

Epilepsy Disease Detection Using Artificial Neural Network and MSE Optimization with GA

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ABSTRACT: Epilepsy is one of the most common neurological disorders that demand analysis of complicated Electroencephalogram waveforms for diagnosis. It is not possible to interpret information from these highly varying waveforms so experts often find it difficult to make a decision about whether the disease is present or not. Hence, it becomes quite essential to develop an automatic detection system that can work over complexities involved in EEG waveforms to predict a most appropriate solution. In this study, Artificial Neural Network is used to make analysis of EEG signals obtained from the Epileptic and healthy brain; further, Mean Square Error of the network is reduced with the help of Genetic Algorithm.

KEYWORDS: Electroencephalogram (EEG), Artificial Neural Network (ANN), Epilepsy, Genetic Algorithm (GA), Mean Square Error (MSE).

I. INTRODUCTION

Epilepsies are a specialized form of brain disorder spectrums that may range between acute to disabling and even to life threatening issues. Currently, around 65 million people throughout the world are suffering from this disease and in India, this count goes up to 12 million patients. A person who is affected with epilepsy face some disturbance in the normal brain activity and it may often lead to loss of consciousness, emotional swings, strange sensations, muscle spasms and behavioral changes [1]. The type of symptoms associated with disease and seizures usually vary from person to person. From long past, medical professionals are using detailed history of patient activities to identify and diagnose this disease but it could not lead to appropriate results as there are no definite symptoms caused by this disease. Another popular method is to analyze EEG waveforms but they are too complicated to be examined without any specialized tool. There are so many cases in history where the complex structure of EEG waveforms leads to a faulty diagnosis. As medical professionals deal with highly sensitive information so it is essential to use some reliable tools for complete analysis of signals obtained from human brain. All these conditions give rise to need of a Computer Aided Diagnosis (CAD) System for Epilepsy Disease Detection.

The modern Machine Learning approaches are capable enough to ensure accurate and highly reliable response for analysis of complex datasets. In this study, authors have worked on Artificial Neural Network due to its ability to follow self-adaption rule for input data and the highly organized structure that ensures quality performance for EEG signal analysis. One of the most commonly implemented architecture in the world of ANNs is feedforward Network. It is widely used for several applications like recognition, prediction, approximation and classification problems hence, in this study, FeedForward architecture is utilized to design CAD system for Epilepsy Detection. The proposed network consists of one input layer, one hidden layer, and one output layer. In order to improve detection accuracy of the network, authors have used efficient and most relevant 13 features that are extracted from EEG signals obtained from the healthy and epileptic patient.

As medical applications demand higher accuracy for disease detection systems so authors have used Genetic Algorithm to optimize the Mean Square Error function obtained from FeedForward Neural network. Studies reveal that GA ensures better performance over conventional Artificial Intelligence based systems. The process in GA deals with the survival of fittest terminology and with the help of few essential parameters the algorithm can provide a highly optimized solution. This algorithm has the ability to converge over best possible solutions for the problem domain [2]. Authors of this paper have tested the performance of GA over FeedForward Network by making a comparison for

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optimization of Mean Square Error from both networks. The results obtained after several repeated measures reveal that GA has the power to improve accuracy for detection process as it leads to efficient reduction in MSE.

