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# Neural Networks Design for Classification of Epilepsy EEG Signals

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**Abstracts**: ***Epilepsy is the brain disorder. It is characterized by a sudden and recurrent malfunction of the brain which is termed as seizure. The Electroencephalogram (EEG) signal is widely used clinically to investigate brain disorder. This paper investigates the application of Artificial Neural Network models for classification of epileptic EEG signals. In this work, the design approach focused to increase the number of hidden neurons and find the optimal value of hidden neurons for neural network model. The proposed work performed in two stages: Initially a feature extraction scheme using statistical measures has been applied and different ANN models with back propagation learning based algorithm classifiers have designed to performed the classification. The performance of the proposed method has been studied using a publically available benchmark database [11] in terms of training performance and classification accuracy. The proposed method provides good classification accuracy and generalization characteristic.***

**Keywords:** Epilepsy, BPNN, Electroencephalogram (EEG) ,Artificial Neural Network (ANN)

## 1. Introduction

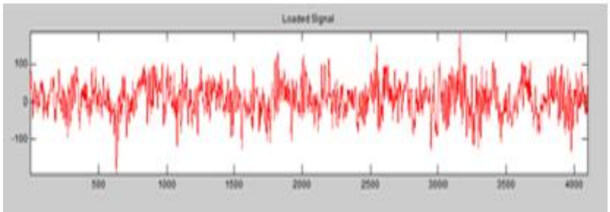
Automatic computer classification is an important tool in biomedical research, particularly in the analysis and classification of large dataset where manual classification is not possible. Artificial Neural Networks (ANNs) have emerged as a powerful tool for classification [1], [2]. The most important task of classification is designing a compact and well generalized Artificial Neural Network topology. The applications of Feed forward Back Propagation (FFBP) system are still the most applied in an extensive range of area including computer network security, handwriting recognition and analysis, medicine ,intrusion detection computer vision [3],[4],[5],[6]. Artificial neural network (ANN) based detection systems for epileptic diagnosis has been proposed by several researchers.

The method proposed by [6] uses a Artificial Neural Network with back propagation learning algorithm (BPNN) with period gram and autoregressive (AR) features as the input for the automated detection of epilepsy. In paper [7] proposed a new neural network model called LAMSTAR network, and two time domain attributes of EEG. The attributes are namely, relative spike amplitude and spike rhythm city. These have been used as inputs for the purpose of the detection of epilepsy. The method proposed in [8], uses the features , namely average EEG amplitude , average EEG duration ,coefficient of variation, dominant frequency, and average power spectrum as inputs to an adaptive structured neural network. The method proposed by Pradhan et al. [12] uses Learning Vector Quantization (LVQ) network with a raw EEG signal as an input. This paper discusses different models of feed forward back propagation neural network for epilepsy EEG signal classification problem using statistical features as the inputs to the networks. As per literature review this is the first study to propose the statistical features as inputs to the neural network classifier design.

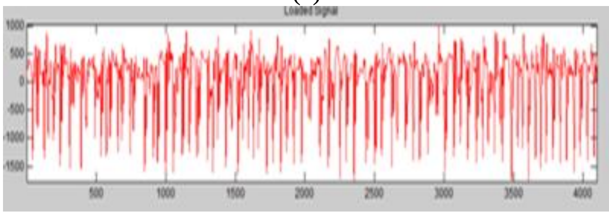
The organization of the succeeding sections of this paper is as follows. In section II, discussed the brief history of epilepsy and database description. In section III, discussed the standard artificial neural network model. Section IV described the proposed methodology. The simulation results and performance of proposed classifier model are discussed in section V._In section VI, the concluding remarks are given.

## 2. Epilepsy and EEG Database Description

Epilepsy is a chronic neurological disorder which is identified by successive unexpected seizures. Electroencephalogram (EEG) is the electrical signal of bran which contains valuable information about its normal or epileptic activity. During an EEG test, an electrode are attached to specific locations on the patients scalp and records the brain waves [9]. About 50 million people worldwide are suffering from epilepsy and 85% of those live in developing countries. Each year 2.4 million new cases are estimated to occur globally [10]. The datasets used in this research are selected from the Epilepsy center in Bonn, Germany by Ralph Andrezejak [11] . The data consists of five groups , free EEG signals both in normal subjects and epileptic patients._The first two groups are recorded from five healthy subjects with open set A and closed eyes set B. The third and fourth groups are recorded prior to a seizure from part of the brain with the_epilepsy syndrome set C and from the opposite (healthy) hemisphere of the brain set D. The fifth group E is recorded is from part of the brain with the epilepsy syndrome during the seizure activity. The two sets denoted set A and set E are used in this work. Each set contains 100 single channel EEG segments of 23.6 sec duration at a sampling rate of fs =173.61 HZ. Set A consisted of segments taken from surface EEG recordings that were obtained from five healthy volunteers using a standardized electrode placement. Set E only contained seizure activity. Figure 1 shows the snapshot of EEG signals for normal and epileptic groups.



