International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Cognitive Behavior: Identification of Autism Disorder in Individuals Based on EEG Signal Using Neural Network Methods

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Submitted: 09/09/2023 **Revised:** 26/10/2023 **Accepted:** 12/11/2023

Abstract: Autism is the word that is used for describing a set of neurodevelopmental disorders. These kinds of disorders have issues with communication and interaction with people. Autism is a Cognitive Disorder it leads to Slow down the Brain Development. Individuals of Autistic find difficulties in learning, talking with others. Autistic people having trouble in learning new things, expressing new thoughts and adapting to new situations, among the others. Because they are unable to interact appropriately with others, they get separated from society. Autistic People are unable to comprehend the actions and intentions of others, and they have trouble understanding from outside their routine. The two commonly used methods are Autism Spectrum Disorder and Attention Deficit Hyperactivity Disorder. People with autism usually explain restricted, repetitive and patterns of character. Based on the centers of disease control autism affected level is estimated. Now Deep Learning (DL) models also play an important role in healthcare fields due to their exactness and better outcome. In this research article uses LSTM, CNN, and MLP models are used to identify the autism diseases from the patients EEG (ElectroEncephalogram) signals in an earlier manner. Among these three models, LSTM provides a better result in terms of sensitivity, specificity, and accuracy. These classifiers are implemented using Python programming.

Keywords: Deep Learning, Autism, Accuracy, Sensitivity, Specificity, Performance.

1. Introduction

Autism refers to a wide range of conditions with the challenges like social skills repetitive characters, speech, and nonverbal communication skills. Many factors influence the improvement of autism it is very usually accompanied by sensitive and medicinal problems like gastrointestinal problems, seizures or sleeping issues, depression, and anxiety. Symptoms of autism disorder usually occur between the youngest stages between 2 to 4 years, certain improvements linked with this disorder can delay even in the earliest manner, and usually, it can be treated earlier in 18 months.

Deep Learning (DL) is a machine learning approach inspired by the intricate structure of the human brain. Neural Networks (NN) form the core of DL, consisting of multiple layers that facilitate the learning process. A typical deep learning neural network comprises an input layer, an output layer, and several hidden layers that constitute the complete architecture. Information processing occurs through connections holding input data, predetermined weights, and activation functions that dictate the information flow within the network. By operating on extensive datasets, the network transmits data through each layer, progressively extracting intricate features at every level. When the model's output deviates from expectations, weight adjustments are made, and the iteration process continues until the desired outcome is attained.

Comparatively, a neural network with five layers grasps more insights than a three-layer counterpart. Learning in neural networks involves two sequential steps. Initially, a nonlinear transformation is applied to inputs, creating a statistical model. Subsequently, model refinement relies on a mathematical construct termed a derivative. These steps iteratively recur thousands of times within the neural network, refining accuracy. The repetitive nature of these steps is referred to as iteration. A neural network with a single hidden layer is termed a shallow network, while those with multiple hidden layers are called deep neural networks. Diverse variants include Convolutional Neural Networks (CNN), Naive Bayes, sequence-to-sequence models, Recurrent Neural Networks (RNN), and Multi-Layer Perceptron's (MLP). This study employs three DL models—LSTM, CNN, and MLP—to identify autism spectrum disorder.

LSTM algorithm is a long short-term memory that is a subset of DL concepts and an artificial RNN algorithm is utilized in the ground of DL because of their feature of selectively remembering the patterns for a long time. These algorithms are the complex area of DL. The function of this article is to demonstrate LSTM and enable it in real-life tine issues. An LSTM had the same control flow as an RNN. It processes the information passing on data as it propagates forward. A CNN is a method of deep learning that can intake input images, assigning importance for different aspects in the image and able to distinguish one from another. It is one of the most important subsets of the neural

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network. CNN is considered the regularized method of multilayer perceptron.

In the medical domain, the signals are collected from the patient's brain and supply to the given models. These models provide the automatic decision for the patient's disorder, it decreased the patient's and doctors valuable time. At the same time models developed based on EEG data signals monitor the people's mental condition continuously and based on the behavior changes, it produces a warning signal. It helps the healthcare people and patients to decrease risk levels [2]. [14]This paper suggests using a bilinear residual network to solve nonlinear evolution equations. However, the residual network can transfer the input layer to the activation function in the final layer to actualize the interaction inside the network. The activation function in the last layer of a deep neural network cannot interact with the neuron within the deep neural network. This makes the model simpler and produces more interactive outcomes. There are presented the steps for solving the exact analytical answer using the residual network.

