Parkinson's Disease Classification Using Deep Convolutional Neural Network Based On Acoustic Signals

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Abstract

Parkinson's disease is one of the neurodegenerative diseases that is actually seen in the elderly compared to the younger ones. Since a patient may have the same behavior compared to a healthy person at the very early stage of the disease, the automatic identification of Parkinson's disease is one of the main medicine-related challenges. Comparison of classifier efficiency in both machine learning and deep learning for the diagnosis of Parkinson's disease through Support Vector Machine (SVM), Random Forest classifiers, and Deep Convolutionary Neural Network (DCNN) is made in stages in this work. The 196 voice samples dataset in.csv format was obtained from the Kaggle database, and the Google Colaboratory framework was used to implement it, and Python is the language we used to implement it. The results reveal the potential of using Random Forest (RF) or Support Vector Machine (SVM) techniques and Deep CNN. Once fit, these algorithms provide a reliable computational method to estimate the presence of PD with a really high accuracy. Through this we measure the classifiers performance.

***Keywords**: Parkinson's disease, neurodegenerative, machine learning, deep learning, SVM, RF classifier, DCNN, Kaggle database, Google Collaboratory, Python.*

I. INTRODUCTION

A common progressive neurodegenerative disorder is Parkinson's disease. It has a significant disability and a negative impact on quality of life. This is a long-term degenerative condition that can affect the motor system, linked to the central nervous system. Non-motor symptoms become more frequent as the disease gets serious. Over time the signs usually develop gradually. Symptoms such as trembling, stiffness, movement slowness, and trouble with walking are typically seen in the early stages of the disease. There may also be improvements to thought and behavioral issues. In the later stages, dementia gets normal. Depression and anxiety are the most common symptoms seen more in a third of the population. A few more symptoms are also rarely seen in some people other than the above mentioned symptoms, which include sensory, sleep, and emotional problems. These symptoms are called "Parkinsonism" or "Parkinson 's Syndrome" collectively. Both tauopathies and synucleinopathies there is substantial amount of clinical and pathological overlap. In comparison to the agitans of paralysis, amnesia is common in Alzheimer's disease, and thus the cardinal symptoms of agitans of paralysis (slowness, tremor, stiffness, and postural instability) are not normal features of Alzheimer's.

II. RELATED WORK

Several researchers suggest various computer strategies over the course of a day to diagnose parkinson's disease. Evaldas Vaiciukynas and Antanas Verikas[1] extracted the signals for screening the Parkinson's disease from the repeated phoning and text-dependent speech modalities. Signals were recorded using both Acoustic Cardioids (AC) and Smart Phone (SP) microphones simultaneously over two channels. Additional modalities were obtained by separating the resulting input (speech recording) into voiced parts and unvoiced parts. Random forest (RF) is used as an algorithm for machine learning for

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both individual feature sets and fusion at decision-level. The detection efficiency is calculated using the Equivalent Error Rate (EER) out-of-bag and the log-likelihood cost ratio. When compared to the SP microphone, detection performance was consistently better for the AC microphone. D Braga et al[2] used the techniques of signal and speech processing integrated with the algorithms of machine learning. During the training and evaluation stage three distinct speech databases are used to estimate the parameters. The results reveal the potential for using Vector Machine techniques in Random Forest and Support. The best results were obtained using the predictive model developed by an RF algorithm, which resulted in a classification result of approximately 85.75%. Saloni, R.K.Sharma, and A.K.Gupta[3] classified healthy people and Parkinson sufferers using certain voice features from data mining. In this process SVM is used as a classifier. It is very important to choose a proper subset size and features that included both things properly to get good classification. Accuracy of 94 % is reached when all 15 features selected have been taken. David Gil. A and Magnus Johnson. B[4] assessed the performance of the classifier, which is constructed through Artificial Neural Network and SVM. The results presented with the two kernel types by multilayer perceptron and SVM are of a high level of precision. The classifiers' precision would be improved by removing a number of outliers from both minority and majority classes, and by the size of the minority class to the same size of the majority class. Accuracy is reached by 89%. Mohammad Islam, Imtiaz Parvez and Hai Deng[5] performed a comparative study to effectively diagnose PD using various voice disorder machine-learning classifiers, and this condition is known as dysphonia. To be successful in investigating robust detection process, three independent classifier topologies were used to differentiate the characteristic features between a patient with PD and a healthy person. As a result the results obtained are correlated with one another. Chen Y.W. and Lin C.J. [6] proposed an article examining the performance of the Support Vector Machine (SVM) combination and various feature selection strategies. Phan, Huy, Marco Maaß, Radoslaw Mazur and Alfred Mertins[7] suggested a regression approach to the random forests. Given the success of the automatic speech recognition program within its own operating area, its adaptation to the acoustic event detection problem has resulted in limited success. This paper presents it as a regression function instead of addressing the problem in a manner similar to the tasks of segmentation and classification in speech recognition.

