



EEG-Based Identification of Schizophrenia Using Deep Learning Techniques

B. Shameedha Begum¹(✉), Md Faruk Hossain¹, Jobin Jose²,
and Bhukya Krishnapriya³

¹ National Institute of Technology, Tiruchirappalli, Tamil Nadu 620015, India
shameedha@nitt.edu

² Indian Institute of Information Technology, Kottayam, Kerala 686635, India

³ Indian Institute of Information Technology, Design and Manufacturing, Kancheepuram,
Tamil Nadu, India

Abstract. A detection system for the diagnosis of Schizophrenia using machine learning and deep learning techniques are used in this study. Schizophrenia is a brain disorder which can be identified by various symptoms. Most common symptoms of Schizophrenia are speech disorder, laughing without any reason, crying without any reason, poor memory, lack of motivation etc. EEG signals are collected from human brains by placing electrodes (metal discs) on the scalp using a device named Electroencephalogram. It measures electrical activity of the brain, and the data is represented in the form of EEG signals. EEG signals are mainly used to study various diseases of the human brain. EEG signals of 14 healthy persons and 14 Schizophrenia patients are used. One machine learning classification algorithm, i.e. logistic regression and two deep learning models, i.e. convolutional neural network (CNN), and combination of multiple layers of convolutional neural networks and gated recurrent unit (GRU) are used to analyze the signals. Manual features are extracted from EEG signals and then feed into logistic regression to classify the signals. Extraction of Mel Frequency Cepstral Coefficient (MFCC) feature is done. Deep learning models are used to classify the EEG signals.

Keywords: Schizophrenia · EEG · MFCC · Features extraction · Logistic Regression · CNN · GRU

1 Introduction

1.1 Background

Diseases can be diagnosed by using biological markers, and doing laboratory tests, or by using imaging techniques. However, based on the interviews with patients and using the behavior of a patient, disease can be diagnosed. Schizophrenia (SZ) is a mental disorder which can be diagnosed in people of any age. It stops normal thinking, behavioral characteristics, and speech of a person. Symptoms of Schizophrenia include speech disorganization, hallucinations, and deterioration of functional work etc. Environmental

dangers like low birth weight, premature birth, exposure to a virus at early age of life, and migrant status hampers the development of the brain, which can lead to Schizophrenia. However, since SZ depends on genetic factors, individuals having the genes zinc finger 804 A and Neurogranin have a greater chance of developing it. Life quality needs to be compromised when a patient is suffering from Schizophrenia, because most of the Schizophrenia patients are not able to live a normal life, twenty to forty percent of the patients try to attempt suicide. Therefore, timely diagnosis of Schizophrenia is very important. Schizophrenia Patients desire a good treatment for the recovery. Brain waves have various bands of signals. EEG signals are categorized into five basic groups: delta band (1–4 Hz), theta band (4–8 Hz), alpha band (8–12 Hz), beta band (12–30 Hz), gamma band (above 30 Hz). When the frequency of EEG signals are too low, it means the person is in deep sleep. And, when the frequency of EEG signals are too high, it means the person is doing multi-tasking. The idea is to identify Schizophrenia patients using EEG (Electroencephalogram) signals. Electroencephalography (EEG) signals are neural activities and generally the integrals of potentials which draw out from the brain with different frequencies. EEG is one of the main diagnostic tests for Schizophrenia. Also, to detect other brain disorders, EEG plays an important role.

1.2 Motivation

One of the popular neuroimaging technique named multi-modal imaging which is used currently to detect Schizophrenia. These processes are MRI scan, CT scan, functional resonance magnetic imaging, and emission positron tomography. But the above methods are very costly to setup and doing the tests. A combination of all these methods can be used when only one method alone not able to detect the brain disease. But, using a combination of all these imaging devices are very costly, and due to motion artifacts, the images coming from the two different devices may not be of a good quality. Therefore, EEG signals can be used to detect Schizophrenia which is more cost-effective. Electroencephalograms (EEG) signals represent electrical activity of the brain collected by placing electrodes on scalp of humans. The method of detecting Schizophrenia using EEG signals are more cost-effective compared to other proposed methods to detect Schizophrenia. In comparison to neuroimaging techniques, when EEG signals are used to detect Schizophrenia, then there is no need for any costly machines like MRI scan and CT scan which are generally used in neuroimaging techniques. Instead of using those costly machines, EEG signals can be used to detect Schizophrenia patients. To collect EEG Signals, only EEG (Electroencephalogram) machine is needed whose cost is much less compared to MRI and CT Scan machines. The models used in this paper gives a good accuracy which can be implemented in real life to detect Schizophrenia patients.

