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RESEARCH ARTICLE

Automated detection of Epilepsy using Wavelet Features

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ABSTRACT:
Epilepsy is generally considered as a group of neurological disorders characterized by epileptic seizures. It is often confirmed with an electroencephalogram (EEG). But identification of epilepsy has to be done by skilled neurologist. This paper proposes an efficient methodology for automatic detection of ictal and healthy EEG signals which is the ultimate goal of machine learning, which has performed efficient classification .We used discrete wavelet transform for feature extraction and obtained wavelet coefficients .Neural network pattern recognition tool is used for classification .The performance of the proposed method is evaluated using in terms of sensitivity ,specifity and accuracy.

KEYWORDS: Wavelet, Electroencephalogram, ictal., Epilepsy, Haar, sensitivity.

INTRODUCTION:
Epilepsy is considered as a group of neurological disorders which is characterized by epileptic seizures[1]. The cause of epilepsy is generally unknown, although some people develop epilepsy due to stroke, head injury, brain tumor. Epileptic seizures can occur for long periods of vigorous shaking and also they tend to recur[2].It affects about 0.8% of world population[3].However, seizures are drug resistant in 70% of cases and in those cases which do not respond to medication neurostimulation, surgery may be considered[4]. Epilepsy is a sudden brain malfunction and is defined by certain conditions such as atleast two reflex seizures should occur greater than 24 hours apart[5]. One reflex seizure and probability of further seizures similar to general recurrence risk (at least 65%) after two unprovoked seizures, occurring over next 10 years[6].ILAE Commission for classification of Epilepsies divided epilepsies into three categories as genetic, structural/metabolic and unknown cause[7]. The diagnosis of epilepsy is based on description of seizure and electroencephalogram and neuroimaging are usually used for detection and diagnosis of epilepsy [8].

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During seizure, the electroencephalogram (EEG) amplitude increases by certain order of magnitude and characteristic patterns which are varying in time and frequency will appear[9]. The detection of such abnormalities requires skilled doctors and is also a time consuming process[10].Early detection of epilepsy is required for controlling it and thus automatic detection of seizure is required[20].

LITERATURE SURVEY:
A method is proposed in [11]based on Partial Directed Coherence for feature extraction as a part of automatic seizure detection whose application reflects the physiological changes of brain activity before and after the seizure occurrence. In this method, multivariate autoregressive (MVAR) model was first established for a moving window and then the direction and intensity of information flow based on PDC analysis was thus calculated. Finally, according to features of epileptic seizures, the outflow information is taken as input to a support vector machine (SVM) classifier for segregating into healthy and ital. EEG signals.

In[12] a method is proposed in which EEG signals are characterized by wavelet, sample and spectral entropy approach and for automatic detection of epileptic seizures the recurrent neural network classifier is employed.

For automatic detection of epileptic seizure in multichannel EEG a method is proposed in [13].In this the healthy, ictal and interictal signals are studied with the help of Higher Order Spectra (HOS).The measures obtained were able to distinguish epileptic images from normal and interictal EEG with high confident level.

In[14] hybrid principal component analysis (PCA) based neural network with fuzzy membership function (NEWFM) for epileptic seizure detection is proposed. The PCA method employed is used for wavelet feature enhancement, which is required to eliminate the sensitivity of noise and redundancy. NEWFM which is a model of neural networks is integrated to improve prediction results by means of updating the weights of fuzzy membership functions.

In[15] a new method was proposed which states that MEG (magneto encephalography) offers greater accuracy in epilepsy detection owing to higher spectral resolution when compared with EEG (electroencephalography) and an automated framework using open source solutions to visualize epilepsy has been proposed and capability of the proposed framework is demonstrated with a case of epilepsy surgery.

