A Proposed Frame Work for Real Time Epileptic Seizure Prediction using Scalp EEG

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***Abstract*— Epilepsy is the brain disorder disease having more than 50 million people worldwide. The treatment for epilepsy is medication and surgery. Some patients are not cured with medicine and surgery. One third of the patients still remain with uncontrolled epilepsy. They need constant monitoring for epileptic seizures. Better treatment can be provided by the doctors or precautionary measures can be taken by the patients themselves if any abnormal brain activity or seizure is predicted before its occurrence. The pre-ictal period has some information about the occurrence of epileptic seizure in EEG signals. The brain behaves normal in inter-ictal and postictal periods. For epilepsy, long duration EEG recording are required from days to week. This keeps the patients to stay in the hospital for many days. Our proposed methodology is to predict the epileptic seizure and monitor the brain abnormality in real time. Still there is no epileptic seizure prediction algorithm using EEG available for clinical applications. Our aim is to study and develop a good epileptic seizure prediction algorithm/method with high value of sensitivity and specificity using scalp EEG i-e noninvasive approach. Also a comprehensive survey is done to find the limitations and research issues related to this. The proposed pattern recognition approach has great potential to be used in real time monitoring for epileptic patients and it can be helpful in improving the quality of life of the patients.**

***Index Terms*— EEG, fMRI, Epileptic seizure**

I. INTRODUCTION

Epilepsy is the mostly second prevalent brain disorder, first being the stroke. Around 50 million people in the world are affected from this disease. Its major characteristic is recurrent seizures[1]. The prevalence of epilepsy changes from one geographic area to the other [2]. Epilepsy is a human brain disorder in which cells of the brain nervous system starts malfunctioning. As a result, it may generate the abnormal electrical signals. These abnormal electrical impulses cause a momentary malfunctioning of the human brain, resulting in change or complete loss of awareness. Sudden burst of excessive brain electrical activity produces this abnormality. Normal message passing between the brain cells is temporarily disrupted and brain's messages are hindered by this disruption. The actual brain messages get mixed together and hence vanished. Recurrent seizures in epilepsy are commonly occurs. Therefore, it is regarded as a brain disorder. The high frequency of occurrence of these seizures can be very dangerous and some days can be very crucial. Normal persons do not suffer from seizures or they may suffer only few times in their whole life. But in case of epileptic patient , he or she can have multiple epileptic seizure attacks in one day[3].

Recently it is observed in developed and also in developing countries, 70% newly diagnosed patients having epilepsy were treated with anti-epileptic medicines successfully and this medication controls their epileptic seizures. Medicines were stopped from 70% children and 60% adults after successful treatment of 2 to 5 years [4]. If epilepsy is properly treated 80% people can have normal life after treatment. About 70% to 90% epileptic people of developing countries cannot have the treatment due to limited medical resources and facilities. Seizure is considered as one of the symptoms of epilepsy. However, there are other causes of seizures as well. A seizure which is not related to epilepsy is due to the reaction of wrong medicine or some other reason[5]. High fever and severe head injury can also be the reasons for this disease.

A. Causes of Epilepsy

The main factors generating epilepsy are classified into two: head injuries and disturbance of balance in the chemicals of brain. Age dependency is also one of the parameters if someone gets brain injury. Common imbalances in chemicals like low blood sugar, low oxygen level and low blood sodium can also produce seizures. Still causes of epilepsy are unknown after considering all these injuries, diseases and disorders. There is always a 50% chance that the reason of epilepsy is not identifiable. Therefore, most of the seizures are treated without knowing the causes. Genetic factors are also considered by the scientists to be one of the causes of epilepsy. Generalized seizures are most commonly related to the genetics or inheritance of the people [6].

B. Parents Child relationship

In most of the cases, the children whose Parents are suffering from epilepsy won't have epilepsy, but there might be a higher chance to have epilepsy in future. For example, if child's mother has generalized seizure then there will be 5-20% chance that child can has epilepsy. Similarly, if anyone from the parents has brain injury in their life, then there is only 5% chance that a child can be suffered from epilepsy[6].

