Epilepsy Detection Using Artificial Neural Network and Grasshopper Optimization Algorithm (GOA)

Buhari U. Umar[1], Mohammed B. Muazu[2], Jonathan G. Kolo[3], James Agajo[3], Ifetola D. Matthew[4]
[1,3,4,] Department of Computer Engineering, Federal University of Technology, Minna
[2]Department of Computer Engineering, Ahmadu Bello University, Zaria

Abstract — **Epilepsy affects about 1 % of the contemporary population and sternly reduces the wellbeing of its patients. It is a neurological disorder of the central nervous system that is usually characterized by sudden seizure. The possibility of detecting and predicting epileptic seizure has engrossed mankind already for over 35 years. One of the main tools in detecting and predicting the Epilepsy seizures are the Electroencephalograms (EEG), which record the brain activity by measuring the extracellular field potentials due to neuronal discharges. This EEG is quite difficult and complex to interpret even by an expert neurologist, even so, it is time-consuming, often challenging, sets in human error as well as delay in treatment. In this research, a hybrid classification model using Grasshopper Optimization Algorithm (GOA) and Artificial Neural Network (ANN) for automatic seizure detection in EEG is proposed called GOA-ANN approach. Nine parameters (mean value, variance value, Standard deviation value, energy value, entropy value and maximum value, RMS value, kurtosis and skewness) were extracted and used as the features to train the ANN classifiers. GOA was used for selecting the best features in order to obtain an effective EEG classification. In comparison with other research, the result was able to detect epilepsy and enhance the diagnosis of epilepsy with an accuracy of 98.4%. The research was also compared with Artificial Neural Network using Feed-Forward network, the result shows that GOA_ANN approach performed better.**

Keywords: Epilepsy Seizure Detection, EEG, ANN-GOA.

I. Introduction

Epilepsy affects about 1 % of the contemporary population and sternly reduces the wellbeing of its patients. It is a neurological disorder of the central nervous system. Due to its unpredictable and sudden nature, everyday activities such as driving, cooking, swimming, hiking etc. suddenly become a challenge. It has the ability to alter consciousness, behaviour, sensation, body movement and perception [1]. Hence, epilepsy patients could take precaution and extra care if seizure could be predicted a reasonable period of time before its manifestation, thereby improving patient safety and worth of life. The possibility of detecting and predicting epileptic seizure has engrossed mankind already for over 35 years. One of the main tools in detecting and predicting epilepsy seizures are the Electroencephalograms (EEG), which record the brain activity by measuring the extracellular field potentials due to neuronal discharges. Epilepsy and seizure are not the same; while epilepsy is the disease, the seizure is the neurological disorder in the brain. This seizure is often unpredictable, sudden, brief and recurrent and it depends on the part of the brain that is involved [1]. The human brain is said to have comprised of billions of neurons, which are in the form of electrical signals working in parallel to solve complications (reasoning) [1]. The occurrence of seizure is irregular, sudden and unpredictable and it spreads over all ages.

Years back, only the expert neuroscientific researchers and clinicians were able to set up records of EEG signals and then examine them under an organized laboratory condition. Electroencephalogram (EEG) is a test or tool for measuring and recording the neurological or electrical activities of the brain. This is done using a special sensor called electrodes that are placed on the scalp of a patient according to the 10-20 International system of EEG electrode positions. The EEG signals are non-linear in nature. These non-linear methods are often used to study EEG signals to provide automatic monitoring of epileptic activities in the brain. The visual inspection of electroencephalogram (EEG) signals for detection of epileptic activities is often strenuous and also time-taking due to large volumes of EEG segments that need to be studied [1, 2].

