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A Survey on the Methods of Seizure Prediction

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Abstract: Seizure prediction is important as far as the safety and health of an epileptic person is concerned. It helps in taking precautions before a seizure strikes a person. There are several methods to predict the onset of seizure. This paper primarily focuses on a survey of such available methods and their important features. The primary aim is to conquer a seizure prediction algorithm which can be used in portable devices which can even be implanted within the patient. Different methods use different EEG features which can uniquely identify the onset of a seizure thereby reducing false positives.

Keywords: seizure, adaboost, fuzzy, spike rate, divergence, ictal, spectral power ratio.

I. INTRODUCTION

Epilepsy is basically a neurological disorder which is characterized by epileptic seizures. Epileptic seizures are sometimes accompanied by heavy and vigorous shivering or shaking which can lead to physical injuries and unconsciousness. Some experience social stigma due to this condition. The main characteristic of epileptic seizures is that there is no immediate underlying cause. It is the result of abnormal neural activity in the cortex of the brain. Seizure prediction can be helpful to provide appropriate medicine or brain stimulation so as to prevent an upcoming seizure from occuring.

An implantable drug delivery system can also be used if proper seizure prediciton is done. Several methods have been proposed for seizure prediction which ,if effectively implemented, can improve the living expectation of many people suffering from such ictal events. An algorithm with maximum efficiency is required to prevent false alarms or false positives. Efficiency of most of the algorithms reduce when implemented for long term recordings. The methods discussed here uses various EEG characteristics like spectral power, spectral power ratios, spike rate, divergence etc. to detect the preictal state and hence make a seizure prediction. The problem mainly lies in distinguishing the preictal state from the ictal state. The seizure prediction system must be clearly defined to distinguish these states. The sensitivity, specificity and the false positive rate of the prediction system is important as it needs to be implemented on an implantable device.

II. BRIEFING OF THE VARIOUS SEIZUREPREDICTION SYSTEMS

A. Seizure Prediction Using Adaboost

A basic block diagram of this technique proposed by ManoharAyinala and Keshab K Parhi [1] is shown in Fig 1.Here the spectral power features are extracted from 9 different subbandsof EEG. The features are ranked and a nonlinear classifier is used. The basic steps involved here are:

Feature extraction: Initially a preprocessing is done to remove motion artifacts and other electrical noises.Spectral power in different frequency bands are extracted in a 20 second long window with 50% overlap whichleads to a prediction every 10 seconds. Spectral bands areselected basedon standard iEEG frequency bands but the wide gamma bandis split into four bands: delta (0.5-4Hz), theta (4-8Hz), alpha(8-13Hz), beta (13-30Hz) and gamma bands (30-47Hz, 53-75Hz,75-97Hz, 103-128Hz).The power in each band is normalizedby the total power and is included as the last feature.

Feature Selection:The complexity of the seizure prediction algorithm is directly proportional to the number of features. Hence number of features needs to be reduced without affecting the performance of the system. Adaboost algorithm can be used for proper feature ranking and selection. It identifies set of strong and weak classifiers and uses it for determining the strength of each feature. Later on, features that contribute the least towards classification are discarded.
Classification: Here the selected features are classified as eitherpreictal or interictal depending on their values.

Post Processing: Here isolated events such as false positives and false negatives are smoothened out.

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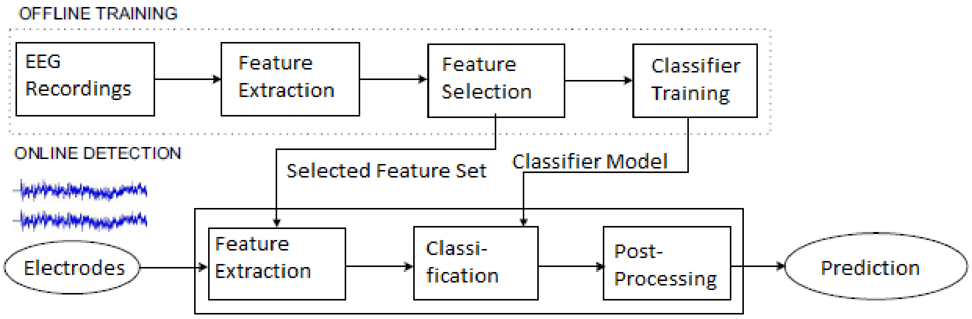

