

Performance Evaluation of Different Neural Networks used for Seizure Detection

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Abstract—Brain is one of the most important and complicated organs of humans. It is also susceptible to degenerative disorder, such as epilepsy. A disease caused due to temporary alteration in brain function due to abnormal electrical activity of a group of brain cells and is termed as epileptic seizure. It is a common chronic neurological disorder characterized by seizures. In epilepsy, the normal pattern of neuronal activity becomes disturbed, causing strange sensations, emotions, and behavior or sometimes convulsions, muscle spasms, and loss of consciousness. The term 'Epilepsy' is derived from the Greek word *epilambanein* or *epilepsia* which means 'to seize or attack'. Anything that disturbs the normal pattern of brain cells (neuron) activity from illness to brain damage to abnormal brain development can lead to seizures. Epilepsy may develop because of an abnormality in brain wiring, an imbalance of nerve signaling chemicals called neurotransmitters, or some combination of these factors. Having a seizure does not necessarily mean that a person has epilepsy. Only when a person has two or more seizures is he or she considered to have epilepsy. The seizure occurs at random to impair the normal function of the brain. Seizures can be classified into two main categories depending on the extent of involvement of various brain regions focal (or partial) and generalized. Generalized seizures involve from a circumscribed region of the brain, often called epileptic foci. EEGs and brain scans are most common and cost effective diagnostic test for epilepsy. Worldwide, epilepsy affects 50 million people. In this paper different neural networks are studied and compared, for the detection of seizure.

Keywords— Support Vector machine (SVM), Elman network (EN), probabilistic Neural Network (PNN), Generalized Feed Forward (GFFNN), Back Propagation Neural Network (BPNN) and Multilayer perceptron (MLP).

I. INTRODUCTION

Epilepsy is common chronic neurological disorder in which clusters of nerve cells, or neurons, in brain sometimes signal abnormally. It is characterized by excessive and uncontrolled activity of either part or whole nervous system. The epileptic seizures are due to sudden development of synchronous neuronal firing in the cerebral cortex and are recorded using the electroencephalogram (EEG) by electrodes on or inside of brain. The Electroencephalogram (EEG) and brain scans are the most common diagnostic tests for epilepsy. At present, epileptic seizure detection and epilepsy diagnosis are performed mostly manual based on visual examination of EEGs by highly trained neurologists. Epilepsy diagnosis is more complicated due to excessive misogenic artifacts, interference,

overlapping symptomatology with other neurological disorders, and low understanding of the precise mechanism responsible for epilepsy and seizure propagation. The traditional methods are time-consuming and very tedious. There are many methods are proposed for the automatic diagnosis of epilepsy. This automated system is based on artificial neural Network. With the advent of technology, it is possible to store and process the EEG data digitally. The digital EEG data can be fed to an automated seizure detection system in order to detect the seizures present in the EEG data. Hence, the neurologist can treat more patients in a given time as the time taken to review the EEG data is reduced considerably due to automation. This paper discusses an automated epileptic EEG detection system using different neural networks, namely Elman network (EN) and probabilistic neural network (PNN), support Vector Machine, Linear classifier, Generalized Feed Forward Neural Network(GFFNN),Back Propagation Neural Network (BPNN), and Support Vector Machine (SVM).

A. Neural networks

There are many definitions of artificial neural networks (ANNs). Neural network is a powerful data modelling tool that is able to capture and represent complex input/output relationships. In other way ANNs are distributed, adaptive, generally nonlinear machines built from many different processing elements (PEs). Each PE gets connection from other PEs and/or itself. The interconnectivity defines topology.

Hence neural networks are a form of multiprocessor computer system, with

- 1 Simple processing unit
- 2 A high degree of interconnection
- 3 Simple scalar messages
- 4 Adaptive interactions between messages

The signals passing on connections are levelled by adjustable parameters called weights. The PEs sums all these contribution and develops an output that is a nonlinear function of sum. It is observed that a weight is associated with every connection. The structure of Neural Network is shown in figure1. The ANN develops discriminate function from its PEs. The ANN topology decides the number and shape of the discriminate function. The shape of the discriminate function varies with the topology. The motivation for the development of neural network technology stemmed from the desire to develop an artificial

system that could perform "intelligent" tasks similar to those performed by the human brain.

Neural networks resemble the human brain in the following two ways:

- . A neural network acquires knowledge through learning.
- . Network knowledge is stored within inter-neuron connection strengths known as synaptic weights.