In[16] a methodology is proposed for automatic detection of healthy, interictal and ictal conditions from recorded EEG signals. The wavelet transform is used for the feature extraction and statistical parameters had been obtained from the decomposed wavelet coefficients .The Generalized Feed Forward Neural Network (GFFNN), Multilayer Perception (MLP), Elman Neural Network (ENN) and Support Vector Machine (SVM) are used for the calculation and performance of the proposed system in terms of classification accuracy, sensitivity, specificity and overall accuracy was evaluated

In[17] the effect of different events on EEG signal and different signal processing techniques used for extracting the hidden information from the signal are discussed and Linear ,Frequency domain, time-frequency and nonlinear techniques like correlation dimension (CD), largest Lyapunov exponent (LLE), Hurst exponent (H),different entropies ,fractal dimension (FD), Higher Order Spectra (HOS), recurrence and phase space plots are discussed in detail with the help of a typical normal EEG signal.

In[18] an automatic system that detects seizure onsets and thus allow patients or people around them to take required precautions and this uses nonlinear features motivated by the higher order spectra (HOS) which differentiate between normal, preictal and epileptic EEG signals is proposed. The features are extracted from the power spectrum and the bispectrum. By feeding them to a Gaussian mixture model (GMM) classifier the performance is studied.

An automated epileptic EEG detection system which is based on neural networks that uses approximate entropy (ApEn) as input feature. ApEn which is a statistical parameter that measuresthe predictability of current amplitude values of physiological signal based on its previous amplitude values is proposedin[19]. The fact used in the paper is value of ApEn drops sharply during an epileptic seizure and two types of neural networks, namely, Elman and probabilistic neural networks are used. The overall accuracy values as high as 100% was achieved by this proposed system

MATERIALS AND METHODS:

A. EEG Dataset:

The EEG signals used in this work are taken from University of Bonn database. The entire database is divided into five sets A to E. Each set comprises of 100 EEG signals each with total time period of 23.6 sec. The sampling rate of data is about 173.61 Hz. Sets A and B consists of recordings which are obtained through external surface electrodes under normal eyes in open and closed conditions .While the sets C-E are recorded with the help of intracranial electrodes which are exhibiting interictal and ictal epileptic activities. While the set C in particular readings are obtained from within epileptic zone during seizure free intervals which indicates focal interictal activity and set D recordings are obtained from hippocampal formation of opposite hemisphere portion of brain which indicates non focal interictal activity[13]. All EEG signals are recorded with the same 128 channel amplifier system with an average common reference ,with 12 A/D conversion bit rate of 12 [13].

B. Methods:

Two sets of EEG signals have been used for training, testing and validation purposes. 25 signals are taken from set A which were considered as healthy signals and 50 signals are taken from set E containing seizure activity which indicates ictal signals. Matlab has been used as a tool for automation and Neural network pattern recognition tool has been used for training, testing and validation of EEG signals into two groups and wavelet toolbox is used for feature extraction from EEG signals. The epilepsy diagnosis problem is modelled into two class group classification problem. The two groups are:
1.Healthy (Normal EEG) 2.Epileptic subject during seizure activity (Ictal EEG)

C. Discrete Wavelet Transform:

Wavelet transform is used in various applications such as feature extraction and signal preprocessing/ denoising. It is a powerful signal processing technique used to overcome the drawbacks of Fourier transform and other methods by providing efficient time and frequency localization. There are two types of wavelet transforms generally 1. Continuous Wavelet Transform 2.Discrete Wavelet Transform. Discrete Wavelet Transform is often more used and it provides information both for the purpose of analysis and synthesis of the original signal with reduction in computation time. In DWT, filters with different cutoff frequencies are used to analyze signals at different scales. DWT is based on sub band coding which is found to perform fast computation of wavelet transform. The DWT is performed by passing the discrete time domain signal through a series of low pass and high pass filters followed by decimation by factor two gives out approximation and detail coefficients respectively. This is called as Mallat algorithm and it is important to note that the two filters used are related to each other and they are known as Quadrature Mirror Filters. The analysis of signal using DWT for one iteration provides one approximation signal (A1) from low pass filter and one Detail signal from high pass filter. If more precision is required Approximation signal (A1) is further decomposed into A2 and D2 and so on as shown in figure. Let is basis function or mother wavelet. All functions which are used in transformation derived by performing scaling and translation operations on mother wavelet and Φ(x) denotesa scalingfunction.