Benba A, Jilbab A, Hammouch A[8] used a variety of voice samples per subject with multiple forms of voice recording to establish an early diagnostic system and to create predictive telediagnostic and telemonitoring models. Acoustic signal representations are used specifically for studying the effect of Parkinsonism on the phonological system. Nonetheless, the findings show that some of the voice samples are not accurate measures of the state of a subject during the different processing stages. However certain criteria will neither indicate the existence of the disorder nor differentiate it from the stable subjects for Parkinson's patients. The best result obtained with running speech samples along with the measurement of jitters was 82.5%. Hamid Karimi Rouzbahani and Mohammad Reza Daliri[9] extracted specific features that were fed to different classifiers to enable them to determine whether or not the subjects had the disease. Zhang H, Yang L, Liu Y, Wang, Yin J, Li Y, Yan F[10] used a combination of Multi-Edit-Nearest-Neighbor (MENN) algorithm and an ensemble learning algorithm to propose and examine this. Next, the MENN algorithm is implemented to iteratively pick the optimal training speech samples so we can obtain the samples with a high degree of separability.

Consequently, PD detection is complex, researchers have suggested a convolutionary neural network to detect parkinson's disease. Froelich, W.Wróbel, K.Porwik[11], dealt with the problem of early diagnosis of Parkinson's disease by classifying characteristic features of the voice of a person. A new, two-step approach to classification is proposed. The proposed two-step classification method also allows for dealing with the variable number of voice samples obtained for each patient. Preliminary tests showed very acceptable accuracy in the classification obtained during the cross-validation leave-one-out.

Ossama Abdel-Hamid, Abdel-rahman Mohamed, Hui Jiang, Li Deng, Gerald Penn and Dong Yu[12] presented measures to reduce the rate of error by using convolutionary neural networks (CNNs) to a greater extent. First they gave a short description of the basic CNN and how it can be used further in

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speech recognition. They also suggested a weight-limited sharing system that might help model features of the speech. Tara N Sainath, Abdel-rahman Mohamed, Brian Kingsbury, Bhuvana Ramabhadran[13] discussed the advantages of applying CNNs to vocabulary tasks on a large scale. Convolutionary Neural Networks (CNNs) are an alternative form of neural network that does not reduce the spectral variations and model spectral correlations that occur in signals. CNNs are a simpler model for speech compared to Deep Neural Networks (DNNs), as speech signals exhibit both of these properties. Tsanas A, Little M.A, McSharry P.E, Spielman J, Ramig L.O[14] suggested ways of testing how these novel algorithms can be directly used to discriminate against PD subjects from secure controls. In total, 132 dysphonia tests from sustained vocals have been computed. E Vaiciukynas, A Gelzinis, A Verikas[15] used Convolutional Neural Networks (CNN) to investigate the efficacy of different segments of a speech signal, such as text, based pronunciation of a short sentence in the task of Parkinson's disease detection. Spectrograms and several other types of short-term features were considered to be stacked into the CNN with two Dimensional (2D) inputs.

III. MACHINE LEARNING BASED PARKINSON'S DISEASE

Parkinson's disease early detection approaches use signals and speech recognition techniques that are combined with machine learning algorithms. The findings demonstrate the advantage of using Random Forest (RF) and Support Vector Machine (SVM) classifiers. Illustration. 1 Shows design of PD Detection based on current machine learning.

