# Parkinson Disease Detection Using Deep Neural Networks

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*Abstract*— **Parkinson's disease (PD) is a neurodegenerative disorder, which is responsible for the deterioration of motor function due to loss of dopamine-producing brain cells i.e. neurons. Tremors, stiffness, slowness in movements, shaking, and impaired balance are some of the primary symptoms of PD. In this paper, two neural network based models namely, VGFR Spectrogram Detector and Voice Impairment Classifier have been introduced, which aim to help doctors and people in diagnosing disease at an early stage. An extensive empirical evaluation of CNNs (Convolutional Neural Networks) has been implemented on large-scale image classification of gait signals converted to spectrogram images and deep dense ANNs (Artificial Neural Networks) on the voice recordings, to predict the disease. The experimental results indicate that the proposed models outperformed the existing state of the arts in terms of accuracy. The classification accuracy on VGFR Spectrogram Detector is recorded as 88.1% while Voice Impairment Classifier has shown 89.15% accuracy.**

***Keywords—CNN, Neural, ANN, Parkinson, Gait, PPMI, Neurodegenerative, UCI***

## I. INTRODUCTION

Everyday there are lots of new cases of Parkinson coming into the hospitals showing different and new symptoms. Parkinson is a very complex problem and there is no proper scale to predict the severity of PD. It is a neurodegenerative disorder that affects the motor functions due to decline of dopamine level in brain and hence effects are being observed physically on the body. The main cause behind the Parkinson disease is that, neurons don’t have the ability to grow again. As the person gets aged, the neurons start dying out and are irreplaceable. Neurons produce a chemical fluid named Dopamine, which is solely responsible for the movement in the body and transmission of signals amongst the neurons. As the Dopamine levels starts dropping with age, the neurological condition starts slowing down, influenced by the various communication modes in the brain. These affects incur very slowly, hence are usually not visible until the patient’s condition is worse. Some of its symptoms are voice impairment, loss of balance, slow movements, unstable posture, stiffness, sleeping, face masking, etc.

WHOs records show that PD has affected around 10 million people around the globe. Patients aren’t diagnosed of it in early stage, resulting in untreatable permanent neurological disorder. In the later stages the disease becomes incurable and results in death in most of the cases. PD affected around 6.2 million people and death toll increased up to 117,400 across the globe in the year 2015. Moreover, the tests for the disease are costly and not accurate. The costs of PD to society is high, the cost incurred per patient in an year in U.S. is approximately $10,000 and the annual cost is $23 billion , while the annual cost in the UK is approximately estimated to be in the range £49 million and £3.3 billion. These facts alarmed a need for a cheap, efficient and an accurate way to diagnose PD in early stages so that a timely treatment could cure the patients before the disease becomes incurable.

This study aims to develop a deep learning model containing 2 modules namely VGFR Spectrogram Detector and Voice Impairment Classifier implementing CNN (Convolutional Neural Networks) and ANN (Artificial Neural Network) respectively, for a cheaper and accurate objective diagnosis of Parkinson Disease in its early stages. It is based on two unique decisive features i.e. walking patterns in the form of its recorded signals depicted as spectrogram and voice impairment. The dataset featured in this project have been taken from PhysioNet Database bank and UCI Machine Repository. The study provides an insight about all the decisive features i.e. various symptoms and takes some of these features as an input to the proposed Neural Networks in order to predict the disease. Moreover it also compares the results of the two modules with three popular machine learning algorithms i.e. XG Boost, Multi Layer Perceptron, and Support Vector Machine. It also presents a critical analysis of the existing technologies which can be integrated together to achieve the goal of Automatic Parkinson Disease Detection.

Remaining of the paper is organized as follows. In section 2, background study is discussed. Section 3 presents research methodology. The results are demonstrated in section 4. Finally, the conclusion detailed in section 5.