2 Literature Review

D. Ahmedt-Aristizabal et al. [1] the prospective identification of childrens who have more chances of developing schizophrenia is an important thing to do early inventions of Schizophrenia. Classification algorithms like KNN and SVM are compared with LSTM to see the improvement in the accuracy using LSTM model to identify schizophrenia within childrens.

S. Roy et al. [2] it used recently released “TUH Abnormal EEG Corpus” dataset for finding out the performance of the algorithms used. It Focused on proper identification of EEG signals. Various differences can be observed between a normal EEG and abnormal EEG. It pre-processed the EEG dataset and applied mean, median and standard deviation to classify the EEG dataset and use GRU model.

T. Wang et al. [3] it focuses on the initial stage in interpreting EEG signals to check if the activity of brain is normal or abnormal. To solve this task, it proposed a RNN architecture known as ChronoNet which focused on the area of image classification and depending of the features extracted from the images it predict the results.

M. Tanveer et al. [4] based on analyzing the schizophrenia patients based on deep belief networks (DBNs). The proposed method is evaluated in the biomedical research center using the database. The region of ventricle from the normal and Schizophrenia images is divided into segments using a method named as multiplicative intrinsic component optimization.

R. L. Miller et al. [5] dataset consist of MRI images (series of X-ray images) to detect Schizophrenia. Dataset consist of a large MRI images having ($x = 631$, including 246 schizophrenia patients from six imaging resources), and a functional connectivity of features was developed using deep discriminant autoencoder network to make difference between schizophrenic patients from healthy persons.

Analysing EEG data is a cost-effective way to detect Schizophrenia. In CT and MRI scan, a series of brain images are captured. Then features are extracted from those images to detect Schizophrenia, which is less effective in detecting abnormality compared to extracting features from EEG dataset. Analysing EEG signals will give more accurate results compared to images, because EEG signals are collected directly from human brain.

3 Implementation

3.1 Proposed Solution

One machine learning algorithm and two deep learning models are used for detecting Schizophrenia. EEG signals are non-linear in behavior, so, the extraction of the features is done to make difference between the EEG signals of healthy persons and Schizophrenia patients. Since there are only two target classes, i.e; when a person is suffering from Schizophrenia (YES) and another target class is person is healthy (NO), so Logistic Regression is used which is a binary classification machine learning algorithm. Here extraction of mathematical features is done manually and feeds the features in the Logistic Regression. When the frequency of EEG signals are in between 25 Hz to 40 Hz, it means that time person is doing multiple thinking. So, bandpass frequency filter is applied to the EEG signal, and only the signals lies in between 25 Hz to 40 Hz will be considered to train into the models. Due to applying bandpass frequency filter, it is giving more accurate results compared to many previous proposed solutions. MFCC feature extraction is also done before training the models. In MFCC feature extraction process, time-domain EEG signals are converted to frequency-domain EEG signals using Fast Fourier Transform. Deep learning models are also used, i.e. CNN and combination of

multiple layers of CNN and GRU. In deep learning, the extraction of features and classification methods both happens by itself. CNN is one of the most powerful technique in deep learning that is attracted by the researchers for the identification of EEG signals which are abnormal and to study those signals to detect disorders like seizure, mental depression and Schizophrenia.

3.2 Block Diagram

First, the raw EEG data is taken. After pre-processing (applying bandpass frequency filter), a pre-processed dataset is generated. From the pre-processed dataset MFCC features and manual features are extracted, and applied one machine learning algorithm and two deep learning models (Fig. 1).