C. Rates of Disease

Active seizure is defined as continuous seizures and it needs the treatment for the seizures. Only 4 to 10 people per 1000 people of the population can have active epilepsy. This rate is higher in developing countries with normal population having active epileptic seizures. Its range lies between 5 to 10 per 1000 persons in developing countries. In developed countries, annual new patient's rate is higher, i.e. it may be in 40 to 70 per one million people. It is suggested during the studies that epilepsy in developing countries can lead towards the permanent brain damage because of lack of medical care and facilities available due to poor economic condition of these countries. Developing countries have nearly 90% cases worldwide [3].

D. Diagnosis and Treatment

In order to treat epileptic patients, correct diagnosis is very important. Various modalities including EEG are being used by clinicians for detection of abnormal brain activity during epilepsy. Preventive measures could be taken by the patient or their doctor if such abnormal brain activity is predicted before occurrence of any seizure. This research deals with the prediction and monitoring of abnormal brain activity using EEG brain signals for partial epileptic seizure.

II. PROBLEM FORMULATION

The real time monitoring of epileptic seizures is still an open area of research. There is no seizure prediction algorithm with high sensitivity and specificity which can be used for clinical application. Research is going on for better prediction algorithm performance which can be incorporated in some close loop intervention system. This intervention can be from human side or some implanted devices on the body. If the epileptic seizure is predicted before in time, it can be able to improve the lives of the patients having uncontrolled epilepsy. Therefore, this research will have a high impact on the society.

A. Literature Review

Researchers over the past two decades working on signal processing methods and also trying to categorize the epileptic seizure. They identified different signal characteristics from EEG signals and also to classify the signal segments based on the measured features [7]. Therefore, various automatic epileptic spike detection methods have been developed. Exact source localization of epileptic area is a mandatory condition for successful surgery and its description from functionally applicable regions. The physiological aspects of seizure generation and the treatment and monitoring of a seizure are important issues that need to be considered.

Electroencephalography (EEG), Magneto encephalography (MEG) and functional MRI (fMRI) are the main neuroimaging modalities used for detecting seizures. EEG/ERP shows the neural activity at scalp[7, 8]. The BOLD (blood-oxygenation-level-dependent) areas in the functional MRI of the skull clearly show the epileptic zone. The EPI is normally used for this kind of observations and data recordings [9]. The fMRI facility is limited to the major hospitals and is costly. Hence, it is not feasible to use fMRI for all the epileptic patients[10]. MEG has the same problem that it is only installed in large and main hospitals.

Finally, the EEG provides the solution to these issues in terms of cost and usefulness for the study of epilepsy. The epileptic seizures can be controlled through medications if it is detected before time. Therefore, it becomes important to detect the conditions leading to epilepsy. Hence, a real time prediction system can be very helpful for the clinicians as well as the patients. The system will be able to predict or detect partial epilepsy attack so that preventive measures can be taken by the patients or caretakers. Fig.1 shows the EEG signal with the pre-ictal and seizure onset periods.

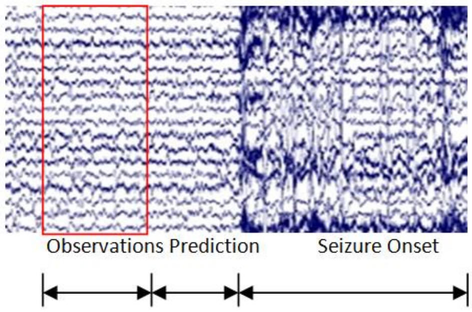

Fig.1. EEG signals with seizure

The time window for prediction is defined by Seizure Prediction Horizon (SPH). It is the minimum time of window in which the alarm is generated or activated by the prediction algorithm [11]. The Seizure Occurrence Period (SOP) is defined as the time duration at which the epileptic attack will occur. Figure 2 shows the SPH and SOP graphically. For accurate prediction, the seizure should take place in the SOP not in SPH.