2. Literature Review

Autism is a kind of brain sickness in youngsters and it is identified using MRI scanning and EEG signals. Tulikapriya Sinha et al., 2019 presented a new system for identifying autism with the help of EEG data signals. Here the authors use recorded EEG data signal, preprocess the signals by digital type filter, and retrieve the major characteristics in time information and frequency value using DWT(Discrete wavelet transform). The extracted features are assigned to the various classifiers like NN(Neural Networks), SVM(support vector machine), KNN(K-nearest neighbor), subspace kind KNN, and LDA(linear discriminant analysis). The experiment outcomes demonstrate that the subspace type KNN affords the leading accuracy rate of 92.8% for time-related domain attributes [1].

EEG signal values dealing with the neuronal function in terms of electrical currents which has been created based the brain cell activities. Ashima Khosla et al., 2020 presented a study for comparing different neuroimaging approaches, exploring the outstanding neuroimaging competencies of EEG data signals like the best chronological resolution, compactness, inexpensiveness, and non-invasiveness and these values are related to other approaches. The main intention of this study is to analyze many EEG signal applications like emotion identification, neurological issues, sleep phase categorization, eye condition identification, observing drowsiness, etc. They also presented public EEG signal datasets, data gathering approaches, preprocessing stages, feature retrieval techniques, and analyze the outcomes using classifiers and statistical investigation. At last, the authors provide brief information regarding the researches expose the mixture of brain data from various modalities. Authors suggest various research gaps in this domain. The important gaps are a) huge datasets not available b) portable devices contains low storage area c) most of the models are very simple and it contains the fewer number EEG data channels d) less number of effective filtering approaches[2].

NN(Neural Networks) plays a major role in many applications because of its combined efficiency in feature retrieval and categorization in DL approaches. P. Nagabushanam et al., 2020 classify the EEG data signals using SVM, LR models, and NN. They use a two-level layer LSTM model and a four-level enhanced NN model to increase the classification performances of EEG data. Various statistical identifiers like mean value, skewness, standard deviation value, and kurtosis are mined from the input EEG signals and supply various classifiers. The outcomes of the classifiers are analyzed using accuracy value, recall, and f1 score value. Here the authors collect the data from the Boon database collection. Enhanced LSTM and NN models give better outcomes compared to other kinds of methods. The proposed work is implemented in Python programming in Keras. In the EEG data signal classification, based on the simulation result LSTM produces 71.3% accuracy, and enhanced NN produces 78.9% accuracy value. One dimensional type gradient value, activation method with radial values in the beginning layers of enhanced NN is the innovation that assists in acquiring better outcomes compared with traditional approaches. Simulate the system using different activation methods, loss models, optimizers to examine the outputs [5].

CNN is mainly used in speech identification, image categorization, neuroscience, and automotive engineering. Zeinab Sherkatghanad et al., 2020 mainly focused on autism detection using the classifier CNN with the brain picture dataset. Here the authors collect the data from the ABIDE dataset and use the fMRI dataset. This technique to categorize the Autism disorder and manage the subjects depends on the patterns of functional associations. The outcome of the proposed work describes the autism is detected with a 70.22% accuracy level using ABIDE I data [7].

The neurological disorder is a lifelong result of low communication ability with other people. This kind of problem starts from the kids' level and continues into the adult stage. Suman Raj et al., 2019 exposes SVM, NBC, LR, KNN, NN, and CNN models for forecasting and examine the autism disease in child, and adult stages. These classifiers are assessed with commonly available nonclinical datasets. According to the investigational outcomes CNN classifiers produce higher accuracy than others. The outcomes of this research work strongly recommend CNN classifier is suitable for autism disease detection instead of existing traditional classifiers [8].