## II. BACKGROUND

Many studies have been conducted on the detection of PD, based on various symptoms like olfactory loss, voice impairment etc. Among the studied symptoms, Most of the patients have been reported with vocal impairment and speech problems. Abdullah Caliskan[1], has used deep neural network. First noise is eliminated and segmented with the time-windows during filtering of the speech signals. Various features are extracted from each segment in the second step, followed by DNN classification using Stacked Auto Encoders (sAE). Srishti Grover[2], has used deep learning on Parkinson’s Telemonitoring Voice Dataset taken from UCI ML Repository to classify data uniquely into “severe” and “not severe” classes. The neural net comprises of an input layer with 16 units, three hidden layers with 10, 20, 10 units in each layer respectively, 2 neurons in output layer. The model shows the accuracy of 81.6667%. In [3], the authors have attempted to classify the PD group on the basis of different feature sets, PCA and OFS based feature sets , which form non-linear features on dataset taken from Max little University Oxford. Authors have used non-linear classifiers, Bagging classification, Regression tree

978-1-7281-3591-5/19/$31.00 ©2019 IEEE

(Bagging CART), Random Forest, RPART for classification with an accuracy of 96.83% using RF with PCA. Clayton R. Pereira[4] presented a different approach based on affected writing abilities. The authors proposed a learning of pen-based features with signals extracted from the smart pen containing 6 sensors by means of 2 different CNN architectures i.e. ImageNet, LeNet. The authors reported best accuracy with ImageNet for meanders and OPF for spirals i.e. 83.77%.Another symptom i.e. Decline in the levels of a fluid dopamine produced by brain cells i.e. Neurons, is a pathological hallmark of PD. It can be determined by dopamine transporter imaging i.e. FP-CIT SPECT and hence in [5], the authors have developed an automated deep-learning model which interprets FP-CIT SPECT image dataset obtained from PPMI repository. Firstly, SPECT images are passed to 3D convolutional layer as inputs. And secondly, it produces 16 3D outputs after passing through 7×7×7 convolutional filters, max-pooling and ReLU activation layer along with output layer. After this research, a unique automated detection system for PD CNN using EEG signals has been proposed for the first time by Shu Lih Oh[6]. The author researched that the implementation of the non-linear features extraction techniques could be used to differentiate between a normal and PD EEG signals. Research has implemented a novel thirteen-layer CNN model using Relu activation function in hidden layers followed by softmax function in output layer. The proposed CNN model yielded an accuracy of 88.25%, and a sensitivity of 84.71%. In [7], the authors used non-motor features i.e. Rapid Eye Movement (REM), Sleep Behavior Disorder (RBD) and Olfactory Loss along with the data from PPMI. Research has used automated diagnostic models using machine learning algorithms i.e. MLP, Boosted Random Forest and Boosted Logistic Regression with a reported accuracy of 97.16%. In [8], the authors have used the neuro-imaging techniques i.e. MRI, PET, etc. are non invasive methods and invasive methods i.e. electroencephalography, which has been useful in studies of neural activities in human brain through functional brain analysis of the generated images. They have used features from like ALFF, fALFF, ReHo and Functional Connectivity. Further, literature witnessed that swarm intelligence can be used to accelerate the performance of the existing neural methods [11]. Moreover, the parallel methods can be used to scale up the performance by training on large scale datasets [12-14].

## III. DATASET

The data used in this study is based on two important symptoms. One of the debilitating symptoms of PD is gait. The dataset has been taken from PhysioNet Database Bank. PhysioNet repository offers access to a huge collection of physiological data for research purposes. It is supported by the National Institute of Biomedical Imaging and Bioengineering (NIBIB). Another dataset based on symptom i.e. voice has been taken from UCI ML Repository. The UCI ML Repository is a database of datasets generated by many surveys, and experiments for the emperical analysis by community working on the studies based on Machine Learning. It also contains domain theories, and data generators for various research based topics. Table 2 shows the details of both the datasets including many features like age, gender of the individual along with the count of samples for training & testing.

### *A. VGFR Dataset*

It contains the recorded signals of vertical ground force reaction of subjects, recorded as they walk at a usual, self-selected pace on a plain surface. Each foot had 8 sensors, which recorded VGFR(in Newton) as a function of time whose output has been digitized and recorded including two more signals that reflect the sum of the sensor's outputs for each foot. This database also includes demographic information, measures of disease severity and other related measures. With this information provided by dataset, it was found that the force is a function of time, determined all the timing parameters (e.g., stride time, swing time), and established relations that depicts center-of-pressure as a function of time. Thus, stride-to-stride dynamics study has been made and the variability of these time series has been recorded.

### *B. Voice Impairment Dataset*

Voice Impairment dataset is obtained from Max Little University of Oxford, having recorded biomedical voice measurements of 91 subjects, 43 suffering from PD with each person on an average giving 5-6 different samples. Each column corresponds to particular voice measure. The first two columns include Vocal Fundamental Frequency (Hz) and its maximum value followed by two measures of ratio of noise to tonal components in the voice in the next column. There are other 5 nonlinear parameters which are considered in the database i.e. 2 dynamical complexity measures and 3 fundamental frequency variation along with signal fractal scaling exponent.