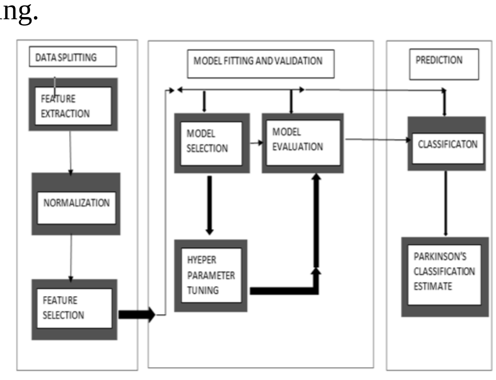

Fig 1. Architecture proposed machine learning based Detection

Through Deep Convolution neural network, the proposed system compares the machine learning technique through supporting vector machine and random forest algorithm, and deep learning technique. This approach is separate from the framework and offers improved precision, reduced time complexity and we can obtain the results of more than one thousand samples at a time. Fig 2. Shows architecture of proposed method

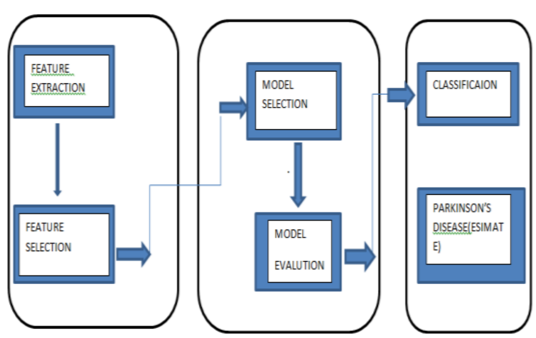

Fig 2. Architecture of proposed method

A. SUPPORT VECTOR MACHINE

The SVM, first proposed by Boser et al . (1992), is a type of supervised learning algorithm with the objective of separating large amounts of data by using the concept of hyperplanes and margins, based on

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the principle of Structural Minimisation Risk. The learning algorithm tries to maximize the street (margin) around the hyperplane dividing that separates a given data into the specified classification.

This effect is achieved with the help of vector support points, which can be described as collection of points with the lowest distance to the hyperplane dividing. These points have a direct influence on the decision plane's optimal position, since they directly influence the decision function (Berwick, 2003). Definition of the decision function is interpreted as a problem of quadratic programming that can be solved using standard methodologies.

Then a subset of the training data, called the support vectors, defines the resulting function. When comparing the SVM with other learning algorithms, it can be observed that these have the advantage of being efficient in high-dimensional data; revealing good flexibility in terms of kernel function utilization and memory requirements. However, if the data is not scaled previously, the SVM exhibits a significant reduction in performance.

The key advantages of the Help Vector Machine Classification Algorithm are
1. Less than two classes can be categorized there.
2. It will be able to process unstructured data.
3. Data segmentation is fast and rapid.

B. RANDOM FOREST CLASSIFIER

Random forest decision technique is a way to assemble multiple decision trees as shown in Fig.3. When applying the parkinson's disease prediction technique it provides greater precision than comparing the previous techniques. Random forests of decision, are used to construct predictive models for problems of classification and regression. Decision tree is one of the most common machine-learning methods. They 're used to learning extremely irregular patterns. We have a low state of bias, but rather high variance. It is used to average multiple deep decision trees, and is trained on parts of variety of the same training set to reduce the variance. This results in a small increase in bias and some loss of interpretability but will boost the model's performance.

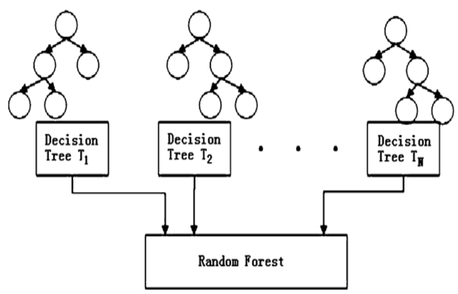

Fig 3. Process flow of Random forest

Random forest technique

It is used to combine several deep decision trees, and is trained to reduce the variance on sections of variety of the same group. This will result in a slight increase in bias and some loss of interpretability but will boost the performance of the model.

C. DEEP CONVOLUTIONAL NEURAL NETWORK

The architecture of the Convolutional Neural Network usually consists of a layer of input and output, as well as several hidden layers. A CNN's hidden layers consist of convolutionary layers, namely pooling layers , fully connected layers, or SVM layers, standardization layers, and RELU (Rectified Linear Unit) layers for activation. Neural network uses convention methodology. SVM layer has higher accuracy so it is preferred to other layers for the most part. Mathematically it is not a convolution but a cross-correlation. This only has meaning for the indices in the matrix, and therefore weights are placed at the index.