3. Materials and Methods

3.1 Description for Data and Procedure:

Data Pre-Processing

The acquisition system uses a frequency range of 0.1 to 60Hz band pass filter to clean the dataset. Additionally, where all the signals of EEG were load with 256Hz frequency are integrated in the acquisition system based on frequency of 60Hz stop band notch filter. The recording time for normal subjects is between 12 and 30 minutes with a total interval of approximately 173 minutes, for autistic subjects is between 5 and 27 minutes with a total interval of 148 minutes. The most important while in the acquisition process the patient should be relaxed and abstain from any muscular activities. There are three groups of dataset namely, 8-15 years old for 18 normal subjects, 11-17 years old for 8 autistic subjects and 40-60 years old for 12 epileptic group. The EEG signals were obtained from the BCI2000 software recording system of 256Hz at a sampling rate using digital amplifier and active electrodes. There are 16 channels in the data acquisition system, which are categorized on the basis of the 10–20 acquisition system based on international standard.

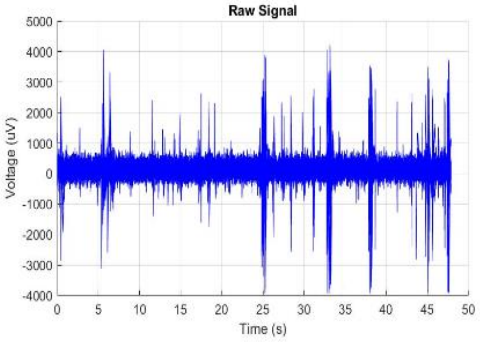

Fig. 1. Autism Raw Signal

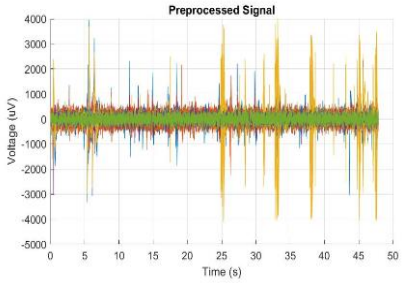

Fig. 2. Autism Preprocessed Signal

The recommended work's general block diagram is shown in figure 3.

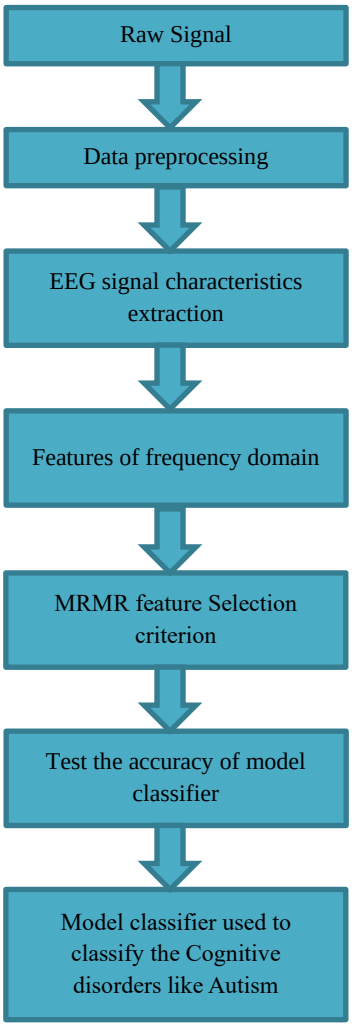

Fig. 3. General Block Diagram

4. Proposed System

In this research work, three DL models such as LSTM, CNN, and MLP are offered to detect autism disorder in the EEG signals.

4.1 LSTM

According to P. Nagabushanam et al., 2020 LSTM is based on the RNN technique it is the DL technique. RNN contains recurrent arrangements which are locally give firing power thereby exterior registers or storage spaces are not compulsory for saving earlier stage outputs. Computing level complexity value is less in LSTM because recurrent arrangements structures are offered in RNN. LSTM model is executed based on the following formulas.

$$y_t = \sigma(W_y, [g_{t-1}, w_t]), - - - - - - - - (1)$$

$$S_t = \sigma(W_s, [g_{t-1}, w_t]), - - - - - - - - - (2)$$

$$\hat{g}_t = \tanh(W.[s_t * g_{t-1}, w_t]), - - - - (3)$$

$$g_t = (1 - y_t) * g_{t-1} + y_t * \hat{g}_t, - - - - - - - (4)$$

Structure and identifier learning are passed out as two stages in RNN. Membership methods are inserted into the given notes depends on the input type identifier. Gaussian kind membership method is allocated with mean value and variance. Spatial and temporal type firing is used to allot one-dimensional membership methods. Structure-based learning is used to finalize when to create a rule and trigger it with a firing value greater than a threshold value (0, 1) for every input value. Parameter type learning is proceeding after structure type learning to decrease the error value cost method.