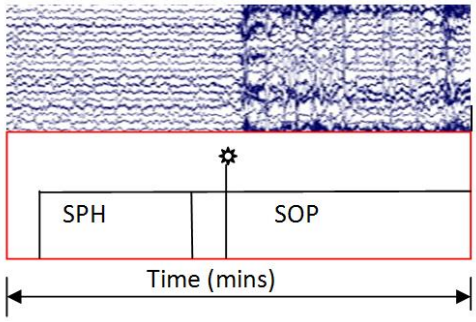

Fig. 2. Seizure Prediction periods[11]

B. Related Work: Seizure Prediction Methods

Different methods are used for prediction and detection of seizures in literature which includes linear and nonlinear methods. The Fast Fourier transform was used as the traditional method to take EEG time domain signal in frequency domain. FFT is non-parametric method for analyzing EEG spectrum. The non-stationary behavior of EEG signals, direct application of FFT is inappropriate[12]. However, for short segments of times, EEG signal can be considered as stationary signal. The wavelet transform up to some extent overcomes the limitations of Fourier transform by decomposing signal into different resolutions and scale levels [13]. Univariate Linear Methods used so far for seizure predication are auto regressive moving average, accumulated energy[14], spectral band power and statistical movements. EEG signal is considered nonlinear in nature. Nonlinear methods used so far are correlation dimensions, correlation entropy, Dynamical similarity index and largest Lypanouv exponents[15].

F. Miwakeich [16] observed the EEG activity using a stochastic model. This method produced better results in terms of noise free activity as compared to the previous techniques. The tuning parameters were set manually which was some limitation to this method. F. Miwakeichi in [17] addressed the limitation of Principal component analysis and Independent component analysis by using PARAFAC (Parallel factor analysis) which uniquely decompose the EEG signal in time, frequency and space [18].

Feature extraction uses both linear and non-linear techniques. For relationship between the channels, univariate and bivariate methods are followed. Classification is based on statistics and algorithms like machine learning, neural networks and genetic optimization [19]. All these methods have some pros and cons. Some constraints are placed on the EEG signal nature. Some show good results as compared to other methods. However the results are not convincing and the research is still on for better seizure prediction algorithm or method[20]. Majority of these techniques cannot be applied because of the non-stationary nature of the EEG signals [21].

TABLE I
DIFFERENT METHODS RESULTS

Year	Methods	Sensitivity (%)	FP/hr
1998	FFT , WT	60	n.a
1999	Similarity Index	83	n.a
2001	Similarity Index	96	n.a
2001	Accumulated Energy	90	0.12
2001	Correlation Dimension	47	0
2003	Phase synchronization	81	0
2003	Similarity Index	60	n.a
2003	Feature selection	63	0.28
2004	Accumulated Energy	32	0.15
2005	Phase synchronization	69	n.s
2006	Phase synchronization	70	0.15
2009	Lypanouv Exponent	80	n.s
2010	Spectral Power/CS-SVM	86.3	0.128
2011	Feature extraction & Classification (SVM)	90.8	0.094
2012	Rule Based Prediction	90.2	0.11

n.s=not specified, n.a=not applicable

Different methods showed different results in terms of sensitivity and specificity or now called false prediction rate per hours. Some methods showed very good sensitivity but on other hand poor specificity value. Table 1 shows detail survey and results of different linear as well as nonlinear methods applied to different data sets and different type of EEG signals. For example some are on scalp EEG and some are applied on intracranial EEG (iEEG). From Table 1 , we can see that there is no method which gives a good results for better sensitivity and specificity values. Stacey[21] surveyed in 2011 that there is still no prediction algorithm that demonstrates acceptable sensitivity and specificity to be used in clinical application by using surface EEG.

III. CHALLENGES AND RESEARCH ISSUES

From the literature review, following limitations & Shortcoming of the existing methods have been found.

