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Epilepsy Seizure Diagnosis Using Artificial Neural Network

Mudit Khandelwal[1], Dr. Jagdish Kumar[2]

[1, 2]Electrical Engineering, PEC University of Technology, Chandigarh, India

Abstract: ***Epilepsy seizure is a disease related to the brain. EEG signals are required for diagnosis of this disease. Highly skilled professional doctors are required to observe the EEG signal and then also it is not possible to get high accuracy. Artificial Neural Network (ANN)is preferred for diagnosis of Epilepsy seizures. ANN provides higher accuracy to diagnose the Epilepsy seizure. With the use of ANN we can observe and analyze the EEG signal and also this approach is faster. Here in this paper Artificial Neural Network is used for training and testing of EEG data and Wavelet Transform for EEG signal processing. An accuracy of about 99% is achieved using feed forward time delaying neural network.***

Keywords: Epilespy Seizure, EEG Signals, Artificial Neural Network(ANN), Wavelet Transform

1. Introduction

Brain is the most important part of human body. It supervises and controls the working of muscles of human body. Brain has three parts: Cerebrum, Cerebellum and Brain Stem. Cerebrum is the largest part of brain and it comprises of four lobes: Frontal lobe, Parietal lobe, Occipital lobe, Temporal lobe. Each lobe in the brain has its different functions in our body. Frontal lobe is responsible for motor muscle movement, learning and reasoning. Parietal lobe is responsible for sensory muscle movement, Occipital lobe is responsible for vision and Temporal lobe is responsible for hearing. If seizure occurs in any of these lobes then that corresponding function will be affected [1].

Brain has nerve cells and these nerve cells have various ions of which potassium and sodium ions have major concentration. Ions in the nerve cells are transmitted through the axon of the neuron and there is difference in ions concentration between intracellular space and extracellular space. This difference creates a resting potential of -70mv. When stimulation is given using Sodium Potassium pump then Sodium channel opens after the stimulated voltage becomes +15mv and then sodium ions enters in the intracellular space from the extra cellular space and makes the intracellular space more positive and this process is called Depolarization. When resting potential becomes +40mv then Potassium ion channel open and potassium ions goes in extracellular space makes the intracellular space negative again and this process is called Re- polarization. To prevent the neuron from false stimuli, resting potential is more polarized then the resting potential and this is called Hyperpolarization. Now because of leaky ions it again comes in its first state of resting potential. This is how action potential is generated in the neuron. This action potential is measured using electrodes on scalp and these brain wave patterns are called Electroencephalograph, Commonly abbreviated as EEG[2]. The action potential graph of the brain is shown in Fig.1.

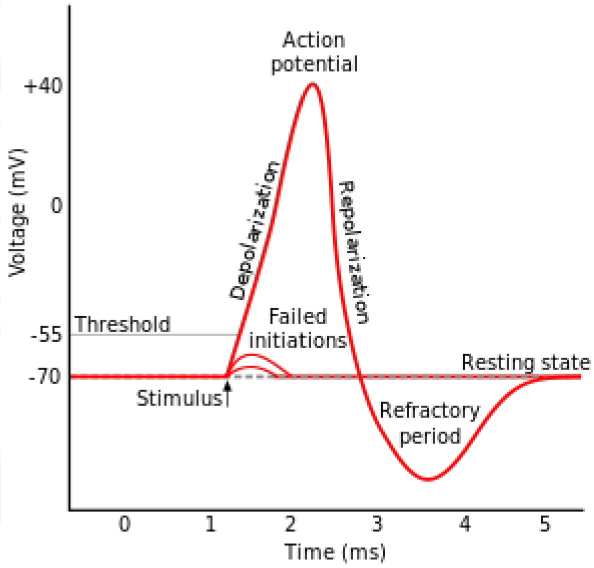


Figure 1: Action Potential Graph [2]

EEG recording is needed for epilepsy seizure diagnosis. Artificial Neural Network is used for diagnosis of Seizures from EEG pattern.

EEG recordings are taken by placing the electrodes on scalp. Placing of electrodes on scalp is performed using some rules. This technique is called “10-20 electrode system”. The 10 or 20 refers to the 10% or 20% inter electrode distance [3].

These electrodes are used to take the EEG recordings. EEG recordings are seen on the machine called Electroencephalogram [3].