II. RELATED WORK

Several researchers till now have worked upon this application and they have developed various detection systems by incorporating different technologies [3]. Sadaat, N and Hossein, P (2011) developed an advanced approach for detection of epilepsy disease by using Dynamic Cascade Feed-Forward Neural Network classifier [4]. Vivek, N.P and Danial, G. (2013) defined epilepsy detection system with a combination of Artificial Neural Network and Multistage Non-Linear Pre-Processing Filter using LAMSTART [5]. Akshata, P et al. (2016) developed a Multi-Resolution Analysis based system in combination with Artificial Neural Network Classifier and Discrete Wavelet Transform [6]. Satchidananda, D et al. (2013) proposed an advanced seizure identification system by utilizing ensembles of RBFN (Radial Basis Function Network); authors in this study used Discrete Wavelet Transform to classify EEG waveforms [7]. Sema, A et al. (2012) developed an epilepsy detection system with the help of Artificial Neural Network and Particle Swarm Optimization [8]. Zainab, H et al. (2011) proposed a novel system for recognizing features of EEG signals obtained from the brain of an Epileptic and Healthy patient; authors in this study developed a high-performance system with a combination of wavelet transforms and Genetic Algorithm [9]. Bruno M et al. (1997) presented a method for automatic detection of slow wave complexities and 3Hz spike using Genetic Programming [10]. Hiram Firpi et al. (2007) designed a system for automatic detection of epileptic waveforms using Genetically Programmed Artificial Features [11]. Sabri Kocer et al. (2011) developed an epilepsy classification system by using a combination of Genetic Algorithm and Artificial Neural Network [12].

III. PROPOSED METHODOLOGY AND DISCUSSION

In this study, authors have worked upon data provided by University of Bonn, Germany. The dataset is divided into five different parts that represent a combination of signals obtained from the brain of a healthy subject, an epileptic patient with ictal and interictal state of seizures. It is arranged in form of S, F, N, O and Z database where each one of these contains 100 complex EEG segments having a total duration of 23.6 seconds. Out of these five sets, authors have utilized the only Z, F and Z set for development of Automatic Epilepsy Detection System.

Note that, these datasets have frequency range varying between 0.5Hz to 85Hz but as per the experts working in the field of Neurology, the valuable content resides only below 60Hz range. Hence, authors have applied de-noising FIR filter with a lower cut of frequency 60Hz to obtain the desired range of EEG signals. After this, essential features of this input raw data was extracted using wavelet transform. This study was carried on the basis of 13 most relevant features; the list includes Variance, Energy, Entropy, Mode, Median, Mean, Zero Crossing Rate, Min Amplitude, Max Amplitude, Signal to Noise Ratio, Mean Power, Coefficient of Variation and Standard Deviation [13]. All these features are normalized within -1 to +1 range because it is difficult for a FeedForward Network to process such a complex and highly variable EEG data as it is.

After extraction of these features, they are processed at the input stage of Artificial Neural Network. As there are 13 features of EEG data that are required to be processed for disease detection so authors have created a neural network with 13 input neurons. Also, at the out of network, it is desired to classify applied input into 3 different sets (F, S, and Z) that represent a healthy and epileptic patient with the ictal and inter-ictal state so 3 neurons are defined at the output layer. The optimization is carried out by adjusting a number of neurons at hidden layer. Authors have tested this network for several combinations of hidden layer neurons but the best performance was obtained for 7, 31 and 40 neurons in the hidden layer. Considering the cost effectiveness parameter, authors have selected 7 neurons at hidden layer as best setting for proposed system for Epilepsy Disease Detection. Later, GA is applied to optimize MSE of FeedForward Network.

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IV. EXPERIMENTAL RESULTS

Proposed Epilepsy Detection system was implemented with the help of MATLAB 2015 software. The performance of the network with 13 input neurons, 7 hidden layer neurons, and 3 output layer neurons is demonstrated by a confusion matrix in Fig. 1.2 whereas Fig. 1.1 indicates the structure of the proposed ANN based epilepsy detection system. The performance of network was tested on the basis of 4 major parameters that are sensitivity, specificity, accuracy, and precision.

