Original Article

Prediction of Parkinson's disease from Voice Signals Using Machine Learning

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Abstract

Parkinson's Disease(PD) is a common neurological condition related to the Central Nervous System, that influence the motion of an individual. Normally, Parkinson's Disease Patients have low voice volume with monotone quality. To automate the prediction of this neurological condition, audio signals from the UCI dataset repository had been taken. The major features like Harmonic/Noise Ratio, Jitter, Noise/Harmonic Ratio, Shimmer etc were extracted for the study. In the prior work, an accuracy of 83% was obtained by the LSTM based model on this dataset. To enhance the model accuracy, a combination of CNN and LSTM were employed in this work. From the proposed study it was analyzed that the combination model was capable exhibited a better classification accuracy of 85% when compared to the traditional machine learning model like Support Vector Machine and Recurrent Neural Network like LSTM.

Index Terms— Machine Learning, Deep Learning, Parkinson's Disease, CNN, LSTM.

INTRODUCTION

Human brain controls all the major functions of the body like Memory, Emotions, Intelligence, Speech etc. Recently, Neuro-scientists have made a big leap in understanding the neurological disorders associated with the brain. Among these, Parkinson's Disease[1] is a common neurological condition which is occurred due to the depletion of dopaminergic neurons in the brain. One of the factors affecting PD is age. Most of the people develop the disease at the age of 60s but more than 5 to 10 percent of the people have "early-onset"disease. Recently, a survey on the risk rate of COVID-19 virus in Parkinson's people was conducted from March-May 2020 in Bologna, Northern Italy. It was noticed that the three-month hospitalization rate and thirty-day mortality rate of patients suffering from both COVID-19 and Parkinson's Disease was 0.6% and 35% respectively [2].

PD occurs when Basal Ganglia neurons, responsible for the control of movement, become impaired. These neurons induce a vital organic chemical called dopamine. Due to the depletion of these neurons, less dopamine is produced resulting in the inhibition of movements. The neuronal pathway of PD can be found in [3]. Studies are still underway to find the reasons for the destruction of cells that produce dopamine. One reason may be the deposit of Lewy bodies (an unusual clumps of the protein alpha-synuclein) between these neurons. Hoehn and Yahr scale helps to monitor the course of Parkinson's and the degree of disability. Unified Parkinson's Disease Rating Scales measures the progress of Parkinson's symptoms and disability [4].

PD has an adverse effect on the speech of an individual. Most PD patients speak slowly and usually give slur speech. The motor defects like stooped posture and low facial expressions are found to be responsible for speech problems. Apart from this, memory, thinking and cognitive problems may also lead to speech impairments. Thus the combination of motor and non-motor deficits results in speech impairments. The modalities for treatment of these impairments include Deep Brain Stimulation, Vocal Fold Augmentation [5] etc. The details of speech and swallow problems is given in [6].

The studies on this neurological condition were fueled by various techniques in the sphere of Artificial Intelligence. To refine the overall accuracy of PD diagnostic procedures, different machine learning models were also implemented to recognize the speech impairment.

In a similar work, Parkinson's Disease was predicted with traditional Machine Learning classifiers like eXtreme Gradient Boosting(XGBOOST) and Logistic Regression classifiers [7]. Another traditional classifier, SVM is capable of classifying audio signals with good accuracy. In a related work, the classification of PD and Essential Tremor(ET) were performed with the help of SVM classifier [8] [9]. A study on the symptoms of PD had been demonstrated with the classifiers like K Nearest Neighbor, Naive Bayes and Random Forest. Studies

showed that Random Forest performed well when compared to other models [10]. In another related work, early stage PD was detected by adopting the fuzzy K Nearest Neighbor method [11]. With the arrival of big data era, Deep learning has made major breakthroughs in the prediction of PD. In a related work [12], deep neural networks were trained to predict the PD condition. Deep Convolutional Neural Network like Alexnet was used to predict this disease and the average accuracy was found to be 89% [13]. In a similar work [14], Isosurfaces were used to implement the PD classification system with the help of AlexNet and LeNet. A study on PD detection with CNN and associated signal processing is given in [15]. PD detection with LSTM model is given in [16]. In a related work [17], CNN-LSTM combination exhibited an accuracy of 77.8%.

About 90% of the Parkinson's patients develop speech impairments. In this work, the features from the voice signals of the PD patients had been extracted for diagnosis. It was observed that the combination of CNN and LSTM gave a better classification accuracy of 85% and precision of 84%. Moreover, the result was also compared with LSTM exhibiting an accuracy of 83% and SVM with an accuracy of 81%. Eventually, from the study it was observed that a better classification accuracy was obtained with the combination model when compared to other two models.

