EEG Signal Classification for Detection of Epileptic Seizures by extracting various Features

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Abstract

Epilepsy is a chronic disorder or disease characterized by epileptic seizures and affects people of all ages. Epilepsy is usually only diagnosed after a person had more than one seizure. Due to which nerve cell activity in the brain becomes disrupted, causes people to have a “Seizure” or period of unusual behavior. It is characterized by unpredictable seizures and directly affects the patient’s life because of the treatment-related side effects, memory dysfunction, injuries, sudden death, abnormal brain development and social isolation when it is run as a long term disease, so it is necessary to detect seizure and achieve the termination of the seizure [12]. The Electroencephalogram (EEG) signal processing techniques is used in detection of an Epileptic Seizure. EEG is most useful and one of the main diagnostic test for the study of epilepsy. Extraction of essential features from EEG Signal to do the correct classification as an ictal signal is one of the most fundamental challenges.

I Introduction

The seizures occur because of a sudden surge of electrical activity in the brain; this causes due to the temporary disturbance in the messaging system between the brain cells. These are classified into partial and generalized seizures. Partial seizures arise due to electrical discharge of one or more localized areas of the brain regardless of whether the seizure is secondarily generalized. Generalized Seizures takes place on both sides of the brain. These are divided into absence, clonic-tonic, myoclonic. Epileptic patients are faced to many injuries such as fractures, sudden death and vehicle accidents. Epilepsy affects more than 1.5 percent of the worldwide population and 25% of epileptic patients whose seizures cannot be entirely controlled, so seizure detection and prediction with high sensitivity and specificity is a very important aim of clinical management and treatment [6][13] [10]. But some 35 million of epileptic patients did not get appropriate treatment. Children’s who suffer from prolong, acute, convulsive seizures may not always receive prompt rescue medication by their neurologist when they are at school or other communities. Over 60% of people in poorer nations do not receive proper medical care for epilepsy. The unpredictability of the seizure when occurs impacts of the life of patients with epilepsy dramatically. It is possible to prevent epileptic seizure with high sensitivity (i.e. detecting the preictal signal) if electrical changes in the brain that occur prior to the onset of an actual seizure can be detected. EEG signal divided into frequency ranges corresponding to different brain states. Table 1 shows main five frequency bands.

<table>
<thead>
<tr>
<th>Rhythm</th>
<th>Amplitude</th>
<th>Frequency band</th>
</tr>
</thead>
<tbody>
<tr>
<td>delta (d)</td>
<td>20-100µV</td>
<td>0.5Hz – 4Hz</td>
</tr>
<tr>
<td>theta (θ)</td>
<td>10µV</td>
<td>4Hz-8Hz</td>
</tr>
<tr>
<td>alpha (α)</td>
<td>2-100µV</td>
<td>8Hz-13Hz</td>
</tr>
<tr>
<td>beta (β)</td>
<td>5-10µV</td>
<td>13Hz-30Hz</td>
</tr>
<tr>
<td>gamma (γ)</td>
<td>----</td>
<td>&gt;30Hz</td>
</tr>
</tbody>
</table>

Table 1: Brain signal (Rhythm)

Fig.1. EEG signal frequency bands

Typically, the wave amplitude measured from the scalp varies from 10µV to 100µV, but may it reach several mill volts in the case of spikes. Electrical activity of the brain is captured by using special
electrodes placed on the surface of the scalp (or a cap of electrodes). In EEG recordings have signal is acquired from various spots from different channels on the human brain [16].

Usually, 10-20 system is used. Several methods are available for analyzing EEG signals, such as mimetic, morphological, parametric modeling, statistical analysis and template matching, to cite a few. Various features extracted by using different methods for seizure prediction.

For accurate seizure prediction first pre-processing of EEG signal then features extraction and classification are carried out.

