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EMPLOYABILITY OF ARTIFICIAL NEURAL NETWORK IN THE EARLY DETECTION OF PARKINSON'S DISEASE

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ABSTRACT

The target of this work is to exhibit an inside and out comprehension of the finding of Parkinson's Disease (PD) is basic for solid neuroprotection in the beginning time. Analytic devices dependent on AI strategies utilizing the Striatal Binding Ratio (SBR) of Caudate and Putamen (left and right) are valuable to recognize early PD. Techniques: This paper exhibits a way to deal with build up an ANN model for the expectation of the Gamma-Amino Butyric Acid (GABA) focus level for PD and Healthy Group (HG). Utilizing multilayer discernment organize having 4-30-1 design for foreseeing GABA fixation level. The system is prepared to an ideal level and prepared system that predicts the GABA fixation level for the interjected estimations of info parameters like Striatal Binding Ratio (SBR) of Caudate left, Caudate right and Putamen left, Putamen right. As per the ANN model, the forecast exhibition is profoundly promising with the least blunder and high exactness. The planned forecast model for GABA focus level defeats the misdiagnosis of early PD. Applications: We propose to think about the improvement of the early expectation of Parkinson's infection, by actualizing the ANN. The prescient model for diagnosing Parkinson sickness utilizing counterfeit neural system is produced in early recognition of the neurogenerative issue.

1. INTRODUCTION

Parkinson's Disease is a chronic gradual neurodegenerative disorder which evidently affects the neural cells of the human brain called the substantia nigra. These neurons generate dopamine content, an inhibitory neurotransmitter that transmits signals which coordinate smooth movement. The PD is due to the death of dopamine transporters and as a result gait system is affected1. The clinical motor symptoms are impairment of movement with tremor, Gait problem, slowness, stiffness, or balance problems and impairment of posture2-4. The calculation of dopamine deficiency in the caudate and putamen of SPECT images of the human mid brainis the significant diagnostic tool for discriminating PD patients from the healthy group5,6. Gamma-Amino Butyric Acid (GABA) is a most essential neurotransmitter widely distributed throughout the Central Nervous System (CNS). GABA mediates presynaptic inhibition of primary blood vessels in the motor neuron system. It regulates brain excitability. Too much excitement can lead to irritability, restlessness, insomnia, seizures, and movement disorders; it must be balanced with inhibition7. Low GABA level causes neurological disorders including Parkinson's disease, anxiety, depression, insomnia, and epilepsy8. The radio receptor assay technique is used to measure GABA concentration level for detecting PD9. Recently the Artificial Neural Network acts as a prediction and modelling tool for diagnosing various diseases in different medical areas10. ANN has weighted interconnected nodes called stimulated neurons and has the ability of the human brain. It can learn from the past experiences and find solutions for complex nonlinear multidimensional

functional relationships11. The unique characteristic is describing the relationship between training and testing datasets from a large number of inputs without any prescribed structure about the problem. The three layered feed- forward with Levenberg-Marquardt (LM) training algorithm serves as an effective, simple, better, fast, compact and efficient tool for predicting mechanical properties12-14.

Diagnostic tool used in machine learning techniques such as Support Vector Machine (SVM), Multivariate Logistic Regression (MLR) and Artificial Neural Network (ANN) is used to construct a prediction model for diagnosing neural disorders15. Since, they allow individual level characterization, high level of clinical translation is potentially obtained. They use multivariate and supervised learning techniques with complex high dimensional feature space to train the network. The input datasets are categorized based on the trained network. SVM finds hyper plane to classify the subjects into early PD and healthy group. MLR determines the probability based on SBR values to discriminate early PD subjects from healthy group. ANN uses input data to train the neural network and the trained network classifies datasets16,17. In the related work, features are extracted from the striatum and the effective feature reduction techniques like Principal Component Analysis (PCA), Independent Component Analysis (ICA) are used to pick up the required features. This makes the system very complex18. In this present work, only four features of Striatal Binding Ratio (SBR) values, namely Caudate left, Caudate right and Putamen left, Putamen right are obtained from Parkinson's Progression Markers Initiative (PPMI) database which focuses on identifying PD progressive biomarkers that determine PD19. We also investigate the level of GABA concentration of Parkinson disease and healthy group using SBR values. The Predictive models using ANN architecture are developed to GABA concentration level based on SBR (Caudate left, right and Putamen left, right) values.

