A Survey on Different Methods for Epilepsy and Seizure Detection by Analyzing EEG

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Abstract: **Approximately 50 million people worldwide, that is 1% of the world's population, have epilepsy. Epilepsy is a neurological disorder that affects people of all ages, causing recurring seizures due to abnormal electrical activity in the brain. The detection of epilepsy is possible by analyzing EEG signals. Hence this paper presents different epilepsy and seizure detection methods by analyzing EEG signals. As the paraclinical evidence from the EEG can allow earlier diagnosis and treatment.**

Keywords: **Epilepsy and seizure detection methods, EEG signals.**

1. INTRODUCTION

The epilepsies are chronic neurological disorders in which clusters of nerve cells, or neurons, in the brain sometimes signal abnormally and cause seizures. Neurons normally generate electrical and chemical signals that act on other neurons, glands and muscles to produce human thoughts, feelings and actions. During seizure, many as 500 times a second, much faster than normal. This surge of excessive electrical activity happening at the same time causes involuntary movements, sensations, emotions and behaviours and the temporary disturbance of normal neuronal activity may cause a loss of awareness. In general, a person is not considered to have epilepsy until he or she has had two or more unprovoked seizures separated by atleast 24 hours. A number of tests are used to determine whether a person has a form of epilepsy, and if so, what kind of seizure the person has. Electroencephalogram (EEG) is one of the main diagnostic tests for epilepsy. EEG is a non-invasive technique used to measure and record the electrical activity in various region of the brain. An EEG can assess whether there are any detectable abnormalities in the person's brain waves and may help to determine if anti-seizure drugs would be of benefit.

2. METHOD

A number of tests are used to determine whether a person has a form of epilepsy and if so, what kind of seizures the person has. So, methods may be based on:

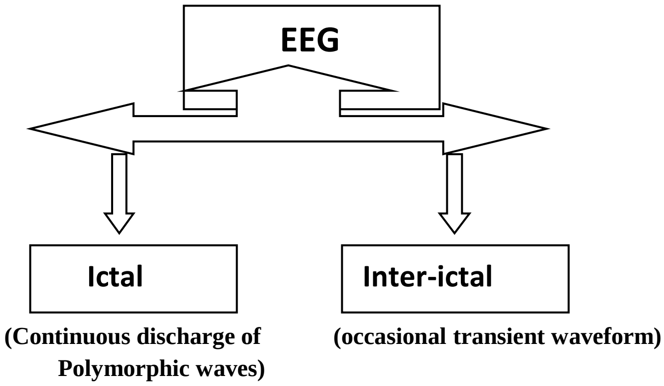
1. Blood test
2. Medical history
3. Imaging and Monitoring

Blood Test: There are a number of blood tests that may be recommended as part of epilepsy diagnosis and treatment. Blood test such as a CBC and chemistry panel helps doctors to assess overall health and identify conditions that may be triggering the seizures.

Medical History: A neurologist uses all responses of asked questions and details surrounding each episode of the seizure to determine the most probable cause of seizure or point to epilepsy.

Imaging and Monitoring: An ELECTROENCEPHALOGRAM, or EEG, can assess whether there are any detectable abnormalities in the person's brain waves and many help to determine if antiseizure drugs would be of benefit.

The goal of treatment is to achieve a seizure-free status without adverse effects. Monotherapy is important, because it decreases the likelihood of adverse effects and avoids drug interactions. Special situation that require treatment is having an abnormal sleep-deprived EEG that includes epileptic form abnormalities and focal slowing, diffuse background slowing, and Intermittent diffuse intermixed slowing. The seizure detection can be carry out by analyzing the EEG signals that reveal the seizure as rhythmic discharge. As soon as the seizure is detected a closed loop device implanted in the body, triggers appropriate stimulation to the epileptogenic zone to suppress the neuronal discharge and thus, abort the seizure. The detection process is carried out by extracting the features from an EEG signal and classify into the appropriate categories such as seizure (ictal) and non-seizure (inter-ictal).