(a)



(b)

**Figure 1:** Snapshot of EEG Signals ( a) Normal EEG (b) Epileptic EEG

## 3. Artificial Neural Network

Artificial Neural Networks (ANNs) are nonlinear mapping structures based on the function of the human brain. ANN are powerful tools for modeling, especially when the underlying data relationship is unknown. ANNs can identify and learn correlated patterns between input data sets and corresponding target values .After ANN training, ANNs can be used to predict the outcome of two independent input data.

An artificial neural network is a computational structure that is inspired by observed process in neural networks of biological neurons in the brain. It consists of simple computational units called neurons, which are highly interconnected. ANNs are now being increasingly recognized in the area of classification and prediction, where regression model and other related statistical techniques have traditionally been employed. The most widely used learning algorithm in an neural network is the back propagation algorithm. Figure 2 shows the standard back propagation neural network.

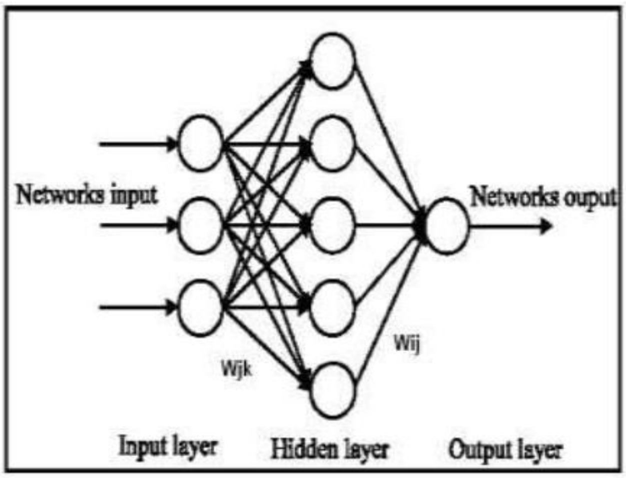



**Figure 2:** Artificial Neural Network model

## 4. Proposed Methodology

Figure 3 shows the proposed block diagram of neural network based automated epileptic classification system.

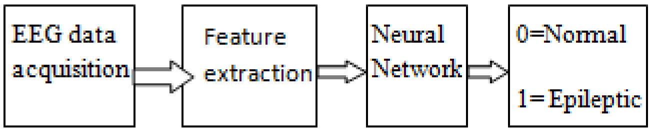



**Figure 3:** Proposed Classification System

In this paper, the benchmark database has used for design of Neural Network classifiers for classification of normal EEG and epileptic EEG. The set A and set E are used individually for feature extraction. The datasets are analyzed and the following features are extracted from each set to describe the basic features of data in a study. These features provide simple summaries about the sample and the measures.

a) Maximum value of variables
b) Minimum value of variables
c) Mean value is the measure of central tendency
d) Standard deviation measures of variability

The extracted features have been used as the inputs to design the neural network models. It is observed that these values are clearly distinguish for classification of normal EEG signals and epileptic EEG signals. The database is divided into two sets as training set and testing set. The proposed study suggested the feed forward neural network design as the classifiers with single hidden layer. The back propagation learning algorithm is proposed for different structures of ANNs. The range of hidden neurons varies from 1to 10 for optimal design of classifier. Table I shows the design parameters to design neural network model.

**Table 1:** Design Parameters of ANN

| *Sr.No* | *Parameters* | |
|---|---|---|
| 1 | No.of Hidden layers | 1 |
| 2 | No.of Hidden neurons | [0 10] |
| 3 | Train Function | Trainlm |
| 4 | Activation function for hidden layer | Tansig |
| 5 | Activation function for output layer | Purelin |
| 6 | Network Performance | MSE |

## 5. Simulation Results

The results of our experiments on epilepsy EEG classification problem with different structure of neural network classifier are summarized in Table II. The Mean Square Error (MSE) has the objective function to design the neural network classifiers.