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Speech recordings from other studies were obtained through recording sessions and databases. Then, each record was labeled with the target prediction class, where, respectively, stable patients and Parkinson's were labeled with the zero and one values. Following the labeling process, the feature extraction, normalization, and selection base was based on the available speech database.

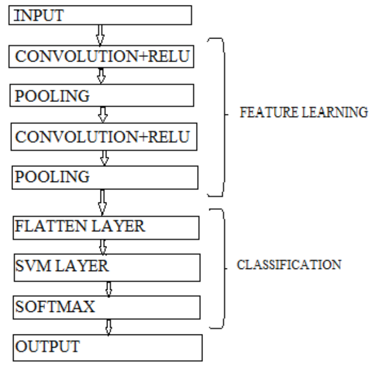

Fig 4. Process flow in DCNN

IV. PROPOSED MODEL

The database, as previously described, consists of three different sources of data, two of which were used for the phase of model generation and the remaining one served as the control group. Extraction of the feature was performed to convert the signal data of the voice into a condensed format which could be interpreted by standard ML algorithms. The resulting data from the extraction of a feature, normalization of feature and selection processes was split into three different types of data: analysis data, training data and test data. The research data contains all speech recordings from the UCI Machine Learning Server, which, as previously mentioned, contains only vowel recording 'o' and 'a' instead of free speech recording. This data were used as the control group, which was used to verify the generalization efficiency of optimized classifiers. For a k-fold cross-validation, the test and train data is split in k-fold.

Various ML algorithms have been applied to the k-folded data to generate several predictive models. These models underwent a process of optimisation which consisted of finding the best values of the hyperparameters of each classifier. Each optimized classifier was evaluated during this process using learning curves, statistical analysis, and data from the analysis. The aim of the statistical analysis was to determine whether there were any substantial differences in output of the optimized classifiers, which served as help for the selection of the best classifier. Each classifier 's final best accuracy was obtained using the cross-validation technique Leave-One-Out. The purpose of the statistical analysis was to decide if there were any substantial differences in the performance of the optimized classifiers, which served as an aid in the selection of the best classifiers. Using the Leave-One-Out cross-validation method, each classifier 's final best accuracy was obtained.

V. EXPERIMENTAL RESULTS:

The proposed model is verified with Random forest, SVM and DCNN and performance are compared.

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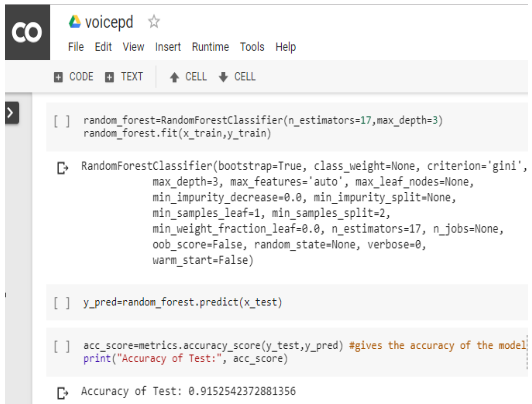

Fig 5 Output of RF

Figure 5 shows RF efficiency. The 91.52 percent accuracy thus obtained is due to the decision trees boosting mechanism implemented in the above algorithm. Boosting is another technique of ensemble which is used to construct a predictor array. Learners are taught sequentially in this method, and the early learners fit basic models into the data and then evaluate the data for errors if present. In other words, we fit the consecutive trees (random sample) and the ultimate goal is to solve the net error from the preceding trees at every step. Figure 6. Shows random forest classification ROC