1) *Sensitivity and Specificity*

The sensitivity and specificity are important parameters to judge the performance output of any seizure prediction algorithm. Even from two decade research on seizure prediction problem, It is not possible to achieve high values for both at same time. Therefore, current prediction techniques cannot be used for clinical applications since they do not satisfy both high sensitivity and specificity.

2) *Univariate and Bivariate Methods*

Univariate method has the disadvantage that it is computed on single EEG channel; hence the inter-channel correlation to judge the seizure state or pre-ictal state is not possible. It only contains the EEG time series having different frequencies and amplitudes. A bivariate method overcomes up to some extent by taking correlation between the channels of EEG data.

3) *Linear Autoregressive modeling*

Autoregressive modeling technique has limitation that it cannot be used for spike tracking accurately. It is useful in normal condition, but for spikes and sudden changes in the EEG data, this method has shown poor results.

4) *PCA and ICA methods*

Principal component analysis solves the problem by mapping the large features dimension space to the small dimension by using the linear transformation. The EEG signal original information is persevered in the lower dimension space. PCA suffers from inherent lack of uniqueness.

5) *Type and Length of EEG*

Different methods were used for intracranial EEG (iEEG) and surface EEG. Some techniques for iEEG produced different results than surface EEG.

6) *Non Stationary nature of EEG Signal*

The EEG signal is non-stationary in nature. Some algorithms were designed by making the signal piece wise stationary or by assuming that the EEG signal is stationary which is not a valid assumption. By doing this, optimal performance cannot be achieved in terms of prediction.

Above mentioned limitations show that epileptic seizure prediction is still an open research area. Our focus will be to develop an efficient and better prediction algorithm or technique which can be used for clinical application by addressing above limitations.

IV. PROPOSED METHODOLOGIES

Different approaches were used to solve the problem of the seizure prediction and the above detailed survey shows there is still need in improvement for seizure prediction methods for real time clinical application. The pattern recognition techniques like spike sorting and subspace techniques has good potential to solve the prediction problem in efficient manner. These are explained below.

A. *Pattern Recognition Approach*

EEG signal contains sufficient information about the epilepsy brain disorder. To predict pre-seizure state from EEG, pattern recognition approach could be helpful. For prediction system, feature extraction is the most important part of the whole system. Some of the dominant features often used in feature extraction techniques includes Hjorth parameters, curve length and nonlinear energy, approximating the coefficients of WT decomposition, PSD, spectrum entropy, mean, skewness and parameters of AR model shall be considered and may be applied on data if considered appropriate[22, 23].Classification can be done using machine learning techniques like support vector machines (SVMs)[24].

For real time application, limited hardware resources put constraints on developing high computational algorithms. The real time epileptic seizure prediction system has to wear and carry by a patient. Therefore, simplified methods are the primary concern to solve this kind of problem. The pre-ictal period some time gives information about upcoming epileptic seizure attack. The increase in beta power of EEG signals during the pre-ictal period shows some significance before occurrence of any seizure [25]. Considering the powers and synchronization between different channels can be used to develop a method for real time epileptic prediction as proposed in Fig 3.

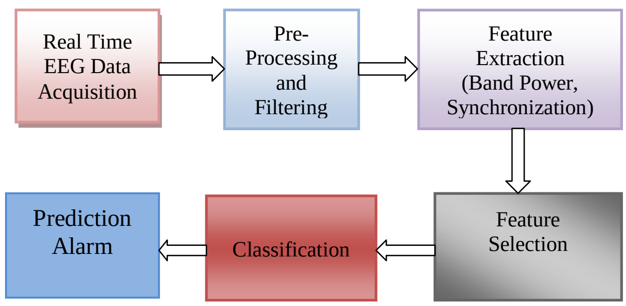

Fig.3. Real time seizure prediction approach

Spike sorting approach in which spike features are extracted and discriminative features are computed and clustered in a 2D or 3D feature space. Figure 5 shows details of this kind of frame work. Classification can be done using SVM classifier and its output used as alarm to show on coming seizure or not. This approach is complex and requires intensive calculation and to detect any kind of spikes occurring before seizure. Normally this approach can be helpful in seizure onset detection as shown in Fig 4.