Fig. 1. Technique based on Adaboost

B. Seizure Prediction Using adaptive Neuro Fuzzy Inference System

This technique was proposed by Ahmed F Rabbi, Leila Azinfar and Reza Fazel-Rezai[2]. In this system, an Adaptive neuro-Fuzzy Inference System(ANFIS)[3] is applied on EEG for seizure prediction. Multiple epileptic seizure predictive features were combined and an ANFIS network was used to predict the preictal state. The main advantage of this technique over others is that it provides the output as a linear regression time series rather than integer values representing classes. The greatest plus point of this method is that it allows the performance analysis within the framework of seizure prediction characteristics. The first step here is the preprocessing step which reduces high frequency noise and low frequency artifacts. In the next feature extraction stage, univariate and bivariate features are extracted from two channels in the epileptic region. Later on, the ANFIS is applied to these features. Fuzzy If-then rules are applied on the feature set. The final fuzzy output variable was applied with a threshold procedure to convert it into an alarm space. The threshold was set in such a way that better sensitivity and lower false positive rates were achieved. A threshold was also set such that no prediction results less than 35 seconds will be considered as true predictions. Alarms followed by seizure events are considered true positives and those not followed by seizure events are considered as false positives.

C. Seizure Prediction Using Spike Rate

This technique was proposed by Shufang Li, Weidong Zhou, Qi Yuan and YinxiaLiu[4]. Seizures are characterized by generalized spike wave discharges. The rate of generation of these spikes is the feature used here. Spike rate shows a significant change before the onset of seizures which is exploited here to detect the preictal state. Initially the EEG waveform is passed through a low pass filter to remove high frequency artifacts. Then a morphology filter is used for spike detection. Morphology filter basically detects objects with specific shapes using structuring elements. Morphological operations include features like opening, closing, erosion, dilation etc. Theopening operation can smooth the signal positive pulse (peak), while the closing operation can smooth the signal negative pulse (valley). In ictal EEG signals, there are positive phase and negative phase spikes. Therefore, the filters of morphological opening-closing (OC) and morphological closing-opening (CO) are used to detect bi-directional spikes. The performance of morphological transform is greatly affected by the selection of structuring elements. In order to remove the background components of original EEG and highlight spikes, the structuring element selected should reflect the geometricalcharacteristic of the original EEG signals, and at the same time, the width of structuring element must be between spike rhythm and background EEG rhythm.

D. Seizure Prediction Using Spatial – Temporal EEG features

This system was proposed by Shuoxin Ma and D.W Bliss[5]. Here multichannel EEG signal is used to build spatial – temporal covariance matrices. Eigen values of these are taken as the features directly. One reason is that we need the relative strength of eigenvalues,which indicates the power distribution among different components, instead of the absolute power of individual components. Another reason is that the individual component power levels may vary from patient to patient, which would become distracting in inter-patient prediction. Thus, attempting to avoid absolute eigen-value level difference, yet conserving the information in that, the first eigen-value is left unchanged and other eigen-values are normalized by it.

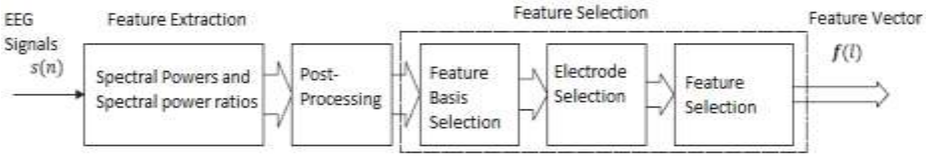

Fig. 2. Technique based on ratios of spectral power

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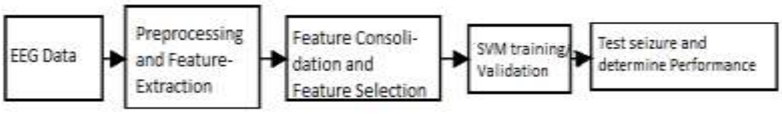

Fig. 3. Technique based on HPD measurement

Accurate determination of covariance matrix requires large number of samples. In case of large dimensions, dimensionality reduction is achieved through Principal Component Analysis. Support Vector Machines are used for classification [6].