Wavelet series expansion of a function f(x) is given by

$$f(x) = \sum_{k} c_{j_0}(k)\,\phi_{j_0,k}(x) + \sum_{k}\sum_{j=j_0}^{\infty} d_j(k)\,\varphi_{j,k}(x) \qquad (1)$$

Where

j_0= arbitrary starting scale

=approximation coefficient

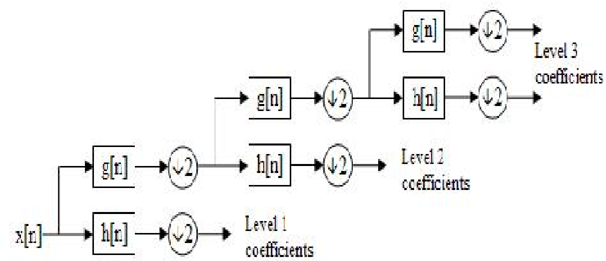
=detail coefficient

DWT transform pair is given by following equations

(2)

$$W_{\varphi}(j,k) = \frac{1}{\sqrt{M}}\sum_{x} f(x)\,\varphi_{j,k}(x) \qquad (3)$$

The wavelet used for obtaining wavelet coefficients in this paper is Haar wavelet which forms a sequence of rescaled square shaped functions which together forms the wavelet basis and this is recognized as first known wavelet basis .It is a special case of Daubechies wavelet and is also known as D2 and is the simplest possible wavelet which is widely used in finding out discontinuities.



IV FEATURE EXTRACTION

Wavelet coefficients (approximation and detail coefficients) which are obtained through Mallat algorithm are used to extract certain features which are used as metrics for segregating signals into healthy and ictal sets .The following are the set of features that are extracted:

1. Variance of approximation and detail coefficients
2. Standard deviation of approximation and detail coefficient.
3. Mean of absolute value of approximation and detail vector.
4. Median of approximation and detail coefficients.
5. Maximum and minimum values of coefficients in each sub band
6. Range of approximation and detail vectors.

By this way, for two level decomposition total 16 statistical parameters are extracted from two approximations and details coefficients. Each dataset A-E consists of 100 EEG signals each .Thus the size of the final feature vector is 16 × 100.