2. COMPUTATIONAL METHODS

2.1 PPMI Database

The input features are obtained from the international PPMI database. All PD subjects are in an early stage of the disease within two years20. The corresponding SBR values are taken for the analysis.

2.2 Calculation of SBR Values

Iterative reconstruction is performed on SPECT raw projection data using Hybrid Ordered Subset Expectation Maximization (HOSEM) algorithm. Iterative reconstruction is done without any filtering to ensure consistency of the reconstructions. The reconstructed HOSEM files are processed for Attenuation correction, which is filtered and normalized to get the same anatomical alignment. Striatal uptake counts densities of the Region of Interest (ROI) are extracted and used to evaluate Striatal Binding Ratios (SBRs) for each region of the four striatal regions. SBR is calculated by PPMI as follows and compared with Occipital cortex region below the Putamen as reference region21.

SBR= (target region/reference region) – 1

Where,

Target region is referred as left caudate, right caudate, left putamen, right putamen and Reference region is referred as occipital cortex. Table 1 shows the number of observations and averaged SBR values.

2.3 Artificial Neural Networks

The ANN is inspired by the biological nervous system and is used to solve a wide range variety of complex scientific problems22. Neural networks are suited for biological counterparts, they can learn, and therefore can be trained to find solutions, recognize patterns, classify data, and forecast future events. A neural network is a framework made out of numerous basic preparing components working in parallel, whose capacity is controlled by the system structure, association qualities, and the handling performed at processing components or nodes23. ANN looks like the human mind in two regards:

Table 1. Averaged SBR value for caudate right, Caudate left, Putamen right and Putamen left for Early and healthy group

Cases	No. of observations	Caudate(R)	Caudate(L)	Putamen(R)	Putamen(L)
Early PD	360	1.91	1.87	0.810	0.729
HG	163	2.96	3.07	2.16	2.23

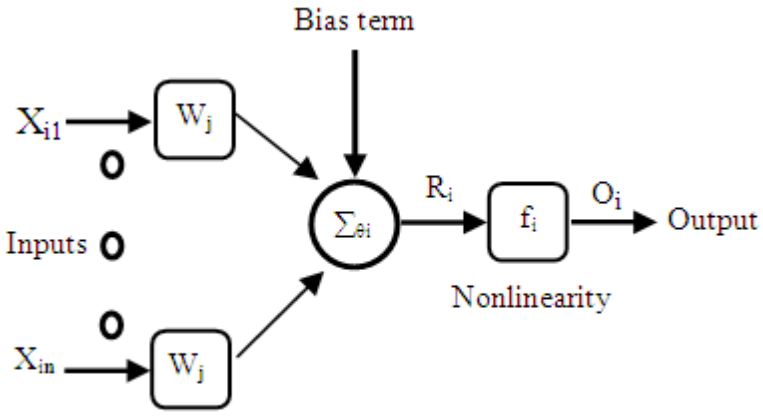

Figure 1. Basic neuron model.

1. Knowledge is obtained from the network by learning process and 2. Interneuron connection strengths (synaptic weights) are effectively adjusted to store the knowledge24. The essential unit of the ANN is characterized as an artificial neuron (or neuron). The neuron has a lot of data sources (Xi) weighted before arriving at the fundamental body of the preparing component by the association quality or the weight we(i.e., Xi is multiplied by wj)25. In addition, it has a bias term, a threshold value that has to be reached or exceeded for the neuron to produce a signal, a non-

linearity function (fi) that acts on the produced signal (Ri), and an output (Oi). The basic model of a neuron is illustrated in Figure 1.

2.4 ANN Architecture

In Artificial neural network architecture commonly consists of Input layer, Output layer and the Hidden layers as shown in Figure 2. Add more number of hidden layers where the size of the input is large to extract higher-order statistics27,28 The input signal propagates through the network in a forward direction, on a layer-by-layer basis. These networks are commonly referred to as Multilayer Perceptron (MLP)29. The hidden layers help to add non-linearity to the system and address interactions between input variables. Choosing the number of hidden layers is the important factor to be considered while solving a ANN problem30.