E. Seizure Prediction Using Spectral Power and Ratios of Spectral Power

This technique was proposed by Zisheng Zhang and, Keshab K Parhi[7]. It uses the fact that the power spectral density of EEG is altered before and during seizures. Here, a spectrogram of the input EEG signals are computed from one or two electrodes. A window based PSD computation is used with a 4 second sliding window with half overlap. This leads to an effective window period of 2 seconds. Spectral powers and spectral power ratios are extracted as features and are input to a classifier. Feature set includes spectral power in different bands, relative spectral power in different bands and the ratio of spectral power in different bands. The actual feature set constitute these three type of features. Electrode selection and optimal feature selection are also done here. Support Vector Machines[8] can be used for classification. Undesired fluctuations of the decision output of the classifier are rectified using post processing steps. A basic block diagram of the technique is shown in Fig 2.

F. Seizure Prediction Using HPD measurement

This method was proposed by Michael Brown, TheodenNetoff and Keshab k Parhi[9]. Here feature selection is done using the divergence measurement method proposed by Henze and Penrose. Power spectral density features are extracted from 6 channels and then HPD measurement is used to test linear combination for beneficial feature consolidation. The feature consolidation process is repeated until the point that no further consolidation would lead to a performance improvement. This method thus helps in reducing the number of features required. Here linear kernel is used for SVM to reduce computational complexity. The basic steps for this process is shown in Fig 3 above.
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III.PERFORMANCE COMPARISON OF VARIOUS METHODS

Two very important metrics for the performance assessment of seizure prediction algorithms are the False Positive rate (FPR) and Sensitivity. The performance assessment of the above mentioned methods has been done based on the EEG data acquired from the Freiburg and MIT EEG database. The Freiburg database contains 80 seizures among 18 patients in 427 hours of recordings. The MIT EEG database contains 78 seizures from 17 children in 647 hours ofrecordings. The method of seizure prediction using adaboost uses a linear SVM for classification which makes it less complex and more suitable for implantable devices. But the issue is that, in case if the selected features are not linearly separable, then this method might lead to misclassification. Also, spectral power is the feature mainly used here. This feature has a major disadvantage. It is the fact that the spectral power fluctuates a lot during interictal and preictal periods. So ultimately it doesn't turn out to be a reliable feature. A statistics showing the sensitivity and false prediction rate is shown in Fig 4 below.

TABLE1

Patient #	Sen%	FP/hr	FP %	# Features
1	100	0	0	3
3	100	0	0	4
4	100	0	0	2
5	60	0.7917	36.3657	8
6	100	0.0833	4.1667	4
7	100	0	0	2
9	100	0.25	12.5	4
10	100	0.1667	8.33	4
11	75	0	0	4
12	100	0	0	5
14	75	0.0833	4.1667	8
15	100	0.1667	8.333	8
16	100	0.1667	8.333	8
17	100	0.125	6.25	5
18	100	0.1667	8.33	3
21	100	0.1667	8.333	5
Mean	94.375	0.135	6.487	4.8125

Fig. 4. Performance of Adaboost based technique

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TABLE2

Sensitivity (%)	false prediction rate (/h)	mean prediction time (min)
75.8	0.09	49.7

Fig. 5. Performance of Spike rate based technique

The fuzzy based method helps in analysis of the seizure prediction characteristics and the results will be more accurate and sensitive but the main issue is that it needs lots of memory since it is addressed as a regression problem rather than classification. The spike rate based prediction system has a major advantage that it is simple since only one feature is considered but the problem lies in the fact that large datasets would be required for proper training of the classifiers since the classification is done based on one feature alone. Its performance analysis is shown in Fig 5 above.

Seizure prediction using spatial-temporal EEG features is a bit complex to implement on an implantable device since the algorithm used involves PCA, SVM etc. Seizure prediction using spectral power ratios are very effective since the spectral power ratio highlights any small change in the power which increases the sensitivity of detection.

The HPD method of seizure prediction uses a novel divergence value to assess the strength of each feature but as the number of features increases, the divergence calculation becomes more complex. Also, since linear SVM is used, linearly non separable features cannot be correctly accommodated into the system.

IV. CONCLUSION

Among all the methods for seizure prediction discussed above, it can be concluded that analyzing more number of features for prediction reduces false positives and enhances sensitivity. But as the number of features increases, the system becomes more bulky for a portable usage. Hence a trade off should be made between the number of features and complexity. Proper feature selection must be done in this regard to identify features that contribute the most to seizure prediction. Using only the very significant features helps reduce the complexity of the system. Spectral features are generally found to be more effective and among those, analysis of spectral power ratios contributes the most for effective seizure prediction. Hence a method which uses this strategy coupled with proper electrode selection and classification strategies would be the best way for predicting an ictal event.

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