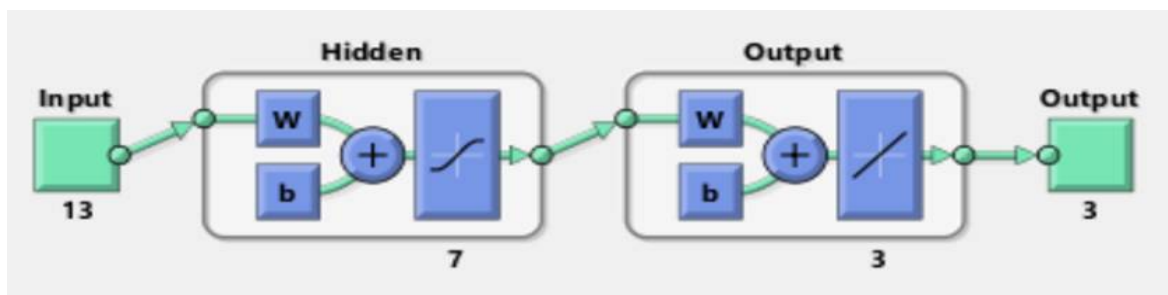


Fig. 1.1 Model of Artificial Neural Network for Epilepsy Disease Detection

Formula to calculate all these values from confusion matrix are give as below:

Accuracy = Sum of correct Classifications / Total Number of Classifications;

Precision = $TP / (TP + FP)$

Sensitivity = $TP / (TP + FN)$

Specificity = $TN / (TN + FP)$

Where;

TP = True Positive Predictions, FP = False Positive Predictions, FN = False Negative Predictions and TN = True Negative Predictions.

V. NEURAL NETWORK FOR EPILEPSY DISEASE DETECTION

This confusion matrix represents following results from proposed epilepsy detection system using Artificial Neural Network:

Overall Precision = 99%

Overall Sensitivity = 99%

Overall Specificity = 99.5% and

Overall Accuracy of Proposed Work = 99%

After obtaining these results, the performance of network was tested for Mean Square Error range and it is done by training network for different hidden layer neuron settings. Several tests were carried out and then each one of them was compared with MSE reduction performance of Genetic Algorithm. This comparative performance is shown in Table 1.

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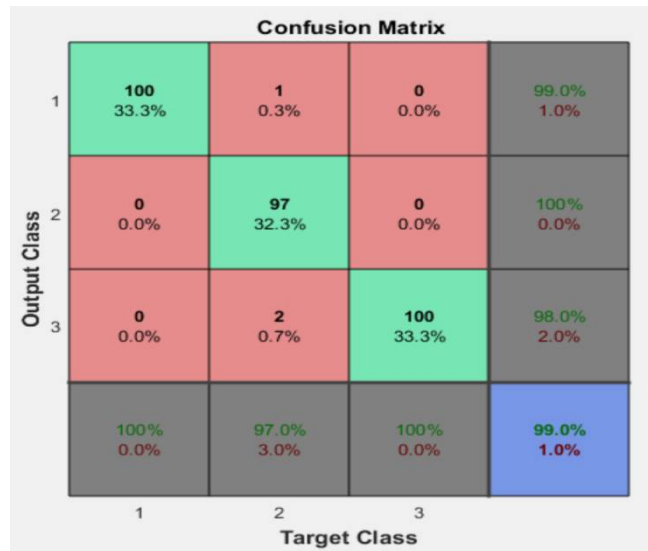


Fig. 1.2 Confusion Matrix Indicating Performance of Proposed Artificial

Table 1: Comparative Performance of ANN and GA for MSE optimization

Number of Neurons in the Hidden Layer	MSE Obtained from ANN	MSE Optimized by GA
3	8.313008567921784e-04	5.978946294360096e-04
7	6.050610856885620e-04	5.788889326771471e-04
9	3.020825474079820e-04	2.542542714501990e-04
20	0.001926583167804	0.001912440148122
31	7.536412089863313e-04	7.449932769683700e-04
40	0.003894753093081	0.003884914054647
51	0.002501209692900	0.001640769716925

The tests in Table 1 reflect the ability of GA to optimize MSE to a much better extent. For all adjustments of hidden layer neurons, this network provides noticeable reduction for Mean Square Error value.

V. CONCLUSIONS

The performance of Artificial Neural Network based CAD System for Epilepsy Detection was tested using Genetic Algorithm and major conclusions are as below:

- Genetic Algorithm shows great improvement over MSE optimization hence it can also improve the overall accuracy of the system.
- It is possible to design a Hybrid System using a combination of Genetic Algorithm and Artificial Neural Network that can be useful for practical applications due to its ability to deliver higher accuracy.

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