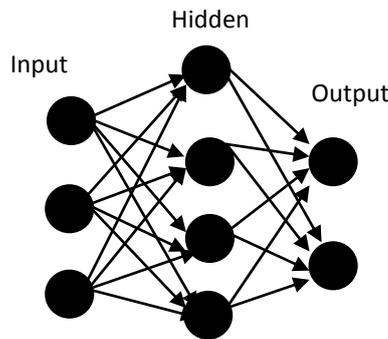


Fig.1 Neural Network

There are many applications of Artificial Neural Network

- [1]. Function Approximation- Ex. Process Modelling, Process Control, Data Modelling, Machine Diagnostics.
- [2]. Classification- Ex. Target reorganization, Characteristics reorganization, Fraud detection, Speech reorganization.
- [3]. Time series Prediction- Ex. Financial forecasting, Sales forecasting, dynamic system modelling.
- [4]. Data mining and processing- Ex. Clustering, Data Visualization, Data extraction.

ANNs are considered to be good classifiers due to their inherent features such as adaptive learning, robustness, self organization, and generalization capability. ANNs are particularly useful in situations where enough data are available for training and where the simpler classification algorithms fail. The results obtained for the epileptic EEG detection using several types of ANNs have been reported.

B. EEG

The Electroencephalogram is time varying electrical signal recorded from electrodes attached to the scalp of human subject. The signal arises from action potentials short lasting changes in potential difference within the neural cells of brain and as such is measure of brain activity. The analysis of EEG recording is the primary method of diagnosis of Epilepsy [8].

II. RELATED WORK

In recent years, a few attempts have been reported on seizure detection and prediction from EEG analysis by examination of the waveforms in the preictal EEG to find events or changes in neuronal activity such as spikes, which may precursors to seizure. Some work has been reported using artificial neural networks for seizure prediction with wavelet pre-processing. Automated diagnosis systems for epilepsy have been developed using different approaches like fuzzy logic, genetic algorithm [1], [2]. Automatic analysis of EEG recordings in the diagnosis of epilepsy was started in 1970, In 1982, Gotman proposed a 'computerised system for the detection of variety of seizure diagnosis' [3]. In 2006 Nicolaos B. Karayiannis, detected 'epileptic seizure by using a Feed forward neural network' [4], In 2007, Vairavan Srinivasan, proposed 'Approximate Entropy-Based Epileptic EEG Detection Using Probabilistic Neural Networks' [5], Wavelet Based Features for Epileptic Seizure Detection is suggested by Thasneem Fathima and M. Bedeuzzaman [6], In 2009, Sivasankari. N and Dr. K. Thanushkodi proposed 'Automated Epileptic Seizure Detection in EEG Signals Using FastICA and Back Propagation Neural Network' [7]. Recently in 2011, Dr. R. Shantha Selva Kumari, J. Prabin Jose proposed 'Time frequency analysis and SVM based seizure detection system' [9].

III. MATERIALS AND METHODS

Automated diagnosis systems for epilepsy have been developed using different approach. There are many methods of artificial neural networks are proposed for the detection of epileptic seizure. All these methods are implemented on the same concept of Neural Network that is, it consist of EEG data collection and pre-processing, feature extraction and classification by using classifier.

The database used for the study is publically available online and is described by Dr. Andrzejak of the Epilepsy Centre at the University Of Bonn, Germany. It includes both Normal and epileptic EEG dataset. The complete dataset is divided in to five types or say categories A, B, C, D and E, or Delta, Theta, alpha, Beta and Gamma. Where dataset is in the form of Delta, Theta, alpha, Beta and Gamma then it will be consider for wavelet transform because it having some fixed frequency range in Hertz. And if the data set is classified in terms of A, B, C, D and E here set A is the dataset of healthy volunteers, in relaxed and awakens state with open eyes; Set B consists of data of healthy volunteers relaxed and awakens state with closed eyes. Sets C, D, E were taken from EEG archive of pre-surgical diagnosis. Sets C and D contains only activity measured during seizure free interval, and E contains only seizure activity. Actually EEG data is analogy signals in pre-processing these analogy signals are converted in to

digital sampled data, and this sampled data is used for feature extraction.

In feature extraction is a form of dimensionality reduction transforming the input data into the set of features. When the input data to an algorithm is large to be processed and it is suspected to be notoriously redundant then the input data will be transformed into a reduced representation set of features. Hence transforming input data into the set of features is called feature extraction. If the features extracted are carefully chosen it is expected that the features set will extract the relevant information from the input data in order to perform the desired task using this reduced representation instead of the full size input.