There are five types of frequencies in EEG signals as: Delta, Theta, Alpha, Beta, Gamma. These frequencies are shown in Table 1. All of these frequencies are related to different states of brain.

Table 1: EEG Frequency [4]

Frequency Band Name	*Frequency Bandwidth(in Hz)*	*State Associated With Bandwidth*
Delta	0-4	Deep Sleep
Theta	4-8	Drowsy
Alpha	8-13	Relaxed
Beta	13-30	Engaged
Gamma	>30	Short term Memory Activities

Here in this paper, Wavelet Transform is used for feature extraction of EEG signal and Artificial Neural Network for diagnosis of Seizures.

2. Theory of Techniques

A. Wavelet Transform

There are various decomposition methods according to the type of signals. If the signals changes with time then it is called non stationary signals and if the signal does not change with time then it is called stationary signals. Fourier transform is used for decomposition of stationary signals. EEG signal is non stationary signal as EEG signal is variable in both time domain and frequency domain. So we use wavelet transform for feature extraction of EEG signal. The decomposition of signal result in set of coefficients called as wavelet coefficient.[5]

Coding algorithm of wavelet decomposition of signals is shown in Fig.2. The decomposition of EEG signal using Wavelet Transform needs low pass filter and high pass filter. Each process requires these two filters and also two down samplers. The output of high pass filter and low pass filter gives detail and approximation images respectively. The first approximation is further decomposed until required level will not be reached [6].

Fourier transform have two basis functions names as sine and cosine functions whereas wavelet transform have infinite number of basis functions [7]. Wavelet series equations are defined in equation 1-4.

$$\varphi_{u,s}(t) = \frac{1}{\sqrt{s}}\varphi\left(\frac{t-u}{s}\right) \qquad (1)$$

Where $\varphi_{u,s}(t)$ is called a wavelet and u is the shift of φ alongthe signal and s is scale. $\frac{1}{\sqrt{s}}$here used for energy normalization.

$$\sum_s a_{r_o,s}\phi_{r_o,s}(x) + \sum_{r=r_o}^{\infty}\sum_s b_{r,s}\varphi_{r,s}(x) \qquad (2)$$

Where$r \geq r_o$, $\phi_{r_o,s}(x)$is scaling function, $\varphi_{r,s}(x)$is wavelet function and$a_{r_o,s}$ and $b_{r,s}$is calculated as:

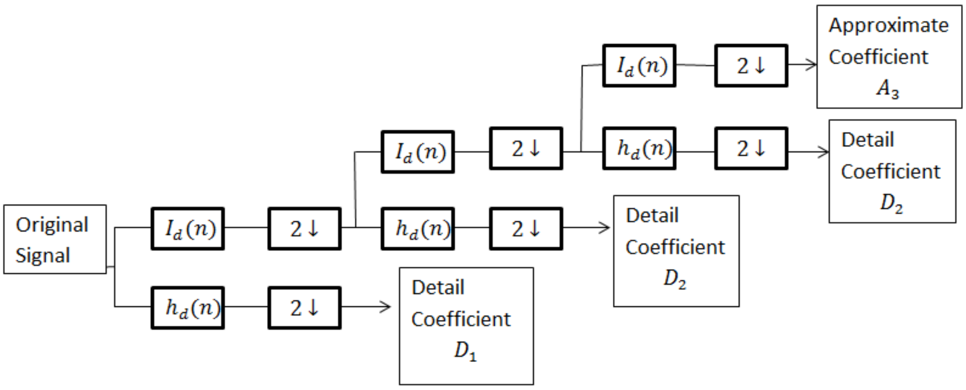


Figure 2: Wavelet Decomposition method [8]

$$a_{r_o,s} = \int f(x)\phi_{r_o,s}(x)dx \qquad (3)$$

And

$$b_{r,s} = \int f(x)\,\varphi_{r,s}(x)dx \qquad (4)$$

This is the wavelet series [8]. Various wavelet functions collectively called as wavelet family. Haar wavelet is oldest and simplest wavelet [9]. Daubechies wavelet is the most popular wavelet [10].

B. Artificial Neural Network

Neurons are the smallest unit of brain and the network in brain is called Biological Neural Network. This network can be approximated using Artificial Neural Network abbreviated as ANN. ANN consists of neurons in its structure and have multiple layers of neurons. ANN has basically three types of layers as input layer, output layer and hidden layer. Input and output layers are one in number whereas hidden layers can be multiple. Learning methods are used for the training of neurons in ANN [11].