The proposed system consists of various steps. Following fig 4 shows the various stages of the proposed work. Initially, this system accepts the people's EEG signals. Next, the gathered signals are preprocessed using various preprocessing techniques. In this step, unwanted signals and noises are removed from the input signals. Here wiener filter is used to remove the noises from the given EEG signal. During the feature extraction stage, the major features are retrieved from the preprocessed signals using the GLCM method. The content of the TFM is obtained using a gray-level co-occurrence matrix (GLCM), and each GLCM is then given four features: homogeneity, correlation, energy, and contrast. The extracted features are classified using LSTM, CNN, and MLP deep learning models. Finally, the performance of the model is evaluated using the terms sensitivity, accuracy, and specificity.

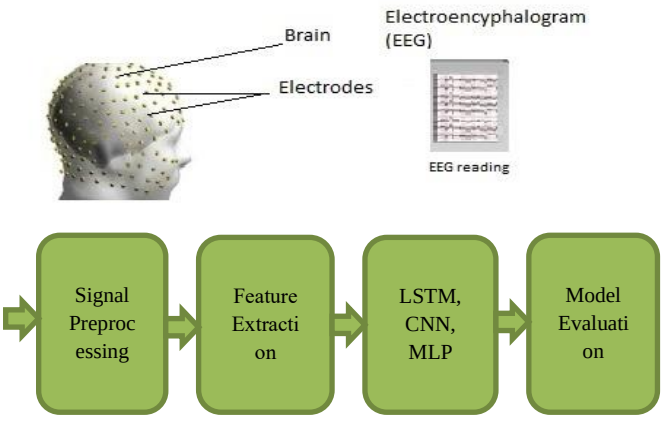

Fig. 4. Flow Diagram of Proposed Model

4.2 CNN

In recent years, deep learning (DL) has garnered significant attention in the field of image recognition, predominantly leveraging Convolutional Neural Networks (CNNs). CNNs constitute a set of hierarchical neurons with adaptable weights and biases. These networks excel in achieving impressive accuracy for disease classification tasks, obviating the need for extensive preprocessing while autonomously acquiring intricate features from provided signals. As a result, DL-based techniques and algorithms are extensively applied to medical digital signals, yielding optimal outcomes in disease detection.

The application of deep CNNs has been instrumental in addressing the intricacies of disease detection. In comparison to earlier algorithms or methodologies, CNNs have exhibited substantial performance improvements. A CNN operates as a multi-layered Feed Forward Neural Network (FFNN), wherein the intelligent selection of the widely recognized Radial Basis Function (RBF) kernel aids weight propagation throughout the network.

The employment of CNN algorithms offers several advantages, including heightened efficiency, expedited deep learning, and automatic feature extraction solely within the concealed layers of the network.

Zeinab Sherkatghanad et al., 2020 say that recently, the usage of the CNN model has involved huge attention in classification-based learning, and representation type learning. It is one of the major classifiers with the best accuracy in most of the applications with more number of arguments. CNN models have higher accuracy for feature extraction and can handle many free parameters. The CNN classifier contains various components like activation method, normal layers, pooling type layers, and convolutional layers. The following fig. 5 demonstrates the simple framework of the CNN classifier.