Detecting epileptic seizure through visual analysis of the EEG signals by the neurologists often takes a long time and leads to human error. Therefore, the application of the grasshopper algorithm for feature selection and ANN for epilepsy detection can significantly help in effective and efficient epilepsy detection. This will reduce false detection or missed detection. Also, less computational feature selection methods. Therefore, the need to develop a system capable of detecting epileptic seizures is much necessary. GOA was used for selecting the best features in order to obtain the EEG classification. In comparison with other research, the result was able to detect epilepsy and enhance the diagnosis of epilepsy with an accuracy of 98.4%. The research was also compared with Artificial Neural Network using Feed-Forward network, the result shows that GOA-ANN approach performed better.

The remaining sections of the article are divided into three. Section two provides a review of related baseline works, Section three shows the methods and materials selected for the developed epilepsy detection using ANN-GOA and Section

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four and five provides results and discussion as well as conclusions. References in section 7.

II. Review of Related Works

In contemporary times, various automated seizure detection systems had been established to help neurologists to accurately diagnosis epilepsy exploiting different methods and techniques. This section contains the related works done by different researchers, the methods employed, their strengths and the weaknesses.

[3], developed a novel robust diagnostic model to detect seizures using a general regression neural network (GRNN). In this study, two different EEG datasets were used. The first dataset used was publicly available in the EEG database from the University of Bonn (UoB), Germany [4]. EEG data from two different repositories were considered for analysis and validation of the proposed system. Dual-tree complex wavelet transforms (DTCWT) was used to decompose EEG signals for the extraction of feature sets. In the research, five feature sets were extracted. These include energy, standard deviation, root-mean-square, Shannon entropy, mean values and maximum peaks. The features were loaded on to general regression neural network (GRNN) for classification under the K-fold cross-validation scheme with varying train-to-test ratios to validate the classifier's performance. The overall result showed that classification accuracy, sensitivity and specificity of 99.147%, 98.318% and 99.552% were obtained respectively with the computation time of less than 0.023 s. Only one classifier was considered in this work. [5], described the classification of EEG signals for the detection of epileptic seizure using high pass filter and comparing the results with low pass filter through MATLAB software. This system comprised of four stages. Loading of EEG data, secondly, a total number of channels presented in certain EEG dataset were plotted. In the next stage, the required channel was cut off from datasets using low pass and high pass filter. The proposed methodology was applied to EEG data sets taking from three epileptic subjects during a seizure. The results confirmed that the proposed algorithm produced an accurate classification of EEG signals and detection of epileptic seizures with the sensitivity, specificity and accuracy of 98.3%, 96.2% and 98.51% respectively. This study was applicable to the patients within the age range of 1.5 to 22 years only.

[6] developed an epilepsy seizure detection using EEG curvelet feature selection and SVM classification. The features of the seizure were collected from the EEG signal through DWT co-efficient analysis. The seizure features were analyzed in all classes like full sleep, semi-sleep and unconscious stages. The features were passed to the SVM classifier for classification. An SVM classifier gave effective result by minimizing the misclassification error with the overall classification accuracy of 93.426%. Similarly, [7] implemented a system for predicting seizure by introducing the statistical behaviour of local extrema using a fuzzy logic system. In this research, two approaches were introduced for evaluating the system. A patient-dependent approach that requires EEG data from the preictal and interictal state. Secondly, leave one out (LOO) technique was used to evaluate the generalizability of the method. Sensitivities of 94.15% and 79.38% were obtained for patient-dependent approach and LOO respectively. However, the system was only restricted to drug-resistant person.

From the reviewed related kinds of literature and progresses made in Epilepsy detection and prediction, it is observed that the research are still ongoing for a better approach for Epilepsy detection and prediction using Artificial neural network and various forms of features extraction. This research developed a hybrid classification model using Grasshopper Optimization Algorithm (GOA) and Artificial Neural Network (ANN) for automatic seizure detection in EEG signal.

III. METHODS AND MATERIALS

The research design that was adopted in carrying out this work, materials required, methods and approaches that were adopted, data set and proposed collection procedure and metrics for evaluation using epilepsy detection and prediction, using grasshopper algorithm and ANN approach are presented in this section. Figure 1 present the data acquisition, pre-processing, features extraction and selection, evaluation and classification.