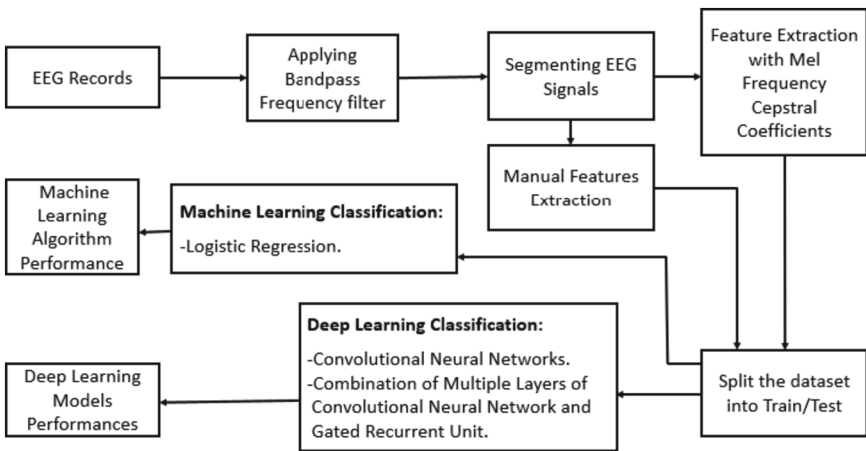


Fig. 1. Block diagram of proposed method

3.3 Data Pre-processing

In the dataset, EEG signals of 14 patients suffering from Schizophrenia, number of male patients were seven and number of female patients were seven, with an average age of 27 and 28 years. And EEG signals of 14 healthy persons were collected of the same age group. So, the dataset contains the EEG signals of 28 people, out of which 14 are Schizophrenia patients and 14 are healthy persons. For each person the data was collected for fifteen minutes at a sampling frequency of 250 Hz. The dataset contains the raw EEG data. At first, preprocessing is done on the EEG data to get the preprocessed dataset. The electrodes (channels) which were used to collect the signals are: Fp2, Fp1, F3, F4, F7, Fz, F8, C3, T3, Cz, T4, C4, T5, T6, Pz, P3, P4, O2, O1.

Since the signals are taken for fifteen minutes, the signals are then divided into segments or epochs. Each segment is of length 25 s, so, the number of samples become 6250. Bandpass frequency filter is applied on the dataset to remove the artifacts and to consider only those signals which are between 25 Hz and 40 Hz.

3.4 Feature Extraction

Features extracted from EEG dataset are: mean, standard deviation, peak-to-peak, variance, minimum value, maximum value, index of minimum value, index of maximum value, kurtosis, skewness and root-mean-square. Features are concatenated and fed into Logistic Regression. MFCC features are spectrum of frequencies of the signals. In MFCC feature extraction, time-domain EEG signals are converted to frequency-domain EEG signals. The total number of MFCC coefficients used are 13. And, 1st derivatives as well as 2nd derivatives of the MFCC features are concatenated before training the deep learning models.

3.5 Logistic Regression

Logistic Regression is a machine learning classification algorithm which is generally used for binary classification. Since in this topic, there are only two target classes, that's why logistic regression has been used, because it's a binary classification algorithm. To increase the accuracy different sets of features which are extracted from the EEG dataset are used to check which sets of features is giving more accuracy (Fig. 2).

$$f(x) = \frac{1}{1 + e^{-x}}$$

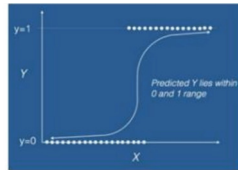


Fig. 2. Logistic Regression function

Logistic Regression use a Logistic/Sigmoid Function to predict the output as 0 or 1, i.e. where, x is the independent variable through which input features are feeded and $f(x)$ is a dependent variable which is the output and it's value always lies in between 0 and 1. A threshold value of 0.5 is taken. So, if the value of $f(x)$ is less than equal to 0.5 then it is considered as 0 (means person is healthy). And if the value of $f(x)$ is more than 0.5 then it is considered as 1 (means person have Schizophrenia).

3.6 Convolutional Neural Networks

Layers in Convolutional Neural Network:

- Filter (Convolution Layer):** In CNN, there are various filters and the values for each filter in the convolutional layer is obtained by training on a particular training set. After the training, a unique set of filter values will be generated that are used to detect specific features in the dataset.
- Pooling Layer:** This layer is for reducing the feature map dimensions. Thus, the parameter's count decreases using this layer. So, it reduces computational work in the network. There are two types of pooling. It finds out all the features present in feature map which is produced by the previous layer.
- Fully Connected Layer:** This layer is a neural network. Each of the neurons uses a linear transformation and fed in the input vector via a matrix. So, layer-to-layer all possible connections are present, means all vectors of input have effect on every vector of output (Fig. 3).