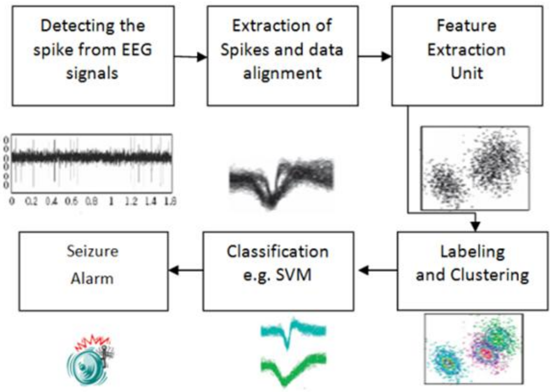

Fig 4. Spike sorting Approach

B. *Feature Extraction using subspace method*

To improve the performance of the classifier, feature extraction plays an important role .Generally, large number of features is available and the selection of the most dominant among them is highly required. Among the different solutions, the subspace provides the possibility of extracting the dominant features and unequally representing them through the principal subspace[26]. The matching process is conducted by finding the angle between the different subspaces [15]. Most of the time, all original features are not useful and due to large size of features, efficient training is not possible. The subspace techniques provide the solution to this and it is used in terms of dimensionality reduction and appropriate representation [16].

In subspace method, Classification is achieved by projection of the data onto basis vectors and by taking the product between the basis and data vectors. These projections make a new way of representing data. These projections are used as input for the classification task.

C. *Close loop epileptic seizure intervention system*

The final aim of developing a reliable partial seizure prediction method is that it is capable of generating alarms about an impending seizure or oncoming seizure before in time. These alarms can be used in close loop intervention system for warning patients for precautionary measures or for implantable devices to control epileptic attack.

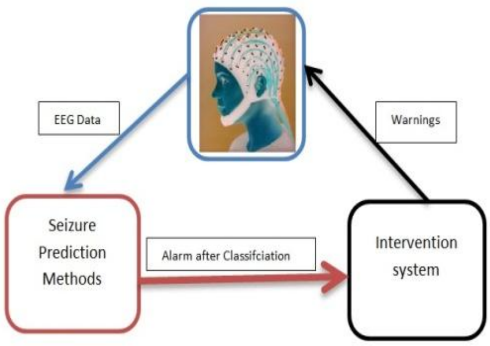

Fig.5. Close loop intervention system

An ideal intervention system has the capability of predicting the seizure before time and raising the alarms to take the precautionary measures [27] as shown in Fig 5.

V. CONCLUSIONS & FUTURE WORK

One third of the patients suffering from epilepsy do not respond to the antiepileptic drugs. There is a need for some prediction mechanism to predict before any epileptic attack. This seizure prediction method can generate the predictive alarm and based on it some precautionary measure can be taken by the patients .This will improve the standard of the life of the people affected by epilepsy. From the detailed literature survey, It is concluded that the seizure prediction is still an open area of research. Our aim is to study and propose a frame work for an efficient seizure prediction method which is capable to predict any possible epileptic attack and can be used in real time seizure prediction system. The proposed pattern recognition approaches can be used in close loop intervention system which will be helpful in improving the quality of the life of the patients with uncontrolled epilepsy.

For implementation point of view in real time monitoring systems, a combination of simple methods are required in contrast to the other complex techniques. Considering one particular band power of EEG which is dominant before occurrence of epileptic seizure provides less computation for real time hardware implementation. For example, the change in the beta band power before occurrence of seizure and synchrony between different channels can be used as input to the classifier to predict the possible epileptic seizure attack. Suitable feature selection plays important role in the seizure prediction mechanism. Simple features are easy to compute and implement in real time hardware point of view. The proposed schemes are capable of generating better features and good prediction results in terms of sensitivity and false prediction rate. In future, the available wireless hardware to acquire EEG data along with proposed methods can be integrated for real time seizure prediction.

VI. REFERENCES

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