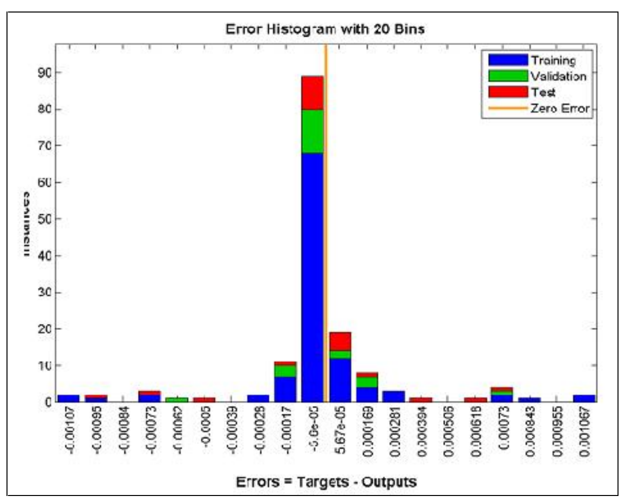


Fig 1: Histogram Representing Error Performance of Input signals

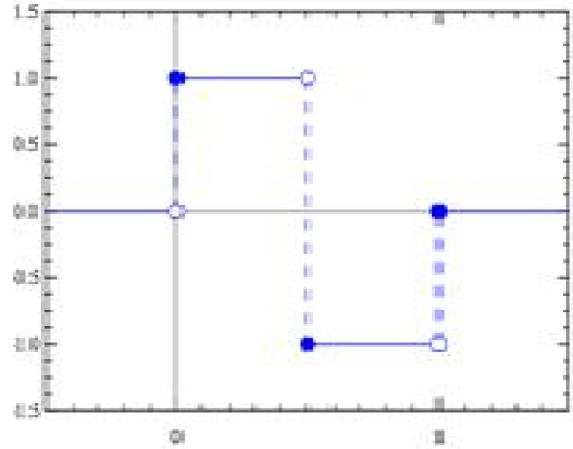


Fig 2: Graph representing Haar Wavelet

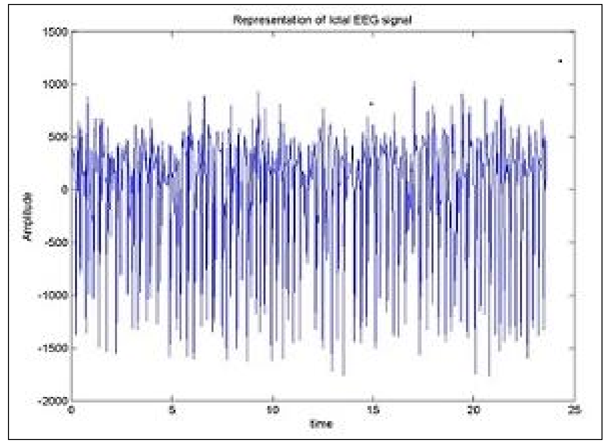


Fig 3: representation of Ictal EEG Signal

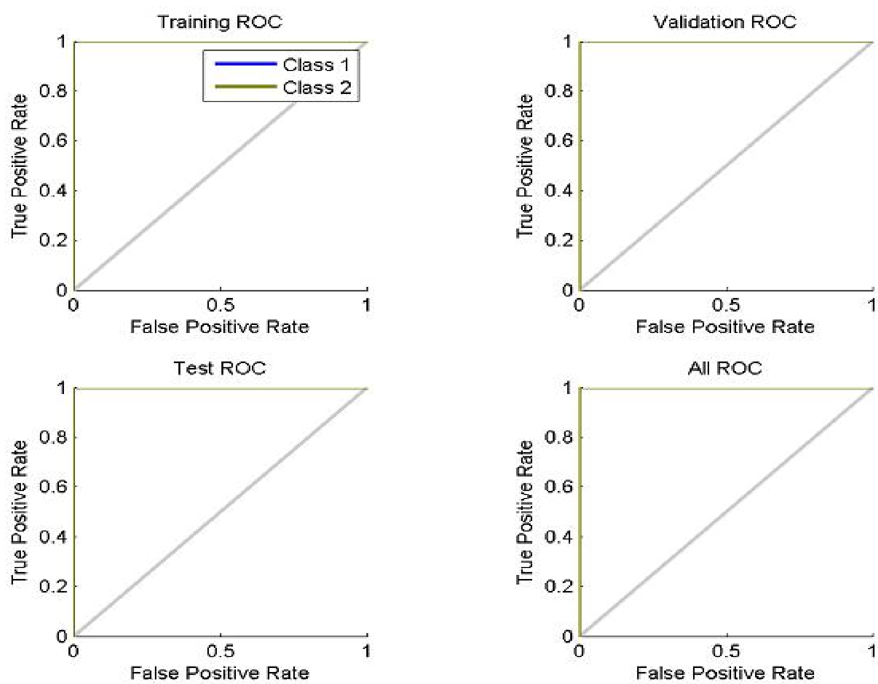


Fig 4:Receiver Operating Characteristics

Table1

SL. NO	METRICS	Healthy (mean ± std)	Ictal(mean ± std)
1	*Mean(app)*	378.3297±158.768	51.60723±16.35106
2	*Mean (det)*	63.61363±35.5242	8.430889±2.431354
3	*Median(app)*	5.569224±90.40816	−4.94976±29.55785
4	*Median(det)*	0.11313±9.699944	0.028284±0.321452
5	Mod(app)	−43.3032±268.0154	−8.90955±39.49683
6	*Mod(det)*	−2.87084±16.50191	−0.14142±1.241627
7	Max (app)	1.32E+03±527.0223	1.94E+02±64.731
8	*Max(det)*	−1.39E+03±738.1136	−1.79E+02±126.2905