Input at the input layer is denoted as x_j and output at the output layer is denoted as y_i.

Output of Neural network is calculated as shown in equation 5.

$$y_i = f_i(\sum_{j=1}^{n} W_{ij}\,x_j - \theta_i) \qquad (5)$$

Where y_i is the output of node i, $x_j$is the input at node j, W_{ij} is the weight between node i and j and θ_i is the threshold of the node. $f_i$is the activation function such as Sigmoid, Gaussian, Heaviside, Step, Identity function etc [12].

Learning or training in artificial neural network is achieved by adjusting the connection weightW_{ij}. Learning of artificial neural network can be supervised learning, unsupervised learning and reinforcement learning. In supervised learning the learning is basically provided using a target output. The difference between actual output and desired or target output is minimized in supervised learning [10].Feed forward Back propagation Network uses supervised learning of neurons. Input data is manipulated using some weights and biases to produce an output. In back propagation Network, Output is computed from each layer and then output is propagated to the next layer [13]. Back propagation network structure is shown in Fig. 3.

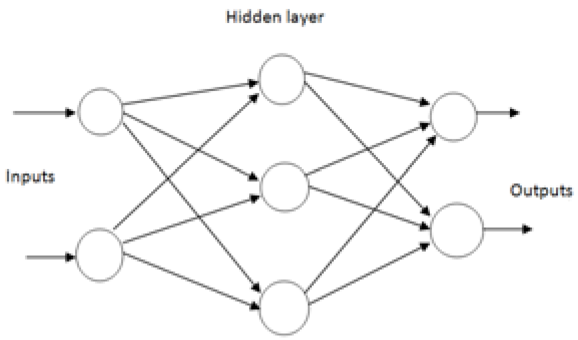


Figure 3: Back Propagation Network [13]

Weights and biases are so adjusted to get the output close to the expected output. Difference in output is computed and then it is back propagated and process is continued till required output is obtained [13, 14].

3. System Description

a) Dataset

EEG dataset are received from University of Bonn, Germany. This dataset consists of five sets F, N, O, S and Z. Each dataset consists of 50 single channel signals and each segment is of 23.6 sec duration and having 4096 samples. Set F and N are for Healthy subjects. Set O and S for Epileptic Patients with Seizure free interval. Set Z is for Epileptic patient with seizure interval. Filters can be used for signal processing of EEG signals to remove the undesirable frequency components.

b) Types of Seizures

There are two types of seizures: Focal Seizure and Generalized Seizure. Focal Seizure occurs in one hemisphere of the brain whereas Generalized Seizure occurs in one hemisphere of the brain but it extends to both hemisphere of the brain. Focal seizure are of two types: Simple seizure and Complex seizure. Generalized seizure are of four types: Absence seizure, Tonic Clonic seizure, Myoclonic seizure and Atonic seizure.

c) Feature Extraction

When we convert input data into useful set of features then it is called as feature extraction. If feature extraction is done carefully and if it is preferred then there is no need of using entire input data set for training of neural network. We can use set of features to extract the information which is intended. Various features can be extracted as Variance, Signal to Noise Ratio, Mean Square Error, Mean Deviation etc.

4. Flow Chart of Proposed System

Flowchart of proposed system of epilepsy seizure diagnosis is shown in the Fig. 4.