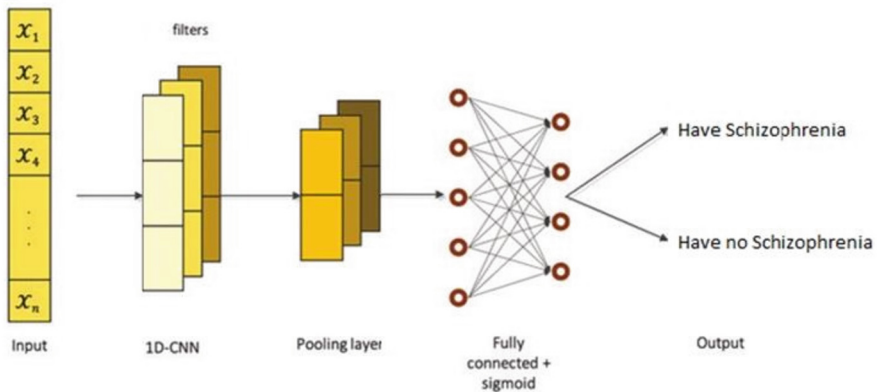


Fig. 3. Layers of Convolutional Neural Networks

The dataset is split into training and test data, then the CNN model training is done. Performance is measured in terms of accuracy.

3.7 Combination of Multiple Layers of CNN and GRU Model

Multiple layers of Convolutional Neural Networks and Gated Recurrent Unit is combined together to build the deep learning model. Output of CNN blocks is fed as input to the GRU blocks. This deep learning model gives an excellent accuracy.

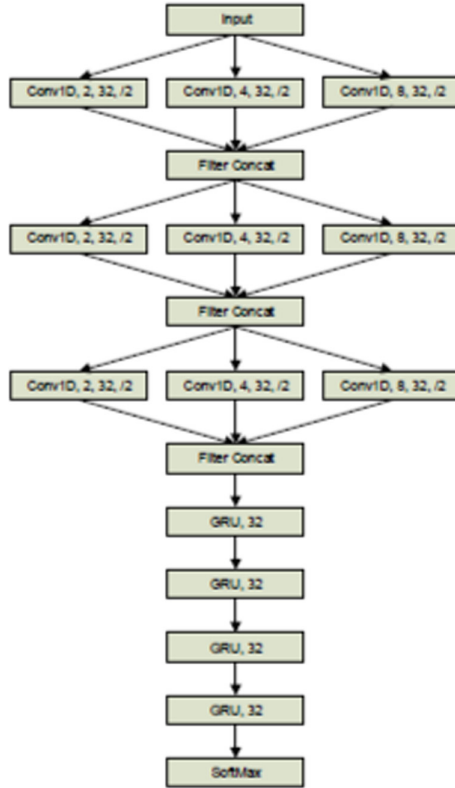


Fig. 4. Combination of multiple layers of CNN and GRU model

The first 3 layers of the model contain CNN blocks. Within each layer 3 CNN blocks are present. After each layer, output of all CNN blocks are concatenated before passing it to the next layer. Total 4 GRU blocks are used in the model with 1 block per layer.

4 Results

Applying the bandpass frequency filter is very much necessary to remove artifacts and external disturbances. Raw EEG signals are shown here, (Collected through 19 channels) before applying the bandpass frequency filter and how they look after applying the bandpass frequency filter in Figs. 4 and 5.