METHODS

Features Extracted

Initially the features like Shimmer, Jitter, NHR, HNR, RPDE DFA and PPE were extracted from the voice signals with the help of voice signal pre-processing algorithms like Mel Frequency Cepstrum Coefficient(MFCC), Time Fre- quency Features, Vocal Fold Features etc. Fig.1 shows the architecture of the proposed model.

Algorithms used

In this study, Parkinson's Disease was predicted from voice signals using traditional ML model like SVM and Deep Neural Networks namely LSTM and CNN.

Support Vector Machine is an effective traditional classifier that is well designed to classify the audio signals. It works well in higher dimensions and also known as margin classifier. The maximum margin solution helps SVM to perform well when compared to other non-linear classifiers even in the presence of noise. In a related work [18], MFCC coefficients were extracted from the speech signals before using the SVM classifier.

Convolutional Neural Network is a deep neural network that can easily learn high level features with high complexities automatically. The pooling layer in CNN is capable of handling even the small frequency changes. So it is well suited for audio signal classification. The major layers in CNN helps to improve the accuracy of the classification [19].

Long Short Term Memory is mainly designed for sequential input. Since it can easily learn the long term dependencies of data, LSTM is more powerful than the basic RNN Architectures. The forget gate, update gate, output gate and the memory cell makes it efficient to work on time series data. In a related work [20], LSTM based model had been used for PD detection.

In the proposed study, in order to take the advantage of CNN and LSTM models, both of them were combined and used. The CNN model helped in the abstraction of complex features and LSTM model helped in classification. In a related work, CNN-LSTM was used to detect diabetes from heart signals [21].

Dataset Used

In this paper, the dataset used for the automation of PD prediction was Parkinson's Disease classification audio signal from UCI Machine Learning repository. This data was taken from 188 PD patients, ages approximately ranging from 33 to 87. The microphone was set to 44.1khz during the process of data collection. From each PD patient, the utterance of the letter /a/ was gathered with three repetitions. The different speech processing methods like Vocal Fold Features, Mel Frequency Cepstral Coefficients(MFCC), Time Frequency Features etc were used for the extraction of clinically relevant features for the study.

Model Evaluation Metrics Used

The model had been evaluated using various performance metrics like Precision, Recall, F1-measures and ROC-curve. The number of samples correctly classified from each class gives the precision measure. Recall measure gives the number of correctly predicted positive samples from all the samples in the class. Precision and Recall measures can be combined to get the F1-score. ROC-curve evaluates the model performance at all classification thresholds.

RESULTS AND DISCUSSIONS

The results are discussed in detail based on the methods mentioned above. In order to avoid the bias in the results (PD and Normal), it was checked whether the train and test splits have the same distribution of data from each class. Ten fold cross validation had been used for evaluation, where 80% had been taken for training and 20% for testing.

All the models used in the work were trained with a learning rate of 0.0001 for 20 epochs and batch size of 128. The loss function and the optimizer used were binary cross entropy and RMSprop. These parameters helped the

combination model CNN/LSTM to meet the accuracy of 85% in twenty epochs. The accuracy graph is shown in Fig. 2 and ROC curve is shown in Fig 3.