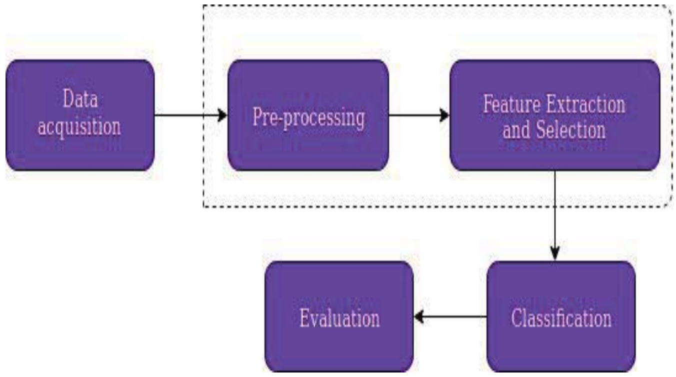

Figure 1: General System Block Diagram

A. Data Acquisition

This collection comprises EEG data coming from three different persons: healthy person, an epileptic person during seizure-free intervals (known as inter-ictal states) and epileptic person during a seizure (ictal states). The datasets constitute five sets; O, Z, F, N and S sets. Each set contains 100 single channels at 23.6-Sec duration. These sets were recorded after thorough inspection for artefacts like muscle activities or eye movement. Sets O and Z were taken with surface electrodes using a standardized electrode placement. Data set O consist of EEG data obtained from healthy individuals with their eyes open. Data set Z consist of EEG data obtained from healthy individuals with their eyes closed. Sets F, N and S were recorded from the EEG archive of pre-surgical diagnosis. Sets F and N constitute EEG data that were collected from ill patients while no seizures were present (during seizure-free intervals) at different zone of the brain while the data set S contains EEG data collected from ill patients during seizures (ictal state). In this research work, sets Z (with eyes closed) and S (seizure activity) were considered only for the results reported here. The two types of signals are shown in Figure 2 and Figure 3 respectively.

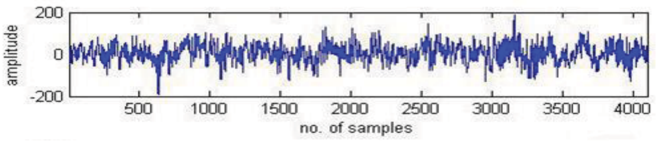

Figure 2: Normal Signal

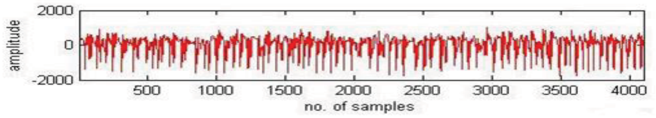

Figure 3 Ictal Signal (Seizure)

B. Pre-processing

This involves analyzing the collected data to best fit the networks. This was done by modifying and transposing the data. Pre-processing made it easy to use the data (load) in the network for efficient classification of the subjects. The EEG data in this study consists of five sets each having 100 single channels at 23.6-Sec duration. Every single channel contains 4,096 samples of one EEG time series. The time series has the spectral bandwidth of the acquisition system was 0.5 Hz to 85 Hz. The signals were sampled at the frequency of 173.61 Hz with low-pass filter settings ranging from 0.5–40 Hz. Low pass filters are filters that allow signals below a cutoff frequency (known as the pass-band) and stops signals above the cutoff frequency (known as the stop-band). So, by removing some frequencies, the filter produces changes in output values to make it easier to see trends and also boost the overall signal-to-noise ratio with minimal signal degradation.