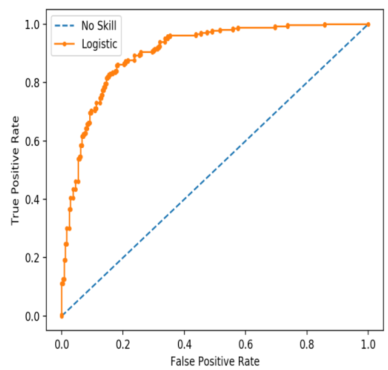

Fig 6 ROC characteristics of Random Forest Classifier

b) SVM Output

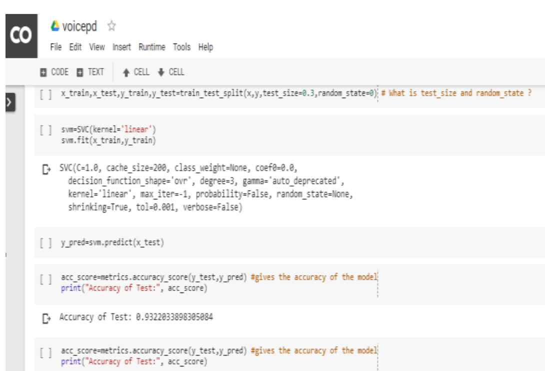

Fig 7 Output of SVM

Figure 7 shows an SVM output. This model reduces the complexity of training data to a small subset of so-called support vectors and the accuracy of these support vectors is about 93.2%. Although the previous approach was pretty much effective, to some degree the accuracy can still be improved and thus support vector was used in the past. Fig 8 shows ROC of Support Vector Machine

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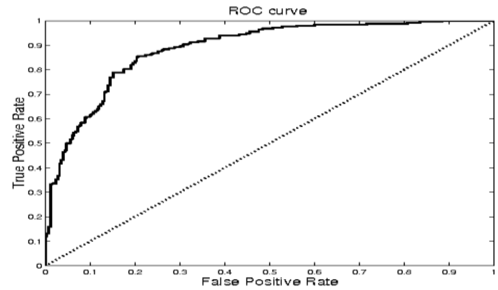

Fig 8 ROC characteristics of Support Vector Machine

c) DCNN output

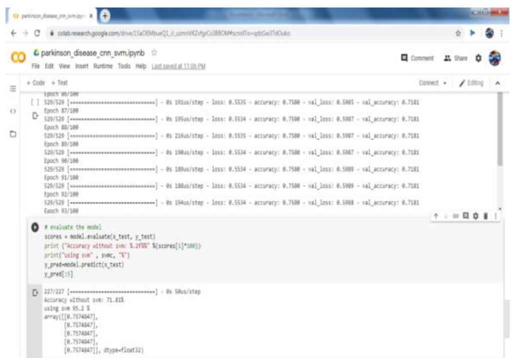

Fig 8 Output of DCNN

Fig.8 lists the DCNN output. Our proposed method is 95.2 per cent accurate, which is far better than previous methods. Not only is the precision good but the processing speed is good as well. With this method, no more samples can be tested in a short span of time, including with greater accuracy. Figure 9 shows DCNN ROC's

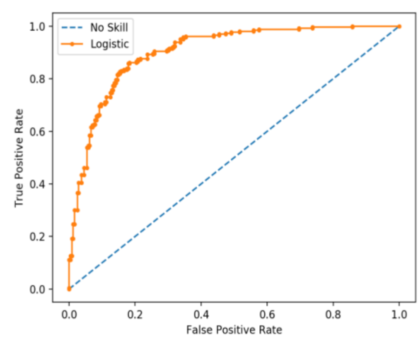

Fig 9 ROC characteristics of DCNN

VI. RESULTS

Table 1 displays SVM, RF, and DCNN uncertainty matrix. It should be noted that Deep Convolutionary Neural Network is more effective compared to other techniques.

The precision determines the best system though this is not the only aspect that describes the best system. Here we also take into account the flexibility and specificity of the structures that define the proportions of true positive and true negatives respectively.

Table 1. Confusion Matrix for SVM,RF and DCNN

Methods	True	True -	False	False -	Accuracy %

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	+ve	ve	+ve	ve	
SVM	139	44	8	5	93.2
RF	140	39	7	5	91.5
DCNN	143	45	4	4	95.2

Table 2. Performance of SVM,RF and DCNN

Methods	**Sensitivity**	**Specificity**
SVM	96.5%	84.6%
RF	96.5%	84.7%
DCNN	97.2%	91.8%

We can see from Table 2 that Deep Convolutionary Neural Network has the highest percentage of specificity and responsiveness that indicates it is the best method.

VII. CONCLUSION

The PD speech dataset has been pre-processed and categorized in this work using Support Vector Machine(SVM), Random Forest(RF) and Deep Convolution Neural Network(DCNN). Multi-Dimensional Voice Program (MDVP) was used to extract the functions.

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