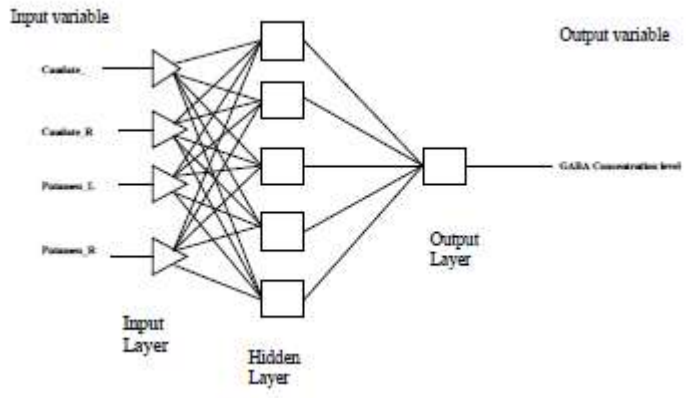

Figure 2. ANN architecture.

2.5 Implementation

In the present work, an ANN was modelled using a Network Fitting (NF) tool box of MATLabV2013. NF tool is an acronym for network fitting tool with Graphic User Interface (GUI) module. The data were further divided into training sets, validation set and testing set in the proportions of 70:15:15 respectively. The back propagation neural network was designed based on delta rule, called steepest descent algorithm. It consists of a forward pass of input, hidden and output training samples. A backward pass of the sample is made to update the weight of all neurons i in layer k. One epoch is presented to the network when a forward pass and backward pass have made. The forward pass output will be

$$\zeta_k(n) = \sum_{j=0}^{m} \omega_{kj}(n)\gamma_j(n)$$

Where *n* – No of conducted epochs
k- No of layers
ω- Current weight vector
m- No of neurons in layer k
is the output vector from the previous defined as?

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$$\gamma_i(j)\,(n) = \alpha_i j\,(\zeta_i j\,(n)$$

The error in the forward pass output layer is represented as the difference between the predicted value and the desired value d as the overall squared error.

$$\epsilon_k(n) = \frac{1}{2}\sum_{j=0}^{m}[d_j \mathbb{I}(n) - \gamma_j(n)]\mathbb{I}^2$$

Differentiating ε with respect to, the delta rule is obtained as

$$\Delta\omega_{kj}(n) = -\ \eta\frac{\partial \in (n)}{\partial\omega_{kj}(n)}$$

Where η is defined as learning rate

Where η is defined as learning rate The LM training algorithm is used in this study by modifying the steepest descendent rule. The LM training algorithm can be obtained. LM is the faster, more accurate with minimum error algorithm. Compared to the steepest descendant rule. The error function is given with a Taylor expansion Where J(n) is the Jacobian matrix31. In this study, the input layer with four neurons representing the four variables viz. Caudate (L), Caudate (R), Putamen (L) and Putamen (R) were used and the hidden layer consisted of 30 neurons with log-sig activation function. The output layer with one neuron was used to model the network. This model is being used to predict concentration level for GABA for PD and HG. The MSE of early PD and healthy group is shown in Table 2.

Table 2. MSE for Early PD and Healthy group

	GABA		Error
	Measured	Predicted	
Early PD	0.155	0.154817	0.000
Healthy group	0.782122699	0.783354299	0.00123

3. RESULTS AND DISCUSSIONS

3.1 Effect of SBR Values on GABA Concentration Level for PD Based on the SBR values of Caudate (L), Caudate (R), Putamen (L) and Putamen (R) the predictive model of GABA concentration level for PD is developed by ANN. Regression plot