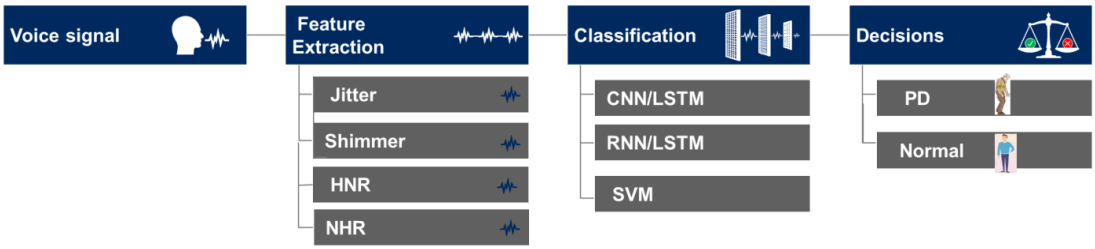

Fig. 1. Architecture of the Proposed Model

TABLE I : CONFUSION MATRIX OF CNN/LSTM MODEL

	PD	***Normal***	***Rate(%)***
PD	26	2	85
Normal	5	15	85
Precision(%)	84	88	

TABLE II : COMPARISON OF PRECISION MEASURES OF CNN/LSTM WITH OTHER MODELS

Models	***PD***	***Normal***
SVM	81	82
LSTM	89	70
CNN/LSTM	85	76

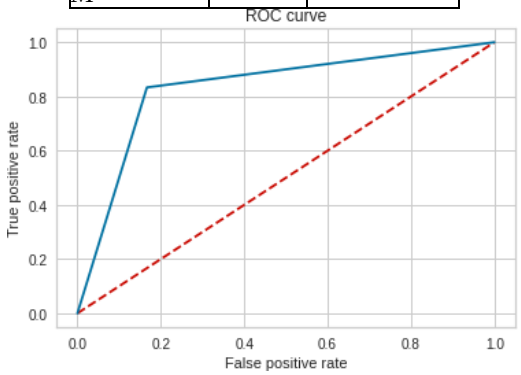

Fig. 3. ROC curve of CNN/LSTM

Confusion matrix shown in Table.1 gives a comprehensive analysis of the result. Out of 48 test data, 41 were correctly classified and only 7 were misclassified. Other models like LSTM and SVM were also included for the study. The model accuracy of LSTM was shown in Fig. 4.

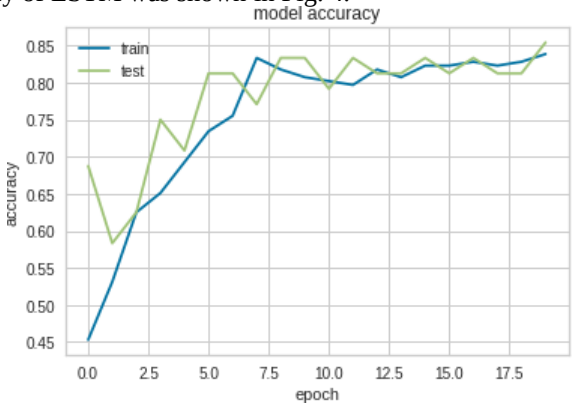

Fig. 2. Learning trend of model CNN/LSTM giving an accuracy of 85%

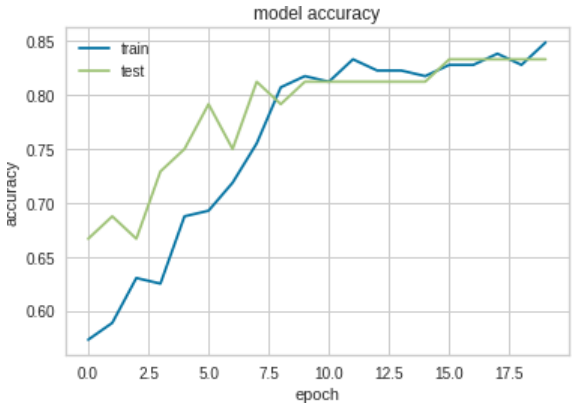

Fig. 4. Learning trend of model LSTM giving an accuracy of 83%

The performance analysis of the model with different metrices were also included in Table. II, Table. III and Table. IV respectively. Eventually, the overall accuracy measures of the models being used are also depicted in the Fig. 5.

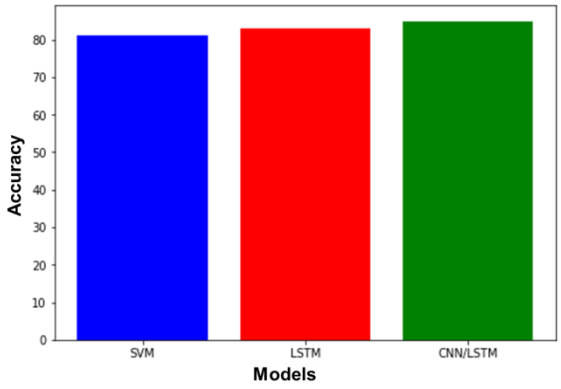

Fig. 5. Accuracy Comparison

TABLE III : COMPARISON OF RECALL MEASURES OF CNN/LSTM WITH OTHER MODELS

Models	***PD***	***Normal***
SVM	89	70
LSTM	89	75
CNN/LSTM	93	75

TABLE IV. COMPARISON OF F1-MEASURES OF CNN/LSTM WITH OTHER MODELS

Models	***PD***	***Normal***
SVM	85	76
LSTM	86	79
CNN/LSTM	88	81

From the demonstration result, it was observed that the traditional model SVM showed an accuracy and precision of 81%. The deep Recurrent Neural Network, LSTM gave an accuracy of 83%. Finally, the combination of CNN and LSTM models exhibited a better classification accuracy of 85% and precision of 84%.

CONCLUSION

In this work, Parkinson's disease was predicted from the voice signals of PD patients with the help of traditional Ma- chine Learning classifiers and Deep Neural Network models. It was found that the combination model CNN-LSTM produced a better classification accuracy and precision of 85%. Thus an efficient PD prediction is possible by hyper tuning the parameter values and combining the models.