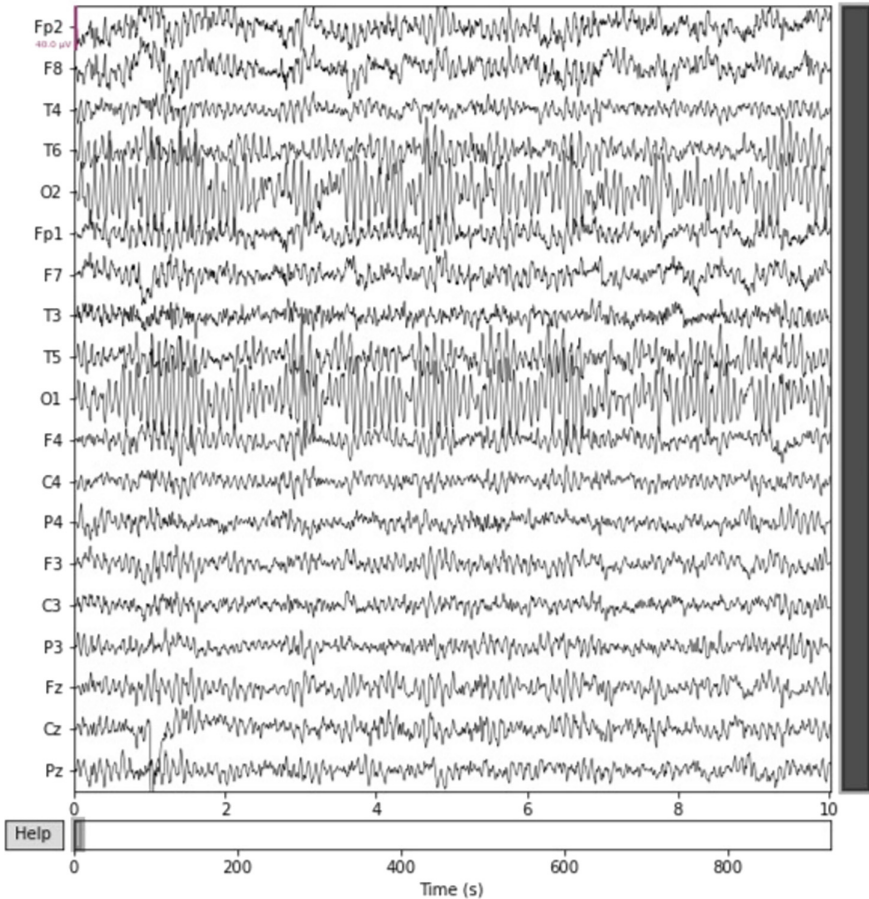


Fig. 5. EEG signals before applying bandpass frequency filter

Here, x-axis represents time and y-axis represents 13 different MFCC coefficients. In the right side, it is the mapping between colours and different numerical values. At each point of the spectrum, it is a value given for MFCC index at a certain point of time (Figs. 6, 7, 8 and 9).

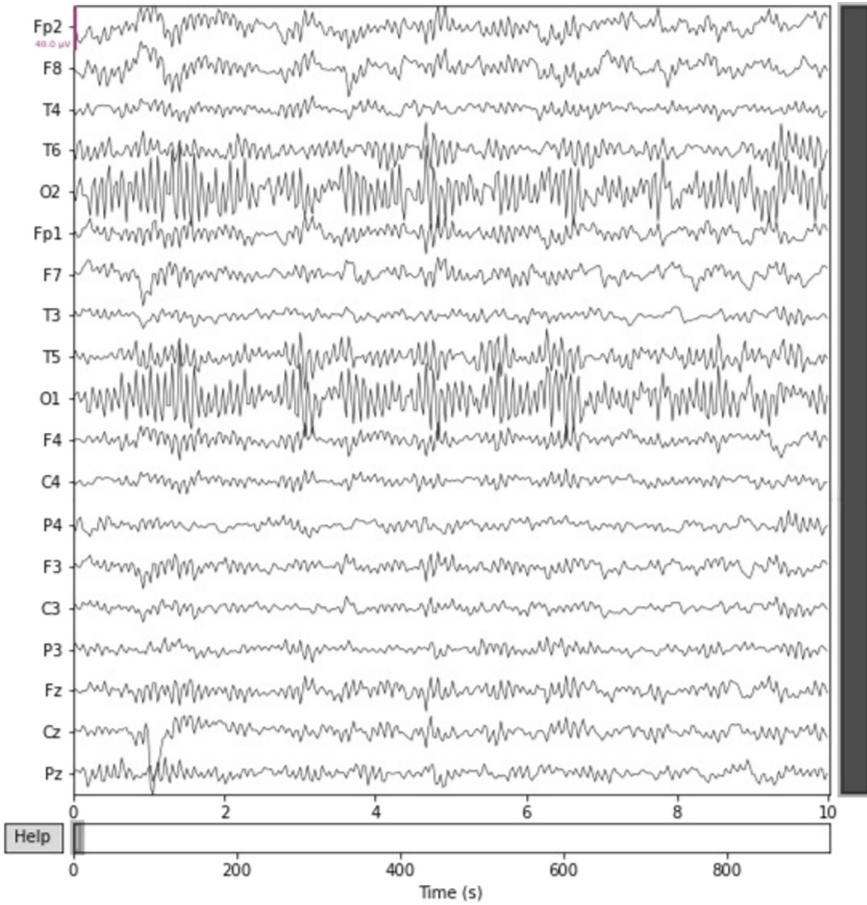


Fig. 6. EEG signals after applying bandpass frequency filter

Logistic Regression gives an accuracy score of 77.3%. The accuracy score of CNN model lies in between 78% and 86% and the mean accuracy is 82.64%. The accuracy score of combination of multiple layers of CNN and GRU model is 96.67% which shown in Table 1