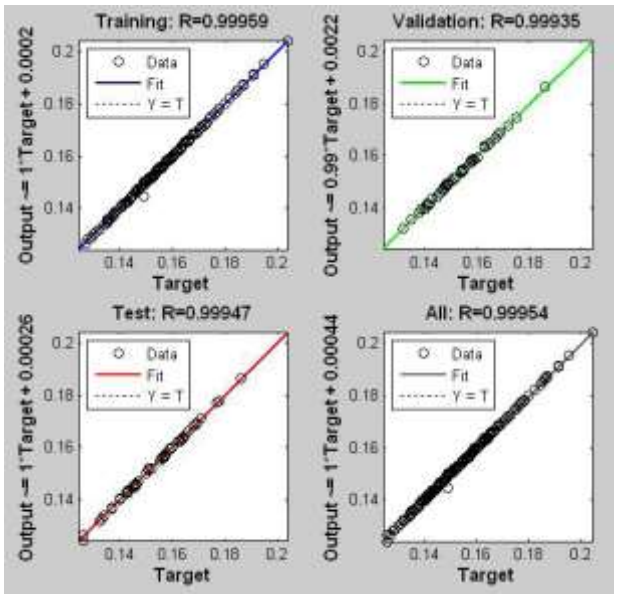

Figure 3. The regression plots of training, testing, validation and average of all sets for PD.

and performance plot are drawn to study the error and accuracy. Figure 3 shows the regression plot for PD. The plot shows the average regression value (R= 0.99954) is almost 1. It indicates that the predicted values and the output values are lie on the fit. Similarly, the same study is implemented for training, testing and validation. Figure 4 shows the performance of the network is measured using Mean Square Error (MSE) over the epochs. It means that the network is carried out number of iterations in order to attain good accuracy with minimum error. The ANN attained a stable state after 12 cycles of training. Figure 4 shows the error curve of training. From the Graph it is clear that the error is minimized by iterations carried out by the network during training, validation and testing. Generalization is stopped at the 18th epoch. The best performance is obtained at the 12th epoch. The MSE during training and validation was found to be 1.7677e-07.

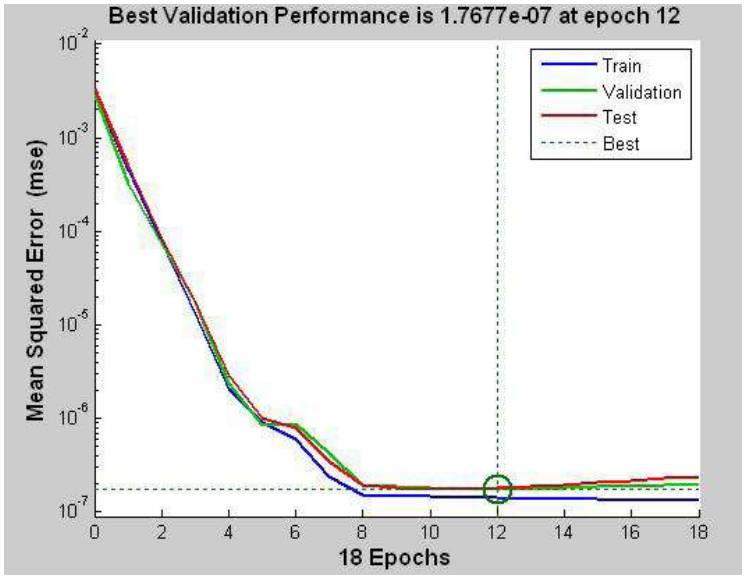

Figure 4. The MSE performance plot of ANN for PD.

