation x (n) is EEG signal, Px is the calculated power and N is the length of the EEG signals.

B. *Method Description*

Molecular and biochemical processes at the start of seizure causes increase in power of beta band in the EEG signal.Analysing multi-channel EEG signal is challenging and the signal may have attenuation.Hence the regions of brain are divided into five zones.The figure-1 shows the placement of electrodes while recording EEG signal:

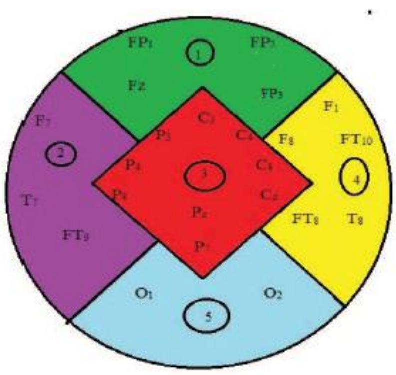

Figure 1. Placement of 23 electrodes into five zones

Now Figure 2 shows the flow diagram describing the method:

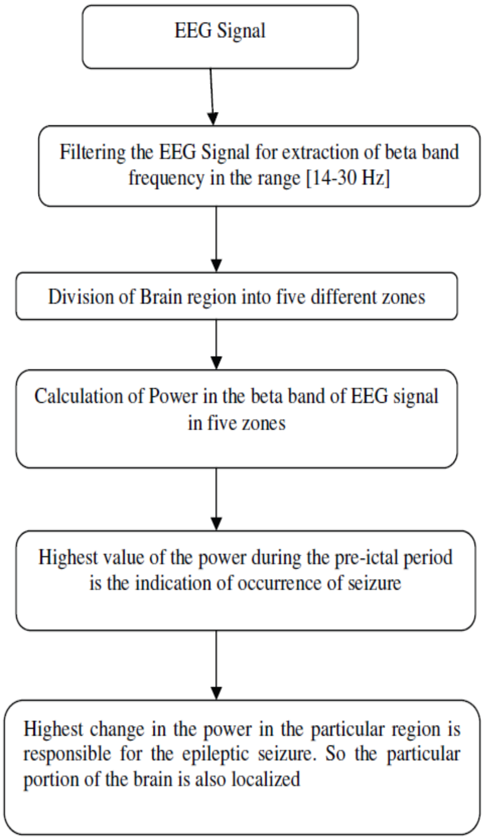

Figure 2. Flow diagram of the method.

III. PREDICTING SEIZURE USING GAMMA WAVE ANALYSIS

A. *Basis of Method*

Frequency and Amplitude of the gamma frequency band is extracted from the EEG signal through a DWT decomposition technique.Then the preictal and interictal signals are classified using LS-SVM.The wavelet transform can effectively localize components of the signal in time frequency space.The continuous wavelet transform defined by Morlet-Grossmann for one dimensional x(t) signal is as shown below[6] :

$$W(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t) \Psi^* (\frac{t-b}{a}) dt$$

where (.)* represents the complex conjugate, a stands for the scalar parameter, ψ(t) represents the wavelet being analysed, and b is the position parameter.

The most frequently used method to obtain discrete wavelet by separating continuous wavelet is to scale factor binary scales.Now let us consider a = 2 j and the equation will be as follows [7]:

$$W(j,b) = \frac{1}{\sqrt{2^j}} \int_{-\infty}^{\infty} x(t) \Psi^* (\frac{t-b}{2^j}) dt$$

B. Method Description:

Every stage of the decomposition algorithm down samples the signal by a factor of 2. In each phase high pass filter is mother wavelet.Low pass filter is the mirror version of it. First Approximation is A1 and Detail is D1.Further the approximation A1 is decomposed onto A2 and D2. This goes on until the decided level (n) is reached and lower frequencies of the signal are obtained. The DWT with four levels is as follows:

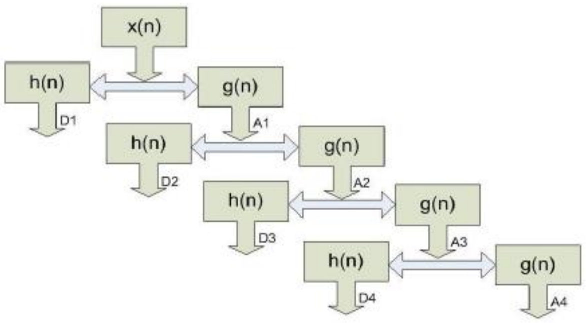

Figure 3. 4 level Discrete Wavelet Transform

The Least-Squares SVM Algorithm is used for classifying the extracted features.It is one of the best classifiers for EEG signal analysis.It can minimize the errors in operations.It also maximizes the margin hyperplane. As a result it also maximizes the classification performance **[8][9]**

IV. Epilepsy Seizure Prediction using Graph Theory

A. Basis of Method

This approach mainly focuses on noting a high correlation level between pairs of electrodes along with voltage peaks in Delta frequencies Threshold for these frequency sub-bands was determined with the help of statistical analysis tools.A Graph topology is used to characterise the seizure signatures of each patient.

B. Method Description:

The unique signature determined will be used to train the neural implant to predict seizures effectively with acceptable sensitivity and reasonable specificity.Tahar Haddad et al. focuses their research to predict seizures tens of minutes before its occurrence in order to allow the patients to take preemptive actions.The method consists of three main steps :

1. Delta Peak Detection :

A sliding window with a 50% interleave was multiplied by the Blackman filter to prevent the edge effects.A good trade-off between frequency and time resolution was maintained by determining the window size empirically.These spectral variations usually occur several tens of minutes prior to the onset of seizure. It is clearly shown in the delta voltage histograms of interictal and preictal phases that a threshold needs to be taken into consideration in the seizure signature of all patients.

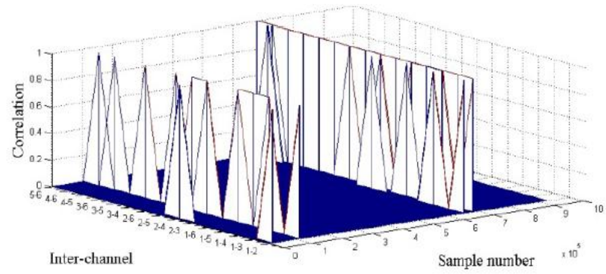

Figure 4. Delta peak voltage is noticed at the approach of a seizure(pre-ictal phase) around sample #720,000.

2. Cross Correlation :

For each pair of discrete signals y(n) and x(n), the cross-correlation is a sequence rxy(l) as shown in the equation given below:

$r_{xy}(l) = \sum_{n=-\infty}^{\infty} x(n)y(n-1)$ l = 0,+-1.+-2, … [4]

3. Graph theory approach :

For an electrode to be considered as a node in the graph, it is necessary that the following two conditions are met, i.e. (1) a peak Delta voltage needs to be observed and (2) in cross-correlation a threshold level needs to be reached between a given electrode and its immediate neighbour.

Afterwards,each time an electrodes reaches cross-correlation thresholds and Delta voltage , the anticipation algorithm considers it as a completely new node. The latter is continuously compared to the reference. Each match means a seizure is being predicted. Results show that the total prediction accuracy is 72% with a false alert rate of 0% and the anticipation time is around 30 minutes.

V. Epileptic Seizure Detection Using Wavelet Analysis of EEG Signals

A. Basis of Method

The method is based on Discrete Wavelet Transform.It extracts the following features from the theta,alpha and beta bands:

1. Energy(E)=$\sum_{n=0}^{N-1}|X_n|^2$
2. Variance (V)=$\Sigma(X-\mu)2^2$/N
3. Zero crossing Rate
4. Fractal Dimension(FD)=$log(L)_{10}/log(d)_{10}$

where μ is the mean value of the signal , Xn is the signal, L is the sum of distances between successive points,N is number of samples in the signal , and d is the distance between the first point and the point with farthest distance of the sequence.