9	*Min (app)*	333.6614±230.7418	40.4737±13.24489
10	Min(det)	−359.733±215.46	−39.2586±19.01
11	Range(app)	2.70E+03±1186.566	4.03e+02±1.07E+02
12	Range(det)	6.93E+02±434.7531	8.15E+01±26.00434
13	Std(app)	4.71E+02±201.7288	5.73E+01±1.45E+01
14	Std(det)	8.51E+01±50.8582	1.07E+01±3.106631
15	Var(app)	2.70E+05±200331.9	3.47E+03±1.75E+03
16	Var(det)	1.64E+04±44222.95	1.23E+02±69.26615

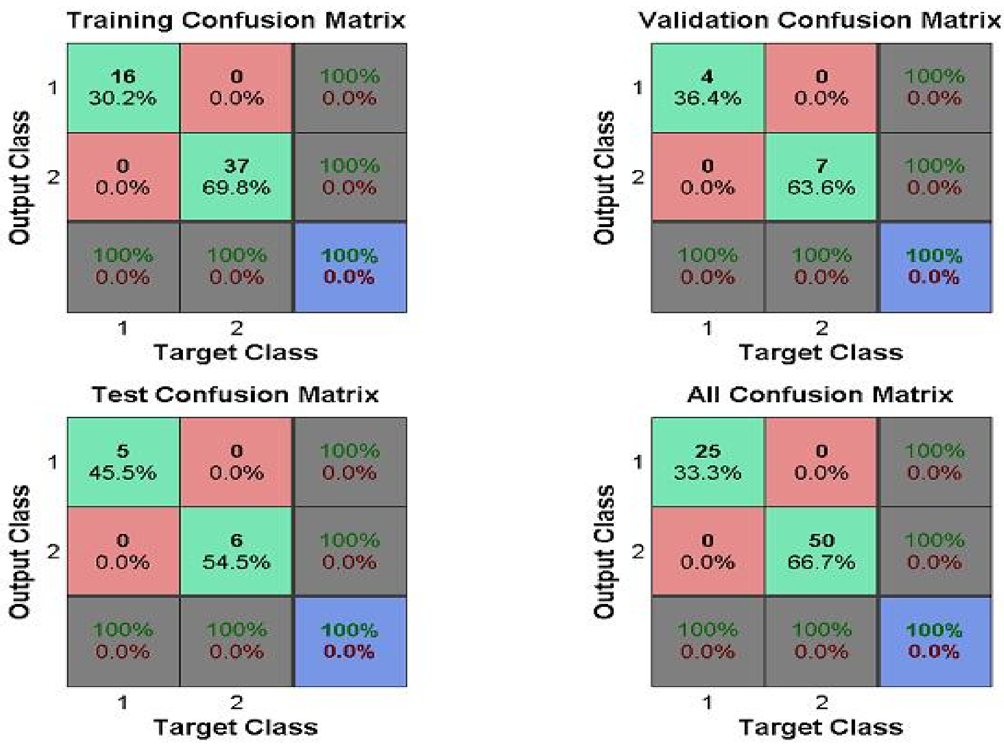


Fig 5: Confusion Matrixes Representing Training, Validation, Testing and overall performance of Input EEG Signals

Abbreviations : 1.std-standard deviation ,var-variance. 2. app-approximation wavelet coefficients 3. detail-detail wavelet coefficients.

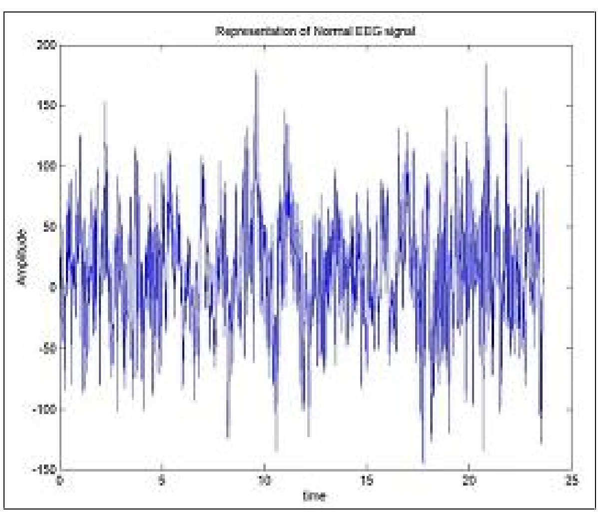


Figure 6: Representation of normal EEG signal .