REFERENCES

1. S., &; Park, J. (2020). A supervised machine learning approach to detect the on/off state in Parkinson's disease using wearable based gait signals. Diagnostics.
2. Cai, Z., Gu, J., Wen, C., Zhao, D., Huang, C., Huang, H., . . . Chen, H. (2018). An intelligent Parkinson's disease diagnostic system based on a chaotic bacterial foraging optimization enhanced fuzzy knn approach. Computational and Mathematical Methods in Medicine, 2018.
3. Srishti Grover, Saloni Bhartia, Akshama, Abhilasha Yadav, Seeja K.R., Predicting Severity Of Parkinson's Disease Using Deep Learning, Procedia Computer Science.

4. Aich, S., Youn, J., Chakraborty, S., Pradhan, P. M., Park, J., Park, S., &; Park, J. (2020). A supervised machine learning approach to detect the on/off state in parkinson's disease using wearable based gait signals. Diagnostics.
5. Ortiz, A., Munilla, J., Mart´ınez-Iban˜ez, M., Go´rriz, J. M., Ram´ırez, J., &; Salas-Gonzalez, D. (2019). Parkinson's disease detection USING isosurfaces-based features and convolutional neural networks. Frontiers in Neuroinformatics.
6. Zhang, Y. (2017). Can a smartphone diagnose Parkinson disease? A deep neural network method and telediagnosis system implementation. Parkinson's Disease.
7. Kumar, S., Kumar, M. A., &; Soman, K. (2019). Deep learning based part-of-speech tagging for malayalam twitter data (special issue: Deep learning techniques for natural language processing). Journal of Intelligent Systems.
8. Kaur, S., Aggarwal, H., &; Rani, R. (2020). Diagnosis of Parkinson's disease using deep CNN with transfer learning and data augmentation.
9. Aich, S., Youn, J., Chakraborty, S., Pradhan, P. M., Park, J., Park, S., &; Park, J. (2020). A supervised machine learning approach to detect the on/off state in Parkinson's disease using wearable based gait signals. Diagnostics.
10. Cai, Z., Gu, J., Wen, C., Zhao, D., Huang, C., Huang, H., . . . Chen, H. (2018). An intelligent parkinson's disease diagnostic system based on a chaotic bacterial foraging optimization enhanced fuzzy knn approach. Computational and Mathematical Methods in Medicine, 2018.
11. Srishti Grover, Saloni Bhartia, Akshama, Abhilasha Yadav, Seeja K.R., Predicting Severity Of Parkinson's Disease Using Deep Learning, Procedia Computer Science.
12. Aich, S., Youn, J., Chakraborty, S., Pradhan, P. M., Park, J., Park, S., &; Park, J. (2020). A supervised machine learning approach to detect the on/off state in parkinson's disease using wearable based gait signals. Diagnostics.
13. Ortiz, A., Munilla, J., Mart´ınez-Iban˜ez, M., Go´rriz, J. M., Ram´ırez, J., &; Salas-Gonzalez, D. (2019). Parkinson's disease detection USING isosurfaces-based features and convolutional neural networks. Frontiers in Neuroinformatics.
14. Zhang, Y. (2017). Can a smartphone diagnose parkinson disease? A deep neural network method and telediagnosis system implementation. Parkinson's Disease.
15. Kumar, S., Kumar, M. A., &; Soman, K. (2019). Deep learning based part-of-speech tagging for malayalam twitter data (special issue: Deep learning techniques for natural language processing). Journal of Intelligent Systems.
16. Kaur, S., Aggarwal, H., &; Rani, R. (2020). Diagnosis of Parkinson's disease using deep CNN with transfer learning and data augmentation.
17. Sasidharan Rajeswari S., Gopakumar G., Nair M. (2021) Speech Emotion Recognition Using Machine Learning Techniques. In: Sharma H., Saraswat M., Yadav A., Kim J.H., Bansal J.C. (eds) Congress on Intelligent Systems. CIS 2020. Advances in Intelligent Systems and Computing, vol 1335. Springer, Singapore.
18. Vidya, V., Poornachandran, P., Sujadevi, V. G., &; Dharmana, M. M. (2017). Suppressing parkinson's diseases induced involuntary movements using wearables. 2017 International Conference on Technological Advancements in Power and Energy (TAP Energy).
19. S. S. Rajeswari and M. Nair, "A Transfer Learning Approach for Predicting Alzheimer's Disease," 2021 4th Biennial International Conference on Nascent Technologies in Engineering (ICNTE), 2021, pp. 1-5,
20. N. Aloysius and M. Geetha, "A review on deep convolutional neural networks", in 2017 International Conference on Communication and Signal Processing (ICCSP), Chennai, India, 2017.
21. G, S., Kp, S.,&; R, V. (2018). Automated detection of diabetes using CNN And CNN-LSTM network and heart rate signals. Procedia Computer Science.