II Methodology

**A Real time data acquisition**

Several invasive and non-invasive techniques available for mapping brain signals such as Electroencephalogram (EEG), fMRI (Functional Magnetic Recourse Imaging), MEG (Magnetoencephalography), PET( Positron Emission Tomography). All methods are used for to examine human brain which is used for seizure detection and prediction. The BOLD regions in fMRI of the head clearly show the epileptic foci. But fMRI machines is in each area are costly, limited and time-consuming [15]. Hence, it is not feasible to use fMRI for all patients suffering from seizure. MEG is also having the same problem. So EEG is the most useful and cost-effective modality for the study of epilepsy. It shows a graphical record of on-going electrical activity regarding voltage fluctuations of the brain through multiple electrodes placed in different locations in the brain [14]. 10-20 electrode system is used for recording human EEG signals [18].Types of EEG: - Scalp EEG, invasive EEG, intracranial EEG

**B Preprocessing and Filtering**

The intention of data pre-processing is to improve the levels of signals of interest, while attenuating or rejecting unwanted signals in the recordings that are marked by artefacts. EEG signals are typically disturbed by artefacts like muscle movements, eye blinking and AC power supply disturbances. Influences of these disturbances are filtered out. Once the dataset is loaded, the preprocessing is performed to remove artefacts which are carried out by filtering algorithms.

**C Feature Extraction and Selection**

Feature extraction is used to detect a seizure or non-seizure EEG signals for the treatment and precaution of elliptical seizure patient due to stimuli and brain locations. To successfully identify seizures, features extracted from EEG signals need to carry sufficient discriminative power to allow for the differentiation between ictal and nonictal EEG signal. For the better performance of the classifier various techniques are used for the feature extraction. Feature extraction is a highly effective approach for dimensions reduction and often applied to complex high dimensional, multivariate data. Different features extracted from each data frame. Features can be categories into frequency domain feature set, Time domain feature set, wavelet feature set and waveform morphology feature set. Features extracted from various methods such as DCT, DCT-DWT, and SVD and IMF. Feature selection that removes the irrelevant feature from the feature set.

Table 2 shows a summary of standard methods for feature extraction methods for seizure detection and prediction.
### Feature Extraction Methods for Seizure Detection and Prediction

For completeness, the brief review of concepts of evaluation of performance. It is necessary to know what metrics are considered and how they must be interpreted.

Assuming experienced neurophysiologists properly annotate both spike and non-spike references (also termed as gold-standard) in EEG, the following measures have been widely used to compute the performance of an automated spike detection system:

1) **True positives (TP):** The number of annotated spikes identified as spikes (hit spikes)

2) **False positives (FP):** The number of annotated non-spikes identified as spikes

3) **True negatives (TN):** The number of annotated non-spikes detected as non-spikes

4) **False negatives (FN):** The number of annotated spikes identified as non-spikes (missed spikes) [1][7]

The following metrics are usually measured to evaluate the performance of the classifier:

- **Sensitivity:** The capability of the system to detect spikes.
  \[ \text{Sensitivity} = \frac{TP}{TP + FN} \quad (1) \]

- **Specificity:** The capability of the system to reject non-spikes.
  \[ \text{Specificity} = \frac{TN}{TN + FP} \quad (2) \]

- **Selectivity:** The capability of the system to select precisely true spikes.
  \[ \text{Selectivity} = \frac{TP}{TP + FP} \quad (3) \]

- **False positive rate:** The average of false positives occurring in an interval of time (i.e. FP/minute, FP/hour, etc.).

- **Accuracy:** The ratio of correct detections to the total number of detected spike events.

The sensitivity metric is an indicator of how capable the system is to identify correctly the ++ events that match those annotated by the experts. The specificity, selectivity and false positive rate are indicators to estimate how capable the system is to reject the non-spike events. A good detection mechanism must achieve a high detection ratio with lowest false alarm rate.