B. *Method Description*

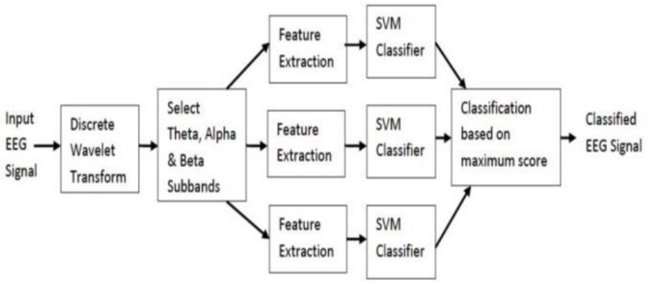

Figure 5. Flow of the method

The method proceeds as follows:

- Discrete Wavelet Transform is applied to the EEG signal.Using that we will get 5 subbands form the signal.On applying inverse wavelet transform the sub-bands recombine to form alpha,beta,gamma,theta and delta
- Alpha, beta and theta subbands are selected from them.
- Four features viz. Energy, Zero Crossing Rate, Variance and Fractal Dimension are extracted from the subbands
- The values of these features are fed to a Support Vector Machine Algorithm.This algorithm separates the classes entered as seizure and seizure- free.
- Linear soft margin formulation of SVM is used.In that an optimal seperation plane is found that keeps in check both training error and model complexity.
- To improve performance of this method in future we can use Bayesian Belief Network or Hidden Markov Model.

VI. RESULTS AND DISCUSSION

The prediction of seizures using beta band analysis succeeds in identifying the various zones responsible for causing seizure by observing unusual surges in power values.It predicts seizure in preictal period for seven patients. However the findings of this method require further validation which is possible only if it is tested against a larger dataset.

PARAMETERS	GAMMA BAND(IN %)		DELTA BAND (IN %)	ALPHA, THETA AND BETA (IN %)
	FRONTAL	TEMPORAL		
ACCURACY	93.12	93.79	72	96
SENSITIVITY	97.05	94.0	72	98
SPECIFICITY	92.73	93.83	100	95
CITATION	[3]		[4]	[5]

Table 1 : Comparison of different frequency band's methods

- The method described in section III uses gamma feature extraction.It makes use of frequency and amplitude of gamma band to predict the seizure.It makes use of a powerful Suport Vector Machine algorithm in the form of Least Squares SVM and also uses Discrete wavelet transform.Use of the stated techniques results in lower number of mis-classified signals and hence improve accuracy and sensitivity.
- The prediction of seizures using Delta band analysis revealed that just 2 features are required to be monitored for temporal seizure behaviour. The proposed prediction algorithm is based on the hypothesis that high cross-correlation rates along with Delta peaks occurring among a certain number of electrodes form a graph topology which is unique for each patient.The advantage of this technique is that it offers 100% specificity.Also the method aims at predicting seizures up to 10 minutes before onset which would really be beneficial for patients
- The method described in section V uses theta, alpha and beta sub bands.It makes use of an expert model for detection of epileptic seizures in EEG signals by using support vector machine and discrete wavelet transform. The wavelet transform is used to split the signal into five frequency bands. SVM classifies EEG signals into seizure and seizure free categories. The performance of this method is notably higher than the other methods discussed.

VII. CONCLUSION

In this paper we analyse and review various methods for predicting epileptic seizure.Each method proceeds on similar lines by extracting features from few selected bands of the EEG spectrum.However the algorithm for extraction and classification differs slightly in most cases.As we will incorporate more number of sub-bands and correlate them with their corresponding features,the performance of the algorithm will improve.Also a large dataset is required for validating the hypothesis stated in above discussed methods.Use of more efficient decision functions will lead to improvement in the accuracy of all methods.

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