**Table 2:** Results of NN Models

| NN Classifiers | Hidden Neurons | MSE | No.of Epochs | Simulation Time (secs) | Training Accuracy | Testing Accuracy |
|---|---|---|---|---|---|---|
| 4-2-1 | 2 | 4.8019e-16 | 36 | 1.84 | 99.3 | 100 |
| 4-4-1 | 4 | 3.7542e-15 | 24 | 1.342 | 99.3 | 98 |
| 4-6-1 | 6 | 1.9854e-06 | 10 | 1.139 | 99.3 | 100 |
| 4-8-1 | 8 | 0.00034787 | 18 | 1.264 | 100 | 100 |
| 4-10-1 | 10 | 1.1806e-09 | 22 | 1.357 | 100 | 96 |

The experimentation results shows that the optimal value for hidden neurons in hidden layer has found 8. The optimal classifier model consists of 4 inputs, 8 hidden neurons and 1 output neurons. The ANN structure (4-8-1) with back propagation learning (BPNN) produced the results based on trial error as shown in table II. Figure 4 shows the learning curve with training MSE 0.00034787. The proposed classification system has achieved 100% training accuracy, less simulation time and good generalization.

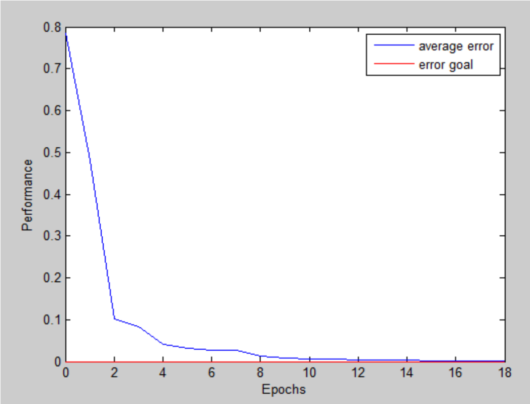



**Figure 4:** Learning curve of BPNN

Table III provides a comparative study of the obtained results for the various cases with those of several methods reported in the literature. For the different methods in table III, the values of the corresponding maximum accuracy are used for comparison. It is seen that the proposed method shows a better accuracy of the case I ( set A represent the normal EEG signals and set the B represent the epileptic EEG signals) ,the accuracy is 100% as compared to the other methods. Compared the paper [19] and proposed method results showed that the classification accuracy is equal to 100% but set of input features proposed have been taken more different with reduced number of features. In paper [19] the reduced interference distance method used for feature extraction and 16 features had been obtained.

**Table 3:** Gives comparison of classification performance obtained for various algorithms.

| Dataset | Reference paper | Features and classifier | Accuracy (%) |
|---|---|---|---|
| Case I (A,E) | Nigam et.al [12] | Nonlinear pre-processing filter –Diagnostic neural network | 97.2 |
| | Srinivasan et.al [13] | Time & frequency domain features- Recurrent neural network | 99.6 |
| | Kannathal et.al [14] | Entropy measures- Adaptive neuro-fuzzy interface system | 92.22 |
| | Archarya et.al. [15] | Chaotic measures- Surrogate data analysis | 90 |
| | Polat et al. [16] | Fast Fourier transform –Decision tree | 98.72 |
| | Subhasi et.al.[17] | Discrete wavelet transform- Mixture of expert model | 95 |
| | Tzallas et.al [18] | Time frequency analysis –Artificial neural network | 99 |
| | Tzallas et.al.[19] | Reduced Interference Dist., ANN | 100 |
| | Bedeeuzzaman et.al.[20] | Higher order statistics linear classifier | 95.75 |
| | Fathima et.al.[21] | Higher order statistics, Linear classifier | 96.9 |
| | **proposed** | Statistical features, Back propagation Neural Network | 100 |

## 6. Conclusion

In this paper a neural network classifiers design based on statistical features have been proposed. An extensive analysis has been carried out to investigate the optimal neural network model. A publically available comprehensive database has been used to study the performance of the proposed method for classification of EEG signals and compare with other techniques. It has been shown that the proposed method provides 100% success rate and good generalization to classify the EEG signal (normal and epileptic).

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