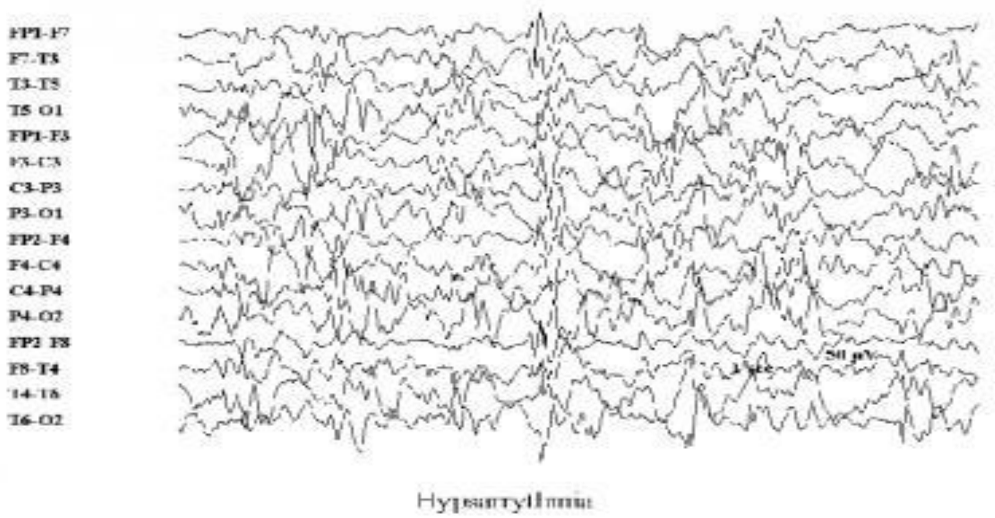


Fig1. EEG demonstrating hysarrhythmia in infantile spasms

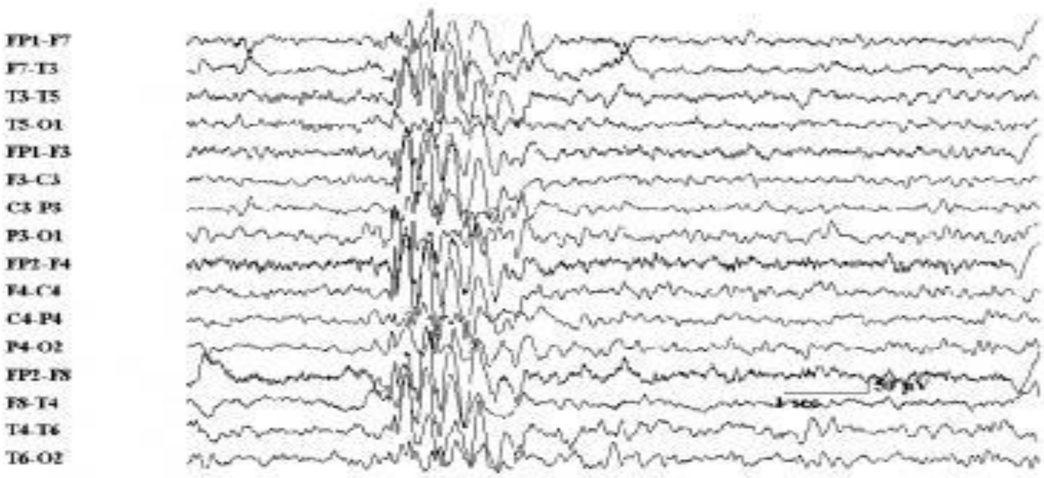


Fig2. EEG demonstrating polyspike and wave discharges seen in junevile mayoclinic epilepsy

The detection of epilepsy can be achieved by visual scanning of EEG recordings for inter-ictal and ictal activities by an experienced. However, visual review of the vast amount of EEG data has serious drawbacks such as: (1) Time consuming and inefficient. (2)Disagreement among the neurophysiologist on the same recording is possible due to subjective nature of analysis. For this reason, methods for the automated detection of inter-ictal waveforms and epileptic seizure can serve as valuable clinical tools for the scrutiny of EEG data in a more objective and computationally efficient manner.