C. Feature Extraction

Feature extraction involves the transformation of input data into a set of features which derive information from the input data in order to perform the desired task. In this work, features extracted include; maximum value, mean value, variance value, standard deviation value, entropy value, energy value, RMS value, kurtosis and skewness. The maximum value illustrates the rapid spiking of patterns during seizure activity. The mean provides the absolute values of each channel signal. The variance of the signals shows how data lie near the mean, that is, the spread out. The standard deviation is a measure of spread out from the variance. This is the changes that occur from the normal state to the epileptic state [3]. Energy is a nonlinear feature. The brain is made up of interconnected neurons working together to perform certain functions. The high energy level is required by neurons to perform its function [3]. The onset of epileptic seizure creates imbalances in the energy level [3]. Finally, entropy is also a nonlinear feature that is defined as the uncertainty or the degree of randomness in the signal. The onset of epileptic seizure also creates imbalances in the entropy level [3].

D. Grasshopper Optimization Algorithm (GOA) for Optimal Feature Selection

Grasshoppers are insects. They are considered a pest due to their damage to crop production and agriculture. Although grasshoppers are usually seen individually in nature, they join in one of the largest swarm of all creatures [8]. The size of the swarm may be of a continental scale and a nightmare for farmers. The unique aspect of the grasshopper swarm is that swarming behaviour is found in both nymph and adulthood [8]. Millions of nymph grasshoppers' jump and move like rolling cylinders. In their path, they eat almost all vegetation. After this behaviour, when they become adult, they form a swarm in the air. This is how grasshoppers migrate over large distances. The main characteristic of the swarm in the larval phase is slow movement and small steps of the grasshoppers. In contrast, long-range and abrupt movement is the essential feature of the swarm in adulthood. Food source seeking is another important characteristic of the swarming of grasshoppers. As nature-inspired algorithms logically divide the search process into two tendencies: exploration and exploitation. In exploration, the search agents are encouraged to move abruptly, while they tend to move locally during exploitation. These two functions, as well as target seeking, are performed by grasshoppers naturally.

E. Classification

The designed ANN models were trained and tested using neural networks. The training process constitutes the inputs, target group and the results of the networks were saved respectively. The saved networks were used for testing. As the data collected for training was inputted into the training set and the ANN training was carried out on the inputted data. While the training performance was checked and it was in order (that is, the predicted output equals the desired output), the network was saved and the process stopped. But if 'NO', the parameters were adjusted thereby retraining the network until the desired performance was achieved, then the network was saved and the process stopped. As shown in Figure 4, the saved networks from the training set were loaded into the testing set where ANN testing was carried out on the inputted data. The performance of each network was evaluated using the performance metrics.

IV. RESULTS AND DISCUSSION

A. GOA Feature Selection Results

This section presents the result of Epilepsy detection using ANN-GOA. GOA was used for feature selection to better optimize the extracted features, four experiments were carried out using 5,10,15 and 20 grasshopper search agents respectively. For experiment 1, Using 5 search agent (grasshopper), three features where selected (position 6,8,9) which are energy value, skewness and kurtosis. An overall fitness value which also measures for MSE (performance) was achieved at 8 iterations and accuracy of 98.2%. It was observed that the optimization algorithm using 5 search agents achieved its best performance at 0.0311. Figure 5 presents the convergence curve, while Figure 6 presents the GOA

Confusion Matrix. For experiment 2 Using 10 search agents, six features were selected (positions 1,2,3,4,8,9) which are Maximum value, standard deviation, variance value, mean value, skewness and kurtosis. An overall fitness value, MSE value of 0.0241 and accuracy of 98.4% was achieved. Figure 7 presents the convergence curve, while GOA Confusion Matrix is presented in Figure 8. It was observed that the optimization algorithm using 10 search agents achieved its best performance at 0.0241 at 0 iterations. Experiment 3 Using 15 search agents, three features were selected (positions 2,6,8) which are Standard deviation, energy value and skewness. An overall fitness value which also measures for MSE (performance) was achieved at 0.0276 and accuracy of 96.2%.was achieved from the confusion matrix. It was observed that the optimization algorithm using 15 search agents achieved its best performance at 0.0276 at 5 iterations. Figure 9 presents the convergence curve for 15 search agents and three features, while figure 10 presents a confusion matrix for 15 Search Agents and Six Features. Lastly, for experiment 4 Using 20 search agents, four features were selected (positions 2, 6, 8, 9) which are Standard deviation, energy value, skewness and kurtosis. An overall fitness value which also measures for MSE (performance) was achieved at 0.0205 at 6 iterations and accuracy of 98.2% from the confusion matrix. It was observed that the optimization algorithm using 20 search agents achieved its best performance at 0.0205 at 6 iterations.