V experimental results And discussion

The performance of the system proposed is measured by considering certain parameters like sensitivity, specificity and accuracy. Sensitivity refers to percentage of correctly classified disease individuals. A total of 75 EEG signals were taken from university of data base .50 EEG signals were taken from set E which represents ictal signals and rest 25 are taken from set A which represents healthy signals. The various features of EEG signals are extracted from wavelet coefficients and these results are loaded as input (16 ×75)to Neural network pattern recognition tool which helps to select data ,create and train a network and evaluate its performance using mean square error and confusion matrices. Now, corresponding targets (2 × 75) are loaded. The given inputs are made to undergo three stages of Training (70%-53 samples),Validation (15%-11 samples), Testing (15%-11 samples). The performance, Error Histogram, confusion matrix and Receiver Operating Characteristics are taken into consideration.

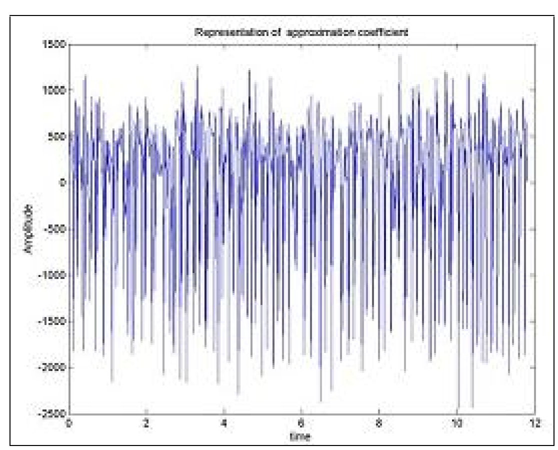


Figure 7: Representation of approximation coefficients.

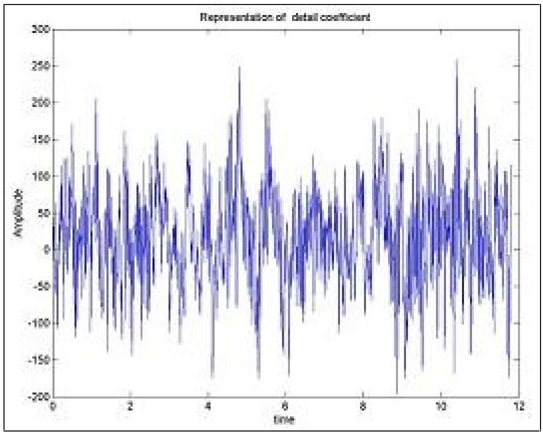


Figure 8: Representation of detail coefficients.

The confusion matrix for dataset tested using Neural network pattern recognition tool is shown in figure 5. With Neural network pattern recognition tool the percentage of average classification accuracy for testing ,training ,validation and CV dataset is 100%,100%,100%,100% respectively thus excellent results were obtained.

Sensitivity is also called True Positive Rate.It is given as follows:

$$TPR = TP/P = TP/(TP + FN).$$

Specificity is also called as True negative rate. It relates to ability of test to correctly detect patients without a condition. It is given by

$$SPC = TN/N = TN/(TN + FP).$$

Accuracy is given by formula given below

$$ACC = (TP + TN)/(TP + FP + FN + TN)$$

Where

TP=True Positive indicates correctly identified.

TN=True Negative indicates incorrectly identified.

FP=False Positive indicates correctly rejected.

FN=False Negative indicates incorrectly rejected.