#### Evaluation Parameters

**Table 2: Feature Extraction Methods for Seizure Detection and Prediction**

<table>
<thead>
<tr>
<th>Ref No.</th>
<th>Feature Extraction Method</th>
<th>Database</th>
<th>Frame Length</th>
<th>Features</th>
<th>Classifier</th>
<th>Accuracy [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DWT, EMD</td>
<td>128 channel amplifier system, 173.6 Samples /sec.</td>
<td>23.6 sec</td>
<td>Amplitude of each EMD component, AM-FM B.W.</td>
<td>KNN</td>
<td>80.60</td>
</tr>
<tr>
<td>3</td>
<td>DWT</td>
<td>28 electrodes, 11 2 elements from 4 sub-bands of EEG</td>
<td>Patient-specific</td>
<td>Mean, standard deviation</td>
<td>Random Forests</td>
<td>96.25</td>
</tr>
<tr>
<td>4</td>
<td>STFT</td>
<td>Five subsets each 100 single channel EEG segments, 173.6 Hz</td>
<td>23.6 sec</td>
<td>Energy of all EEG signals</td>
<td>Four rule base classifiers</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td>Method based on EEG signals using EMD with DCT.</td>
<td>21 patients, 128 channels, 256 Hz, 16-bit analogue to digital converter</td>
<td>2 min</td>
<td>Energy, Entropy</td>
<td>LS-SVM</td>
<td>83.4</td>
</tr>
<tr>
<td>7</td>
<td>Wavelet transform</td>
<td>128 Channels, 256 Hz, 16 bit analogue to digital converter</td>
<td>10 Sec</td>
<td>Amplitude and frequency parameter</td>
<td>Binary Classifier</td>
<td>--</td>
</tr>
<tr>
<td>8</td>
<td>EMD into EMF</td>
<td>100 Single channel, 173.6Hz</td>
<td>23.6Sec</td>
<td>Euclidean distance, Histogram intersection</td>
<td>NN</td>
<td>98.67</td>
</tr>
<tr>
<td>10</td>
<td>DWT</td>
<td>Five subsets of each 100 segments, 173.6Hz</td>
<td>23.6 Sec</td>
<td>Energy ratio, mean, standard deviation</td>
<td>ANT colony classifier</td>
<td>--</td>
</tr>
<tr>
<td>11</td>
<td>Wavelet, HoS method and analysis of variance</td>
<td>Three sets of data each 100 single channel EEG</td>
<td>23.6 Sec</td>
<td>Entropy</td>
<td>SVM, AdaBoost</td>
<td>--</td>
</tr>
<tr>
<td>12</td>
<td>Prediction error filter and two-level wavelet decomposition</td>
<td>18 datasets of 21 patients, 256Hz</td>
<td>60 min</td>
<td>Power Spectral Density</td>
<td>SVM, AdaBoost</td>
<td>--</td>
</tr>
</tbody>
</table>

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Ref. No.

Feature Extraction Method

Database

Frame Length

Features

Classifier

Accuracy [%]

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E Classification
The goal is to find seizure and non-seizure state of the patients for the prediction and detection of the epilepsy. For classification, various techniques/methods are applied. Least Square Support Vector Machine is one best classifiers used for EEG signal analysis. Different types of classifiers such as Support Vector Machine, AdaBoost, KNN, and Binary and ant colony classifier are used to classify normal and abnormal brain activities. SVM is commonly used as a powerful and tool for the classification of real-world data. Support Vector Machines (SVM) are highly performing and easy to handle classifiers with very good generalization abilities. These are binary classifiers.

KNN is a non linear classifier based on learning by analogy. The output of the classification given regarding detection of a seizure signal or non-seizure signal [11].

III Conclusion
EEG signal obtained from human brain using 10-20 electrode system. For the prediction and detection of the seizure using signal processing methods has been important issue of researchers for the last two decades. Researchers are tried to highlight different signal characteristics and classify signal segments based on the essential features. The EEG signal contains information which can be correlated with the neurophysiology and brain activity of human brain. It is very helpful to extract features due to the discriminate properties. Hence, this technique can be further explored in extracting the EEG signal in seizure detection.

References