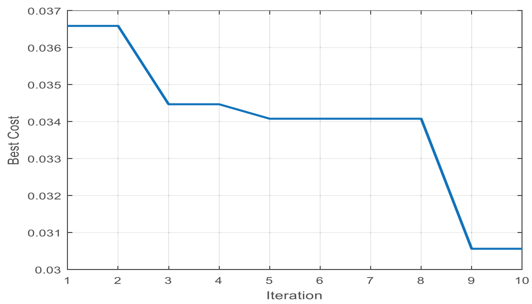

Figure 5. GOA Convergence Curve for 5 search agent and three features

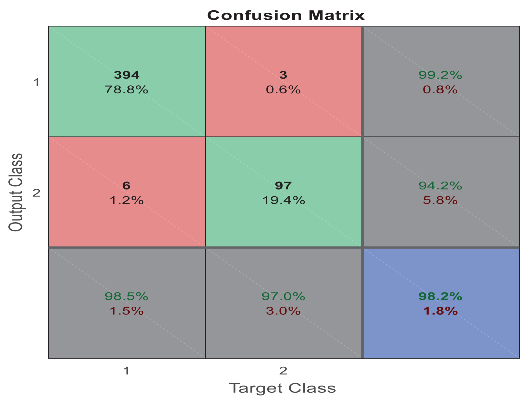

Figure 6. GOA Confusion Matrix for 5 search agent and three features

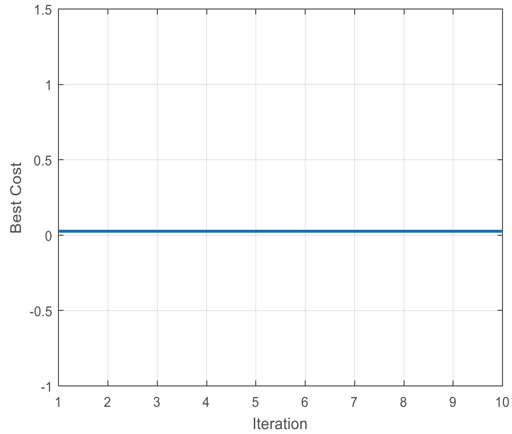

Figure 7. Convergence Curve for 10 Search Agents and Six Features

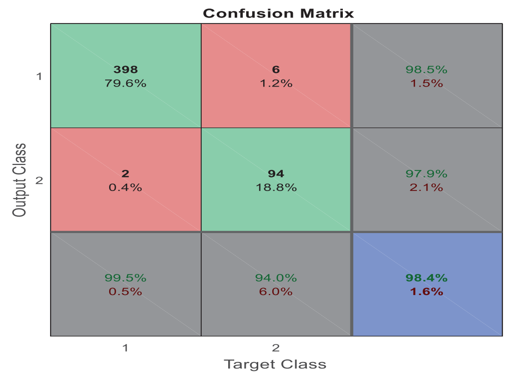

Figure 8. GOA Confusion Matrix for 10 Search Agents and Six Features

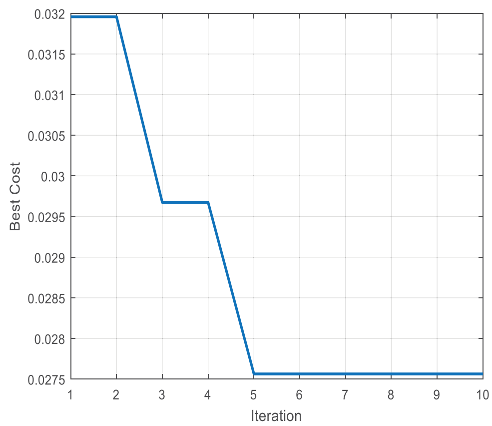

Figure 9. Convergence Curve for 15 Search Agents and Three Features

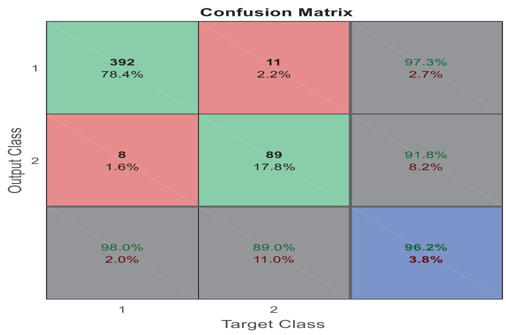

Figure 10. Confusion Matrix for 15 Search Agents and Six Features

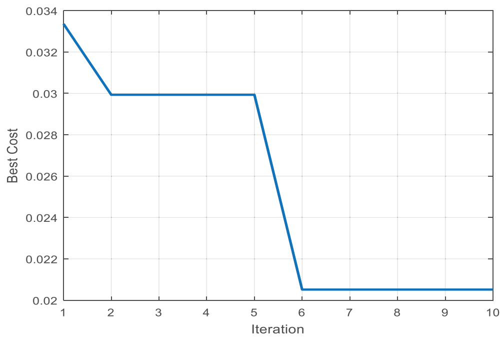

Figure 11. Convergence Curve for 20 Search Agents and Three Features

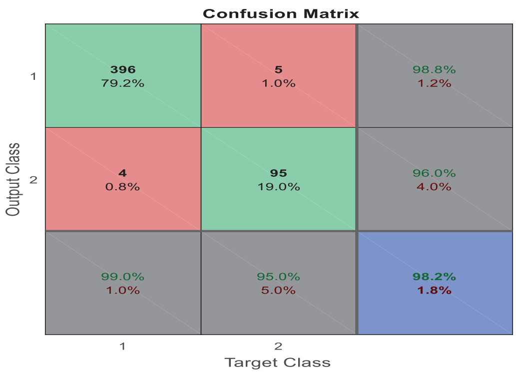

Figure 12. Confusion Matrix for 20 Search Agents and Three Features

B. ANN Classification Results

The results obtained after training/testing the ANN using the feed-forward network is shown in Figures 13 and 14 respectively. The result shows the performance metrics used to evaluate the system during training/testing. From the results in Figure 13, it is observed from the upper quadrant that the sensitivity of the ANN after the training was 92.6% since it correctly classified 100 positive cases and incorrectly classified 8 negative cases. The specificity was 100% since it correctly classified only 92 negative cases. The overall classification accuracy of the ANN after the training/testing was 96.0% since only 100 cases were correctly classified against the total number of 200 cases. This result shows that the system was able to classify correctly normal patient and the epilepsy patient (seizure). From the results, as shown in Figure 14, it was observed that the network achieved its best performance after 59 iterations under zero (0) second using Scaled Conjugate Gradient training algorithm. The results obtained after validating the performance of the ANN are shown in Figure 13.