AUTOMATED ANALYSIS OF EPILEPTIC EEG RECORDINGS:

Inter-ictal spike or spike detection method: Several methods for spike detection have been proposed based on single and multichannel approaches. Those methods were classified into six categories.

- **i.** Mimetic technique that copy the human expert
- **ii.** Template matching algorithms based on finding events that match previously selected spikes.
- **iii.** Parametric approaches based on traditional signal processing techniques
- **iv.** Neural Network techniques
- **v.** Knowledge based rule techniques

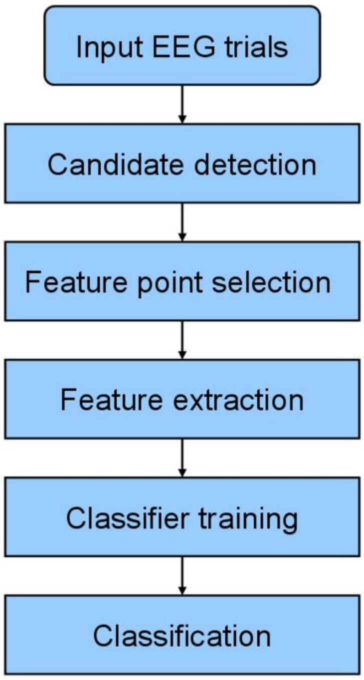


Fig.3.The spike detection problem seems to be broken down into two main stages: feature extraction and classification

Mimetic technique: Mimetic techniques are based on the hypotheses that are process of identifying a transient in the EEG as epileptogenic could be divided into well-defined steps representing the reasoning and expertise of an EEG expert. Distinctive attributes of the spikes such as slope, height, duration and sharpness are compared with values provided by the EEG experts. Gotman and Gloor decomposed the waveform into two half-waves with opposite direction. Feature et al. introduced a concept where the duration, amplitude and slope attributes of half-waves were used to classify them into states.

Template matching algorithm based: The user visually selects a few spikes from a set of test signals. These spikes are averaged to create a template. Many researchers like Park et al. used wavelets to obtain feature of the signal for template building and spike detection.

Parametric approaches: Researchers assume local stationarity of the noise and spikes are detected as deviation from that stationarity. Tzallas et al. presented a new technique based on a time varying autoregressive model that made use of the nonstationarities of the EEG. The autoregressive parameters were estimated via Kalman filter. The signal was first processed to accentuate the spikes and attenuates background activity and then passed through a thresholding function to determine spikes locations.

Neural Network Technique: Neural Network has been trained using either raw data or select features to detect spikes. Pang et al. explored the performance of NN in spike detection. Webber et al. compared multilayer perceptron networks using both raw digitized data and half wave attributes as input. Ozdamar et al. believed that it is very difficult for the EEG experts to select and define all these waveform parameters; therefore they forge the creation of attributes and instead used the raw waveform as input to NN. Use of raw data eliminated the need to define half-wave, slopes and sharpness.

Data mining technique: Data mining techniques were used to build automatic detection models. In DM, the recognition of spikes does not need a clear definition of spike morphology.

Knowledge based rule techniques: Considerable use of spatial and temporal contextual information present in the EEG aids both in spike detection and background activity rejection. Arising from the need to incorporate knowledge of the EEG experts, Davey et al. presented an expert system approach to detection of epileptic form activity in the EEG. The first is a feature extractor that produces a list of all spikes like occurrences. The second stage reads the list and uses rules incorporating knowledge elicited from the EEG expert to confirm or exclude such of the possible spikes.