When we used neural network as classifier, it will give output in terms of true or false or in the form of yes or no type. For the classification various classifiers like Elman network, linear classifier, generalized feed forward neural network, back propagation neural network, probabilistic neural network, multilayer perceptron etc are used. Generally these three steps are common for the detection of seizure by using artificial neural network, but the difference is in data used i) wavelet ii) sampled data, and classifier used for the classification. In this paper we will study and analysed the different neural network classifiers.

The following cascaded block diagram shows the generalized system for the diagnosis of epilepsy.

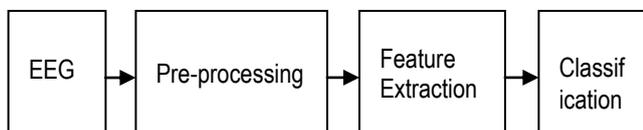


Fig. 2 Block diagram of EEG processing system

Automated diagnosis systems for epilepsy have been developed using different approaches like fuzzy logic, genetic algorithm. Here we will analyse various neural networks.

A. Elman network and probabilistic neural network

In 2007, Vairavan Srinivasan, proposed ‘Approximate Entropy-Based Epileptic EEG Detection Using Probabilistic Neural Networks’.

Elman network is a special type of recurrent neural network. It is a two-layered back propagation network with a feedback connection from the output of the hidden layer to its input. This feedback connection allows EN to recognize and generate temporal patterns, as well as spatial patterns. The ApEn values corresponding to the normal and epileptic EEG signals are used as the inputs for the neural network. For the two-layered EN, the activation functions used as tan-sigmoidal and log-sigmoidal for the hidden and output layers, respectively. The number of neurons used in

the hidden layer and the output layer are 90 and 1, respectively. Gradient descent algorithm with an adaptive learning rate is used for training the EN. The network is trained with a target value of 0 for normal EEG and 1 for epileptic EEG. The range of the output values used for the classification is 0–0.3 for the normal EEG and 0.7–1 for the epileptic EEG.

Probabilistic Neural Network is a type of radial basis network. It is a feed forward neural network with two middle layers called radial basis and competitive layers. The two layers employ radial basis and compete activation functions, respectively. The Probabilistic neural network trains immediately but execution time is slow and it requires a large amount of space in memory. It really works for classifying data. The training set must be a thorough representation of the data. Probabilistic neural networks handle data that has spikes and points outside the norm better than other neural nets. The ApEn values corresponding to the normal and epileptic EEG signals are used as the input for the neural network. The network’s target values correspond to a value of 1 for normal EEG and 2 for epileptic EEG.

The performances of EN and PNN are evaluated by using three parameters namely, sensitivity (SE), specificity (SP), and overall accuracy (OA). In this paper the experimental results of EN is in the range of 95% to 100% and it is accepted by clinical test, while PNN is having accuracy range from 98% to 100% for some special parameters not for all parameters. Hence EN having better performance in all cases than PNN, the feedback configuration and the incremental training process associated with the EN may be considered as possible reasons for its superior performance.

B. Linear classifier

Thasneem Fathima and M. Bedeuzzaman suggested “Wavelet Based Features for Epileptic Seizure Detection”. In this method the discrete wavelet is used for study purpose, the main advantage of the WT is that it has a varying window size, being broad at low frequencies and narrow at high frequencies, thus leading to an optimal time–frequency resolution in all frequency ranges. Furthermore, owing to the fact that windows are adapted to the transients of each scale, wavelets lack of the requirement of stationary.

The following statistical features were used to represent the time– frequency distribution of the EEG signals:

1. Maximum of the wavelet coefficients in each sub band.
2. Minimum of the wavelet coefficients in each sub band.
3. Mean of the wavelet coefficients in each sub band.
4. Standard deviation of the wavelet coefficients in each sub band.

The selected features are then applied to classifier. Here also the classification results are expressed in terms of specificity; sensitivity and accuracy. Classification was done by using linear classifier which gave an accuracy of 99.5%.

C. Generalized feed forward neural network

Nicolaos B. Karayiannis and Amit Mukherjee proposed “Detection of Pseudo sinusoidal Epileptic Seizure Segments in the Neonatal EEG by Cascading a Rule-Based Algorithm with a Neural Network”. In this paper

Feed-forward is a term describing an element or pathway within a control system which passes a controlling signal from a source in the control system's external environment, often a command signal from an external operator, to a load elsewhere in its external environment. GFFNN is perceptron Neural Network, because it is fully connected means that the output from each input and hidden neuron is distributed to all of the neurons. In this paper five sets of data is used for the study (A to E). Some Statistical features are extracted like Entropy, minima, maxima, mean and standard deviation etc, and then applied to feed forward Neural Network. The accuracy obtained by using GFFNN is 99.05%.