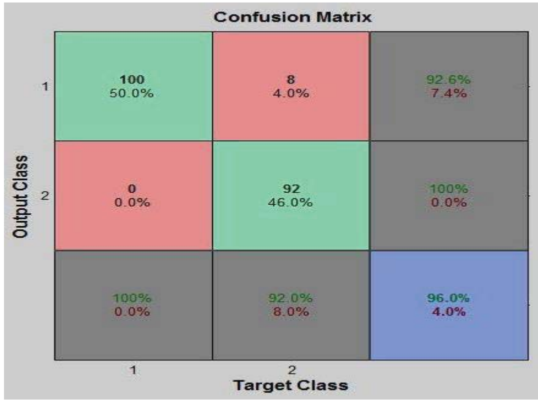

Figure 13: ANN Training/Testing Confusion Matrix

C. Comparison of ANN and ANN-GOA

Table 3 shows the distribution of the neural network used in this research work against the overall accuracies for training/testing of the network. Table 2 shows the result of the GOA-ANN analysis used in this research against the overall accuracies for training/testing of the network. It, however, showed that the ANN Feed-Forward network performed best when grasshopper algorithm was used for feature selection. However, comparing this work with the previous works reviewed, particularly the work done by [8] in which 98.3% overall accuracy was achieved for the Feed-Forward network using Regression method, this work achieved 98.4% overall accuracy for Feed-Forward network using statistical methods of feature extraction and grasshopper algorithm for feature section. Therefore, this system performed well in the classification of an epileptic seizure.

Table 2: Summary of GOA_ANN Result.

Number of Searches Agent	Fitness value	Accuracy	Feature Selected
5	0.0311	98.2%	3[6, 8, 9]
10	0.0241	98.4%	6[1, 2, 3, 4, 8,9]
15	0.0276	96.2%	3[2, 6, 8]
20	0.0205	98.2%	4[2, 6, 8, 9]

Table 3: Summary of ANN Result

Performance Evaluation	Feed-Forward Network
Sensitivity	92.60%
Specificity	100%
Accuracy	96.00%
Training Function	Scaled Conjugate Gradient
Hidden Neurons	50

Figure 15 present the Graphical User Interface (GUI) for the developed system where user can relate with the system. It has the load EEG button for loading the data and Extract Features button for extracting features. At first, the user will load the EEG data by clicking on the load EEG button and it will call a folder where the user can select the EEG data to load for healthy (normal) and seizure (epilepsy) respectively. Once the EEG data are loaded, the user can now proceed by clicking extract features button for extracting the features, thus, optimized features are selected. And finally, once the features are extracted and selected, the user can proceed with training the networks. The user can train/test and observe their performance, train state and confusion matrix respectively.

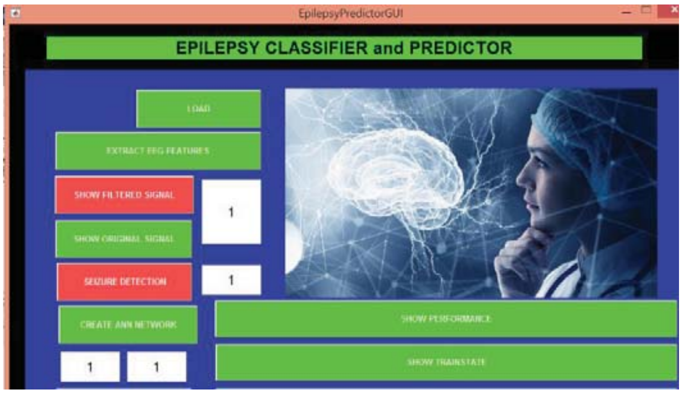

Figure 15: The System Graphical User Interface (GUI)

V. CONCLUSION

Epilepsy is a disease that affects the brain from the disorderliness of the central nervous system. It is characterized by recurrent seizures. The electroencephalogram (EEG) signals provide an important means in the diagnosis of epilepsy. This research work developed an intelligent ANN and GOA based model that learns from EEG signals acquired from epilepsy patient to classify between healthy (non-ictal) and seizure (ictal). The purpose of developing this system is to reduce the time, physicians' mistakes (human error) and reduce the computational cost of seizure detection in analyzing EEG signals. Moreover, this is also to solve the problems of unavailability `of neurophysiologists in the developing countries where epilepsy cases are much pronounced. This system was implemented and demonstrated using ANN toolboxes in MATLAB and GOA. The ANN GOA model parameters were selected by looking out to the best parameters to be considered. However, the performance of the developed system was evaluated using sensitivity, specificity and classification accuracy, using the Feed-forward network. Overall accuracies of 98.4% were achieved.

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