EPILEPTIC SEIZURE DETECTION AND PREDICTION METHOD: There are many well-known detection and prediction algorithms for inter-ictal recordings. In the following we give a brief overview of these different approaches: (1) Linear and Non-linear methods (2) Wavelet domain method.

Linear and Non-linear features:

Linear methods have been widely used in the area of epilepsy detection mainly due to their simplicity and versatility. One of the simplest linear statistics metrics is the variance of the signal. It offers an insight into dynamics underlying the EEG and is usually calculated in consecutive windows. A further linear method is based on the auto-correlation function. Liu et al. distinguished EEG epochs containing seizures using scored autocorrelation moment with an accuracy of 91.4%.A non-linear analysis of recorded from an experimental system usually begins with a state space reconstruction. An advantage of obtaining a multi-dimensional state space is that it may reveal the underlying dynamics. A number of non-linear statistics have been used to investigate changes in the EEG are: Correlation density, cross-correlation integral, lyapunov exponent.

Auto-correlation Method: Theiler points out that for a finite autocorrelation data set, the plot of C(m,Ɛ) on a logarithmic scale can exhibit approximately linear regions with distinct slopes that do not increase with m. Assuming that we have a window of data $\{x_j\}_{j=1}^{N}$, the autocorrelation of the data ,α ,is computed through the following average: α=(1/M)$\sum_{k=1}^{M}(\alpha_k)^{1/k}$, where M=number of data for computation and $\alpha_k = \langle x_j\, x_{j+k}\rangle/(x_j^2)$. Theiler considers a Gaussian stochastic time series consistency of N data points with autocorrelation $0< \alpha \leq 1$ and argues that if N is large enough, or if α is small enough (near zero), then the effect of autocorrelation is negligible. However, if N is not sufficiently large and/or if α is not close to zero, the effect of autocorrelation becomes noticeable, leading to an anomalous scaling region in the plot of C(m, Ɛ). Hence as per this method we can that the de-correlation time is computed as a function of time difference with the first zero-crossing representing the de-correlation time. Using autoregressive modeling techniques, preictal changes have been reported. The linear modeling of a time series assumes that each value of the series depends only on a weighted sum of the previous values of the same series and "noise". The main assumption in linear modeling is the stationarity of the signal. So, for non-stationary signals like EEG, one needs to segment it into stationary parts.

LOCAL VARIENCE: One of the simplest linear statistics that can be used for investigating the dynamics underlying the EEG is the variance of the signal calculated in consecutive non-overlapping windows. Let s_i denote the EEG signal at time i. The variance of this EEG signal is given by

$$\sigma^2 = \langle [s_i - \mu]^2 \rangle$$

Where the mean is $\mu = \langle s_i \rangle$, and $\langle . \rangle$ is the average taken over the time interval being considered. The F-test (Press et al.) provides a statistical test of the hypothesis that two given data sets have different variances. The F statistics is the ratio of one variance to the other, so that $F \gg 1$ and $F \ll 1$ both indicate significant differences. The probability that F would be as large as it is. If the first data set's underlying distribution actually has smaller variance than the second is given by p= $Q(F/v_1 , v_2)$ where v_1 and v_2 where v_1 and v_2 are the number of degree of freedom in the first and second data sets, respectively. This probability can be computed using $Q(F/v_1 , v_2)=I_{v2/(v2+v1F)}(v_2/2,v_1/2)$, where $I_x(a ,b)$ is the incomplete beta function.

Entropy based analysis: Entropy is a thermodynamic quantity describing the amount of disorder in the system. From an information theory perspective the above concept of entropy is generalized as the amount of information stored in a more general probability distribution. First Shannon applied the concept of information or logical entropy to the science of information theory and data communications. Recently a number of different entropy estimators have been applied to quantify the complexity of the signal. Different entropy based analysis are based on: Shannon entropy, Spectral entropy, Approximate entropy, Sample entropy, Permutation entropy.