CONCLUSION:

This paper proposed a feature extraction technique using wavelets for efficient classification of epileptic EEG signal with the help of artificial neural network. The classification problem is divided into two groups, namely healthy (Normal EEG) and ictal (Epileptic subjects during seizure activity). Neural network pattern recognition tool is employed for classification purpose of input EEG signals. With Neural network pattern recognition tool the percentage of average classification accuracy for testing ,training ,validation and CV dataset is 100%, 100%, 100%, 100% respectively and the sensitivity, specificity and accuracy of proposed method are 100%, 100%, 100% respectively which are clear from confusion matrix outputs, thus excellent results were obtained. The proposed system is able to classify the given input signal into either of two classes (healthy or ital.) with good accuracy

REFERENCES:

1. S Gigola et al. Prediction of epileptic seizures using accumulated energy in a multire solution framework, *J. Neurosci. Methods.*138; 2004: 107–111,
2. R Harikumar et al. Fuzzy techniques for classification of epilepsy risk from EEG signal. IEEE Conference on convergent technology for Asia-Pacific region TENCON. 3; 2011:33-37.
3. J Gotman .Automatic recognition of epileptic seizure in the EEG. Electroencephalograph. Clin. Neurophysiol.54; 1982:530
4. Kaur. Intelligent system for the diagnosis of epilepsy. Word congress on computer science and information engineering, IEEE 2009:755-758.
5. NV Thakor et al. Advances in quantitative Electroencephalogram analysis methods. Annu. Rev. Biomed. Eng. 6; 2004 : 453-495.
6. Abdulhamit Subasi. EEG signal classification using wavelet feature extraction and mixture of expert model, Expert system with application. 32; 2007: 1084-1093.
7. J Bruhn et al. Approximate entropy as an electroencephalographic measure of anesthetic drug effect during desflurane anesthesia. *Anesthesiology*. 92; 2000: 715–726.
8. Georgios Lappas. Designing neural networks for tackling hard classification problem. WSEAS transaction on system. Issue 6. 8; 2009:743-752.
9. NH Guler et al. Recurrent neural networks employing Lyapunov exponents for EEG signal classification. Expert System with Applications.25; 2005: 506-514.
10. PJG Lisboa et al .Outstanding Issues for Clinical Decision Support with Neural Networks. *J. Artificial Neural Networks in Medicine and Biology,* Springer. 2000: 63- 71.
11. Gang Wang*, *Member, IEEE* et al. Epileptic Seizure Detection Based on Partial Directed Coherence Analysis. IEEE Journal of Biomedical and Health Informatics. 2015:1-7
12. S Pravin Kumar et al. Automated Detection of Epileptic Seizures Using Wavelet Entropy Feature with Recurrent Neural Network Classifier.
13. Selvin Pradeep Kumar. S et al. Early Detection of Epilepsy using EEG signals. 2014 International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT).2015:1-7.
14. Chastine Fatichah et al. Principal Component Analysis-based Neural Network with Fuzzy Membership Function for Epileptic Seizure Detection. 10th International Conference on Natural Computation. 2014: 186-191.
15. Waqas Rasheed. Automated Visualization for Epilepsy Surgical Evaluation. 6th Annual International IEEE EMBS Conference on Neural Engineering San Diego, California.2013:545-548.
16. Pravin A. Kharat1 et al. Daubechies Wavelet Neural Network Classifier for the Diagnosis of Epilepsy.WSEAS Transactions on Biology and Biomedicine.2012: 103-113.
17. D Puthankattil Subha.EEG Signal Analysis: A Survey. 34; 2010:195-212.
18. Chua K. C. Automatic Identification of Epilepsy by HOS and Power Spectrum parameters using EEG Signals: A comparative study. 2008 :3824-3827.
19. Vairavan Srinivasan, *Member, IEEE.* Approximate Entropy-Based Epileptic EEG Detection Using Artificial Neural Networks. IEEE transactions on information technology in biomedicine. 11(3); 2007.
20. George JT. An optimize neural network for predicting settlement during tunneling excavation. WSEAS Transaction on System. Issue 12. 9; 2010 : 1153-1167.