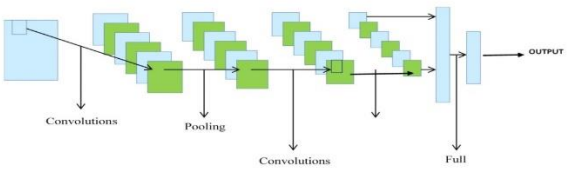

Fig. 5. Structure of CNN Classifier [8]

4.3 Multilayer Perceptron (MLP)

In this research two unseen layer MLP is used. According to Taban Eslami et al., 2019, the input level layer accepts Pearson's association coefficients of all brain areas. Assume that x_i denotes the input value of layers, the weight value W_i associating nodes i th layer to the $i+1$, and the bias value b_i, $i+1$ layer is triggered using equation (5).

$$z_{i+1} = f(W_i x_i + b_i), - - - - - - - (5)$$

f denotes the activator method and it is described as the equation(6)

$$f(x) = x^+ = max(0, x), - - - - - - - (6)$$

At last Softmax method is offered to the output level layer, it measures the possibilities of the input vector feature values similar to every class. Softmax method is measured using equation(7)

$$z_i = \frac{e^{z_i}}{\sum_{j=1}^{k} e^{z_j}}, - - - - - - - (7)$$

Here z_i equivalent to the activation nodes. This current research problem contains two kinds' classes like healthy people and autism-affected people, so the k value is 2. The loss that occurs in the classification is assessed using the formula $L_i = -log(p_i)$. Here p_i denotes the exact class measured using the softmax method. The loss value is the offer for improving the arguments of the model with the help of the backpropagation approach.

5. Results and Discussion

Autism is a spectrum disorder, each individual with this disorder has a distinct group of strengths and challenges. Most people are affected by a combination of environmental and genetic factors. Some of the people with this disorder need useful support in some of the people don't expect any help and they live independently. Analyzing EEG data is one of the difficult tasks due to its variations. It takes more time and the outcome of the analysis varied based on the people's expertise level. The ML model's signal processing approaches based on computing techniques are providing several tools for EEG signal research. These tools are mainly used to retrieve the major features from the EEG and assists to develop the automatic system that decreases the human intervention and improves the accuracy level. This work uses LSTM, MLP, and CNN models are offered for identifying autism in an earlier stage. The performance of the proposed work is measured using accuracy, sensitivity, and specificity scales. The following formulas are used to assess the accuracy, sensitivity, and specificity values.

$$Specificity = \frac{True\ Negative}{(True\ Negative + True\ Positive)} - - - - - - (8)$$

$$Sensitivity = \frac{True\ Negative}{(True\ Negative + False\ Negative)} - - - - - (9)$$

$$Accuracy = \frac{True\ Positive + True\ \ Negative}{(True\ Negative + Tru\ Positive + False\ Positive + False\ Negative)} - - - - (10)$$

This work is implemented using the Python programming language.

Model/Performance Metrics	Accuracy	Sensitivity	Specificity
LSTM	95.45	0.99	1.0
CNN	92.05	0.91	0.91
MLP	90.15	0.89	0.88

Following fig 6 shows the performance of the DL models in terms of accuracy.

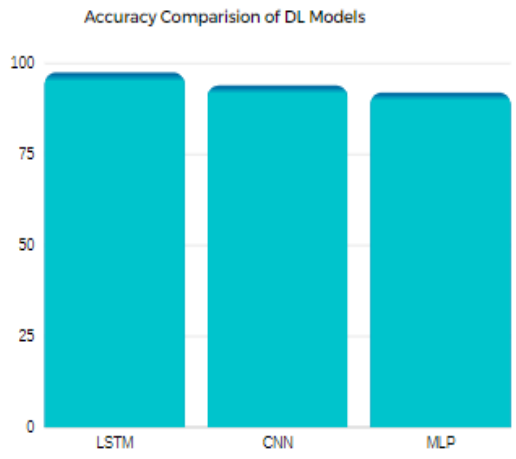

Fig. 6. Accuracy Comparison of DL Models

Among the three used classifiers, LSTM produces a better result.

6. Conclusion

Deep learning, an artificial intelligence technique, emulates human brain processes to analyze data and establish patterns crucial for decision-making. This method encompasses structured and unstructured data in its training. Noteworthy applications of deep learning encompass virtual aides, fraud detection, facial recognition, and more. Within the realm of machine learning, deep learning operates as a subset, mirroring the neuron operations of the human brain. This deep neural network interconnects numerous neurons across layers, enabling automated feature acquisition without explicit programming. Each layer signifies a progressively intricate level of information, embodying a hierarchical knowledge structure. Comparatively, deep learning classifiers outperform conventional methods, with LSTM emerging as a particularly effective component in this proposed system, yielding enhanced outputs across various dimensions.

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