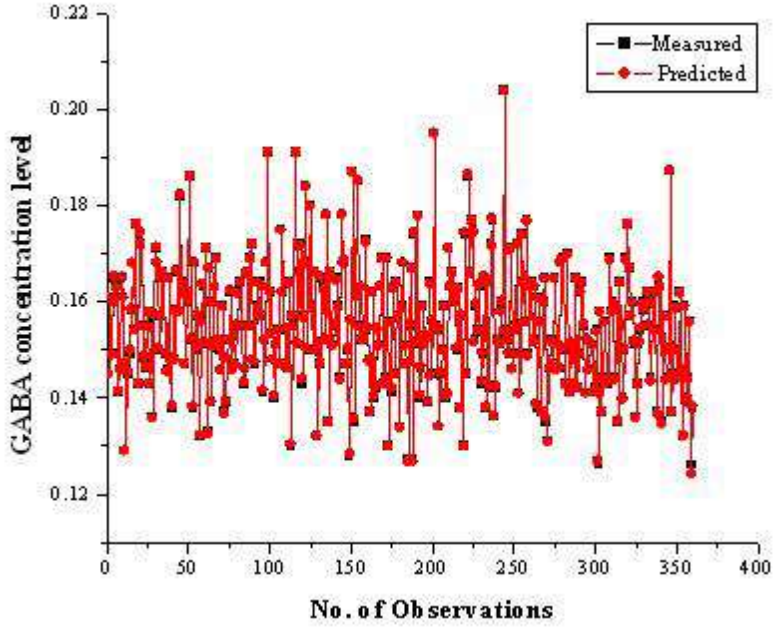

Figure 5. Comparison of GABA concentration level of PD among measured and predicted values.

The measured values and predicted values of GABA concentration level are plotted as shown in Figure 5. From the comparison, it clearly shows that the models predict the GABA concentration level with reasonable accuracy.

3.2 Effect of SBR Values on GABA

Concentration Level for HG Similarly, based on the SBR values of Caudate (L), Caudate (R), Putamen (L) and Putamen (R) the predictive model of GABA concentration level for HG is developed by ANN. Regression plot and performance plot are drawn to study the error and accuracy. Figure 6 shows the regression plot for HG. The plot shows the average regression value (R= 0.9981) is almost 1. It indicates that the predicted values and the output are lie on the fit. Similarly, the same study is implemented for training, testing and validation.

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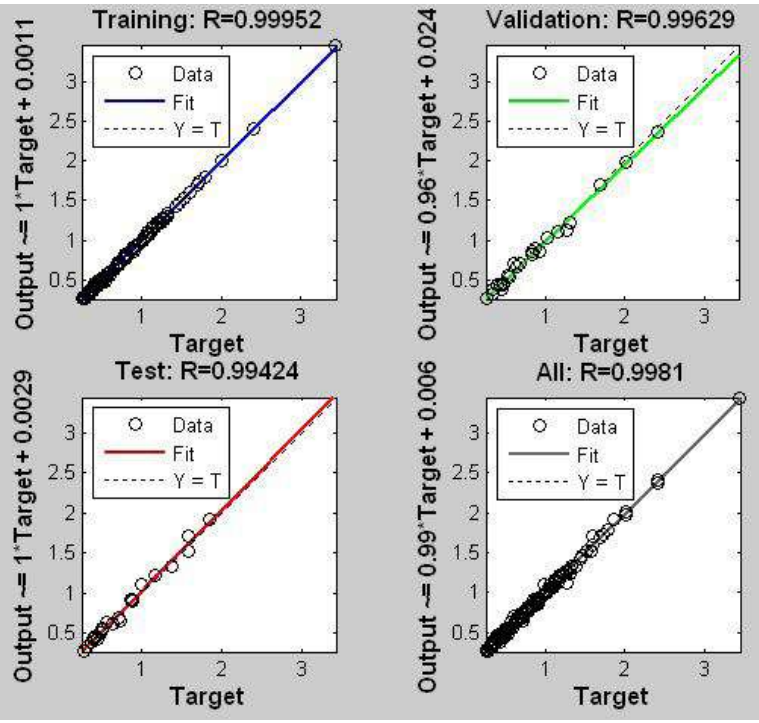

Figure 6. The regression plots of training, testing, validation and average of all sets for HG.

Figure 7 shows the performance of the network is measured using MSE over the epochs. It means that the network is carried out number of iterations in order to attain good accuracy with minimum error. The ANN attained a stable state after 11 cycles of training. Figure 7 shows the error curve of training. From the Graph it is clear that the error is minimized by iterations carried out by the network during training, validation and testing. Generalization was stopped at the 17th epoch. The best performance is obtained at the 11th epoch. The MSE during training and validation was found to be 0.0025906. The measured values and predicted values of GABA concentration level were plotted as shown in Figure 8. From the comparison, it clearly shows that the models predict the GABA concentration level with reasonable accuracy.