D. Back propagation neural network

“Automated Epileptic Seizure Detection in EEG Signals Using FastICA and Neural Network”, proposed by N. Sivasankari. And Dr. K. Thanushkodi. This paper is based on Back Propagation Neural Network this is a network of simple processing elements working together to produce a complex output.

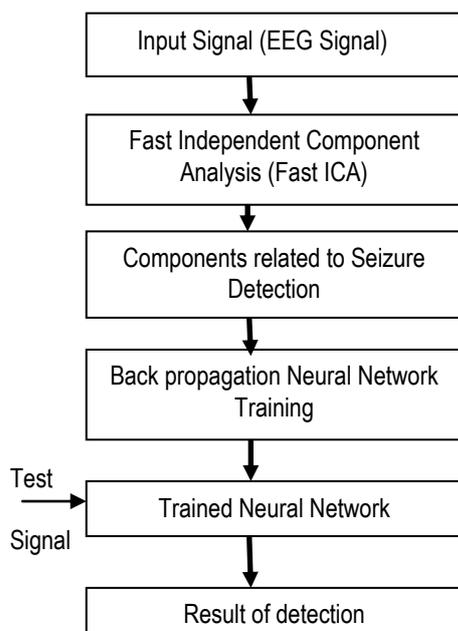


Fig. 4 Block diagram for epileptic seizure detection approach

BPNN is also perceptron Neural Network, The advantages of Back propagation algorithm are, it is simple and its speed is also reasonable. If this pattern is dissimilar from the preferred output, an error is intended and then propagated backward through the network from the output layer to the input layer. Back propagation is an iterative process that can often take a great deal of time to complete. The accuracy obtained by Back Propagation Neural Network is 76.5%.

E. Support vector machine

Dr. R. Shantha Selva Kumari, J. Prabin Jose proposed ‘Time frequency analysis and SVM based seizure detection system’ in this paper author proposed a process for the detection of epileptic seizure in EEG based on Time frequency analysis and SVM. Here EEG input decomposed into five EEG sub bands, the discrete wavelet transform- i).Delta ii).Theta iii).Alpha iv).Beta v).Gamma. These WT are having some fixed frequency range in Hz. Author describe the method as below. The statistical features such as variance, energy, maximum sample value in Power Spectral Density (PSD) as computed for each subband and form a feature vector. In Support Vector Machine classifier linear kernel function is used to classify/detect seizure EEG signal and normal EEG signal. The proposed method was implemented in MATLAB 7.8. The data used for this study is publically available. The accuracy of this classifier is better.

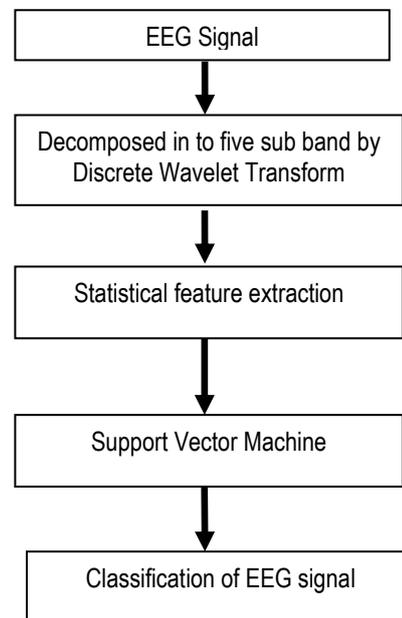


Fig. 5 Flow chart proposed by Dr.R.Shantha et. al.

IV. ANALYSIS

There are many Neural Networks are used for the Automatic diagnosis of seizure. Following table shows the comparison between accuracies of different Neural Networks.

TABLE I
ANALYSIS OF DIFFERENT NEURAL NETWORKS

Sr. No.	Authors	Neural Network	Accuracy
1	Vairavan Srinivasan et al.	ENN	95-100%
2	Vairavan Srinivasan et al.	PNN	98-100%
3	Thasneem Fathima et al.	LNN	96%
4	Nicolaos B. Karayiannis et al	GFFNN	99.05%
5	N. Sivasankari et al.	BPNN	76.5%
6	Dr. R. Shantha et al.	SVM	80%

V. CONCLUSIONS

It is conclude that, Automatic diagnosis of seizure is stable, cost effective and time saving system useful for doctors and also for human welfare. Different neural networks are used to implement automated diagnosis of seizure. In this paper, We have analyse and compare different NNs, It is conclude that the accuracy of ENN and PNN is varying between 95-100% and 98-100% respectively, GFFNN having more accuracy among all NNs that is, 99.05%.

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