Lyapunov Exponent Analysis: The Lyapunov exponent of a dynamical system determines the separation rate of a very closely related trajectory. Hence, two signal vectors in the phase space with an initial separation of δZ_0 will eventually diverge at a rate given by:

$$|\delta Z(t)| \approx e^{\lambda t}|\delta Z_0|,$$

Where λ is the Lyapunov exponent. This can be achieved if the divergence can be dealt with within the linear approximation. The separation based on the initial separation vector orientation. The maximal Lyapunov exponent can be estimated as:

$$\lambda = \lim_{t \to \infty} \lim_{\delta \mathbf{Z}_0 \to 0} \frac{1}{t} \ln \frac{|\delta \mathbf{Z}(t)|}{|\delta \mathbf{Z}_0|}$$

The limit $\delta Z_0 \to 0$ ensures the validity of the linear approximation at any time.

Wavelet based analysis: The early methods of automatic EEG processing were based on a Fourier transform. Such methods have proved beneficial for various EEG characterizations, but FFT, suffer from large noise sensitivity. A powerful method proposed that perform time-scale analysis of signals: The Wavelet Transform. This wavelet transform is appropriate for analysis of non-stationary signals. Hence the WT is well suited to locating transient events. Such transient events as spikes can occur during epileptic seizures. The main advantage of wavelet transform is that it has varying window size, being broad at low frequency and narrow at high frequency. It leads to an optimal time-frequency ranges. By performing spectral analysis using wavelet transform, EEG signals consisting of many data points can be compressed into few features. In this method the wavelet transform can be categorized into continuous and discrete types. To calculate a vast amount of data the discrete wavelet transform is commonly used.

The wavelet transform can be categorized into continuous and discrete types. Continuous wavelet transform is defined as

$$\mathrm{CWT}(a,b)=\int_{-\infty}^{\infty} x(t)\, \Psi_{a,b}(t)dt$$

Where x(t) represents the analyzed signal and a and b represent the scaling factor(dilation/compression coefficient) and translation along time axis(shifting coefficient) ,respectively. The $\Psi_{a,b}(.)$ is obtained by scaling the wavelet at time b and scale a:

$$\Psi_{a,b}(t)=\frac{1}{\sqrt{|a|}}\Psi\left(\frac{t-b}{a}\right),$$

Where $\Psi(t)$ represents the wavelet. In continuous WT, the scaling and translation parameters "a" and "b" change continuously. Hence, to calculate a vast amount of data the discrete wavelet transform is commonly used.

Epileptic Seizure Detection Method

Author	**Year**	**Feature extraction**	**Classification**
Subasi & Gursoy	2010	WT and principle component analysis	SVM
Naghsh-Nilchi & Aghashahi	2010	Eigen Vector Method and music	ANN
Altunay et al	2010	Linear Prediction Filter	Thresholding function
Lima et al	2010	Wavelet Transform	SVM
Wang et al	2011	WT & Shannon entropy	k-nearest neighbor classifier
Iscan et al	2011	Cross Correlation & power & power spectral density	SVM, Decision tree
Martinez-Vargas Et al	2011	Time-frequency analysis	Thresholding function
Orhan et al	2011	Wavelet Transform	k-nearest neighbor classifier, ANN

After the feature extraction, seizure detection/prediction can be evaluated using either threshold based methods or trained classifiers, an advanced classifier like SVM and ANN.

3. CONCLUSION

Despite the fact that EEG is an important clinical tool for diagnosing, monitoring and managing neurological disorders, distinct difficulties associated with EEG analysis and interpretation which hindered its wide spread acceptance. Traditional method of analysis of the EEG is based on visually analyzing the EEG activity using strip charts. This is laborious and time consuming task which requires skilled interpreters, who by the nature of the task are prone to subjective judgment and error. Furthermore, manual analysis of the temporal EEG trace often fails to detect and uncover subtle features within the EEG which may contain significant information. Hence many researchers are working to develop an automated tool which easily analyzes the EEG signal and reveled important information present in the signal.

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