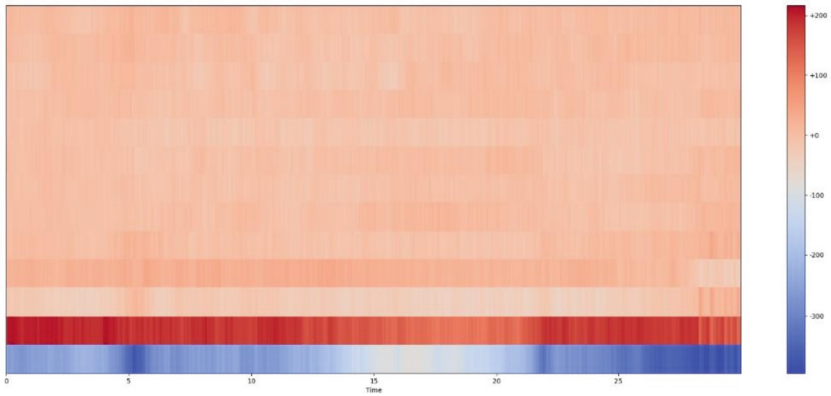


Fig. 7. Spectrum of MFCC features

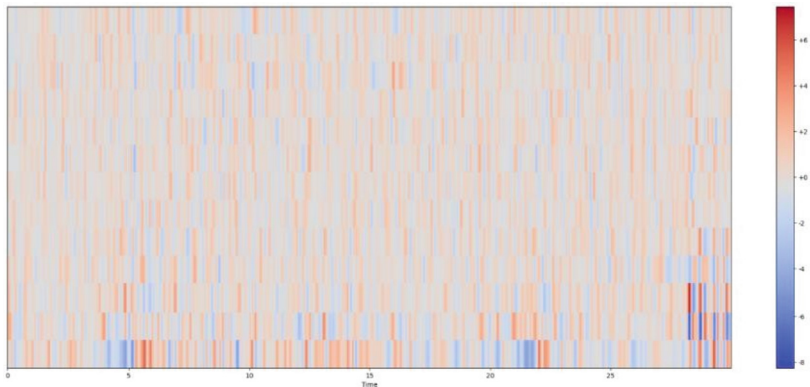


Fig. 8. 1st derivatives of MFCC features

From the above results, it can be clearly seen that combination of multiple layers of CNN and GRU model has outperformed the Logistic Regression as well as CNN model, because of its multiple layers in the model configuration.

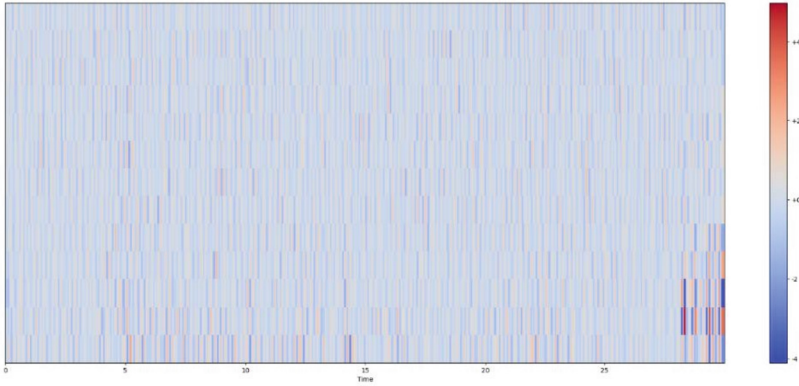


Fig. 9. 2nd derivatives of MFCC features

Table 1. Performance comparison between machine learning & deep learning models

Model	Accuracy
Logistic Regression	77.30%
CNN	82.64%
Combination of multiple layers of CNN and GRU	96.67%

5 Conclusion

In this paper successful implementation of Schizophrenia detection is done using Logistic Regression, Convolutional Neural Network, and combination of multiple layers of CNN and GRU. In the proposed models different sets of features are used which are extracted from EEG dataset. The proposed models are giving better results in many scenarios compared to other models. The proposed models predict good accuracy compared to other Schizophrenia detection techniques.

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