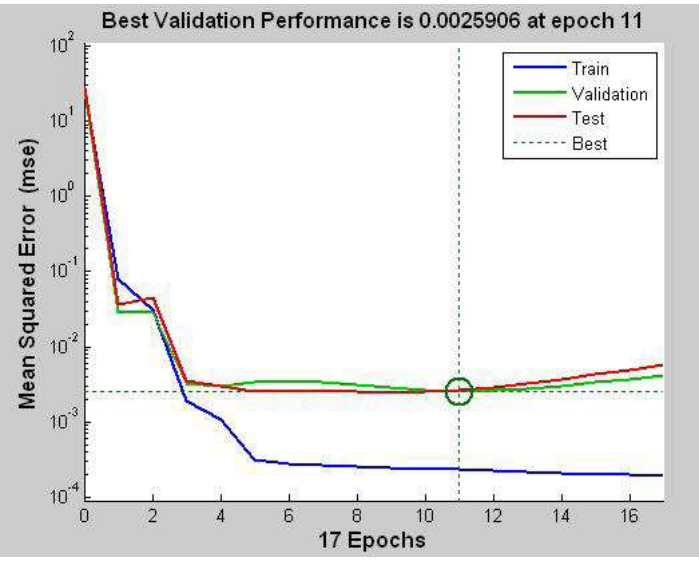

Figure 7. The MSE performance plot of ANN for HG.

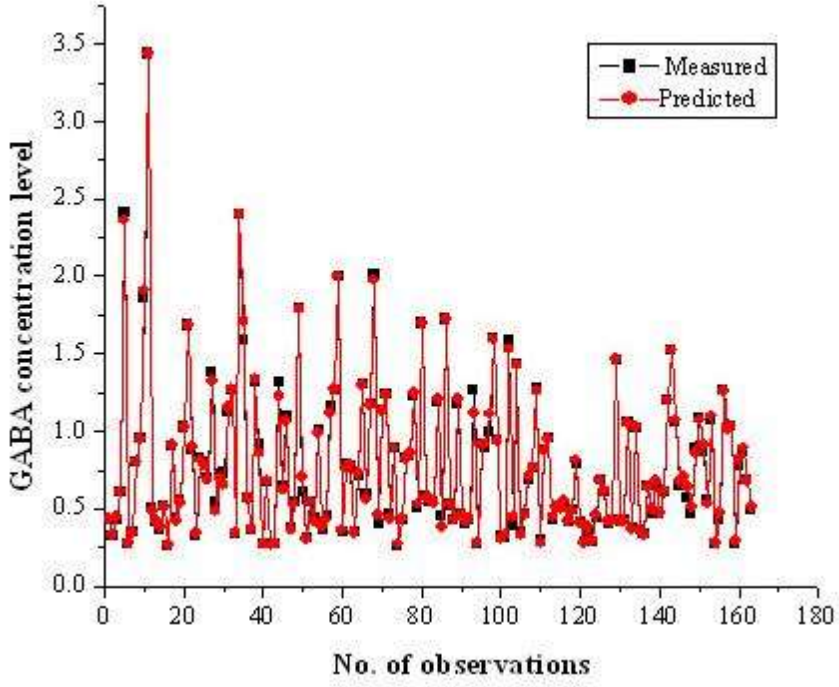

Figure 8. Comparison of GABA concentration level of HG among measured and predicted values.

4. CONCLUSION

The significant conclusions have been drawn from the proposed prediction system: Striatal Binding Ratio (SBR) values for the four striatal regions (left and right caudate, and left and right putamen) obtained from the Parkinson's Progression Marker's Initiative (PPMI) database. A multilayer ANN network having neurons of 4-30-1 architecture is found. The network is trained

the SBR values and the trained network generates the predictive models for GABA concentration level based on SBR (left, right Caudate, left, right Putamen) values of PD patients and healthy group. These models have the potential to distinguish Early PD from healthy group. The regression plots for PD and healthy group are obtained. The average regression value shows a close correlation between predicted value and the calculated value of GABA concentration level and the minimized Mean Squared Error (MSE) also calculated which implies high accuracy. The prediction models based on SBR values for estimating GABA concentration level is a novel method, which overcomes misdiagnoses of early PD.