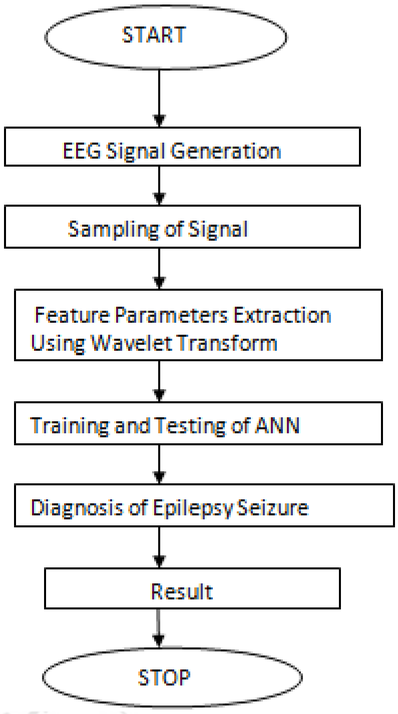


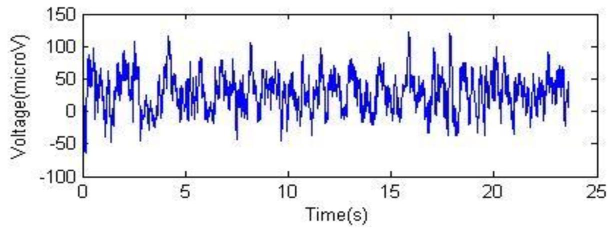
Figure 4: Flow Chart of Proposed System

EEG datasets are collected and then these datasets are converted into EEG signals using MATLAB R2013a. Sampling of signals are done to get different frequency categories separately. Now Feature Extraction is done using Wavelet transform. Signal to noise ration and Means square error is computed using MATLAB. These features are then used to train the neural network and then testing of neural network is done to diagnose the seizure.

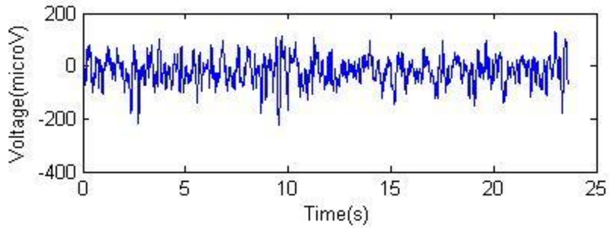
5. Results

a) EEG dataset

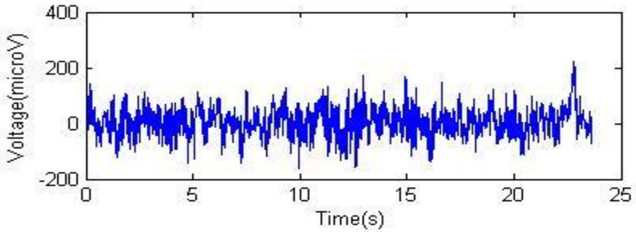
Here Set F is the result for seizure free interval of seizure patient. Set N is for the hippocampal formation in the temporal lobe of the brain. Set O is taken from the healthy person with his eyes closed. Set S is taken from seizure patient in seizure interval. Set Z is taken from healthy person with his eyes kept open. These sets are shown in Fig. 5.



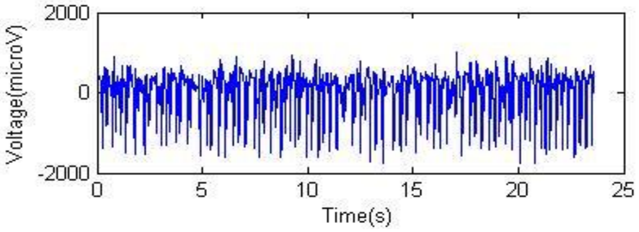
(Set F)



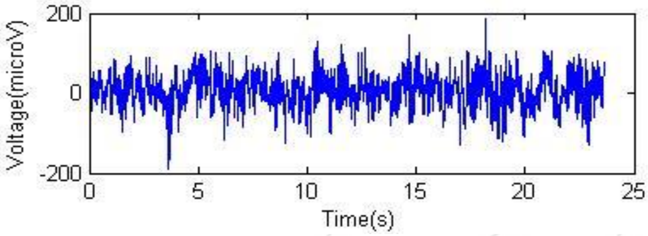
(Set N)



(Set O)



(Set S)



(Set Z)

Figure 5: EEG Datasets in Time domain (F, N, O, S, Z) [15]

b) EEG Frequency

EEG Frequencies are shown in table 2.

Table 2: EEG Frequency

EEG Frequency	Expected Value (in Hz)	Average Value Measured (in Hz)
Delta	0-4	2.18
Theta	4-8	5.50
Alpha	8-13	10.80
Beta	13-30	21.64
Gamma	>30	>30.52

These are the frequencies that we have received from the EEG datasets and these frequencies are lying in the region of their expected value.

c) Diagnosis of Seizure

We have taken 500 datasets and out of which 300 are used for training the artificial neural network and 200 are used for testing of neural network.

Table 3: Seizure Diagnosis

Output	No of Datasets	Healthy person	Seizured patient
Actual	200	100	100
Calculated	200	100	98

So we got an overall accuracy of 99% when we use artificial neural network for diagnosis of seizure.

Results have been calculated using feed forward time delaying network and using two hidden layers with ten neurons in each layer.

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