## IV. METHODOLOGY

In this study model based on deep learning , neural network has been introduced to detect Parkinson disease using two unique symptoms of Parkinson i.e. gait and speech impairment. This model contains 2 modules i.e. VGFR Spectrogram Detector based on the distorted walking patterns of PD Patients and Voice Impairment Classifier based on speech impairments of PD patients. Figure 1 illustrates the proposed module.

TABLE I. VGFR SPECTROGRAM CNN MODEL LAYER DESCRIPTION

| Layer | Layer Type | Filter Shape | No. of Units | Stride | Output Dimen. | Regular-ization |
|---|---|---|---|---|---|---|
| 1. | Input | - | - | - | 16x192 | - |
| 2. | 2-D Convo-lutional | 3x3 | 32 | 1 | 14x190x 32 | - |
| 3. | Max Pooling | 2x2 | 32 | 2 | 7x95x32 | - |
| 4. | 2-D Convo-lutional | 3x3 | 16 | 1 | 5x93x16 | - |
| 5. | Max Pooling | 2x2 | 16 | 2 | 2x46x16 | Dropout (0.5) |
| 6. | Dense | - | 16 | - | 2x46x16 | - |
| 7. | Output | - | 1 | - | 2 | - |

### *A. VGFR Spectrogram Detector*

A disturbed gait is a common, debilitating symptom in Parkinson disease. Patients with severe gait disturbances are prone to falls and may lose their functional independence. Each recorded readings of 16 sensors per subject are converted into a spectrogram image that depicts a pattern by plotting the varying signal values taken by the sensors. Spectrogram is a plotting technique very useful in showing change in the signal values of various kinds, highly used for depicting audio signals. These spectrogram 2D images are then given as an input to the Convolutional Neural Network to be processed as an image. The proposed CNN model comprises of 2 convolution layers (layer 1 with 32 units and layer 2 with 16 units), 2 max-pool layer and 1 dense layer and 1 output layer, where the activation function used is ReLU. The description of each layer of CNN model including no. of units, output shape, etc is shown in Table 1.

*B. Voice Impairment Classifier*

Before pre-processing of data, the status of patients were extracted out from the table, followed by the evaluation of data. After normalizing the data through standard scaler, readings were made to pass through 3 layer perceptron network consisting of 64, 32 and 16 neurons respectively and then at the end of model a single output layer was chosen to get the output. On the several failed runs of a simple model it was found that there was a lot of imbalance in data, approximately for every 3 Parkinson patient voice recording there was a single recording of healthy patient (3:1), to remove that imbalance of data, a weight measure was chosen and based on that the model was trained.

TABLE II. DETAILS OF DATABASES USED

| DATABASES | DETAILS | VALUE | COUNT OF SAMPLES | | | |
|---|---|---|---|---|---|---|
| | | | ***TRAINING SET*** | | ***TESTING SET*** | |
| | | | ***PD Patients*** | ***Normal People*** | ***PD Patients*** | ***Normal People*** |
| VERTICAL GROUND FORCE REACTION DATASET (PHYSIONET DATABASE BANK) | Age (Mean) | 52-74 (66.3 years) | 70 | 55 | 23 | 18 |
| | Gender (M/F) | 99/67 | | | | |
| | Time of Experiment (Minutes) | 2 | | | | |
| | No. of Sensors (per foot) | 8 | | | | |
| | No. of Samples per second | 100/s | | | | |
| VOICE IMPAIREMENT DATASET (UCI MACHINE REPOSITORY) | Age (Mean) | | 100 | 40 | 38 | 17 |
| | Gender (M/F) | | | | | |
| | No. of Variations of Fundamental Frequency (Hz) | 7 | | | | |
| | Measures of variation in amplitude (dB) | | | | | |

ReLu activation function has been used till penultimate layer whereas in the output layer sigmoid activation function has been used. For optimizing part Adam classifier was used, with binary cross-entropy loss function, model was made to run for 25 epochs, till it started facing vanishing gradient problem. Running the model for more than 30 epochs it started facing the vanishing gradient problem resulting it to deviate from the better weight learning. After tuning a little around with learning rate manually, the model adjusted the learning rate , and was able to achieve a better accuracy.

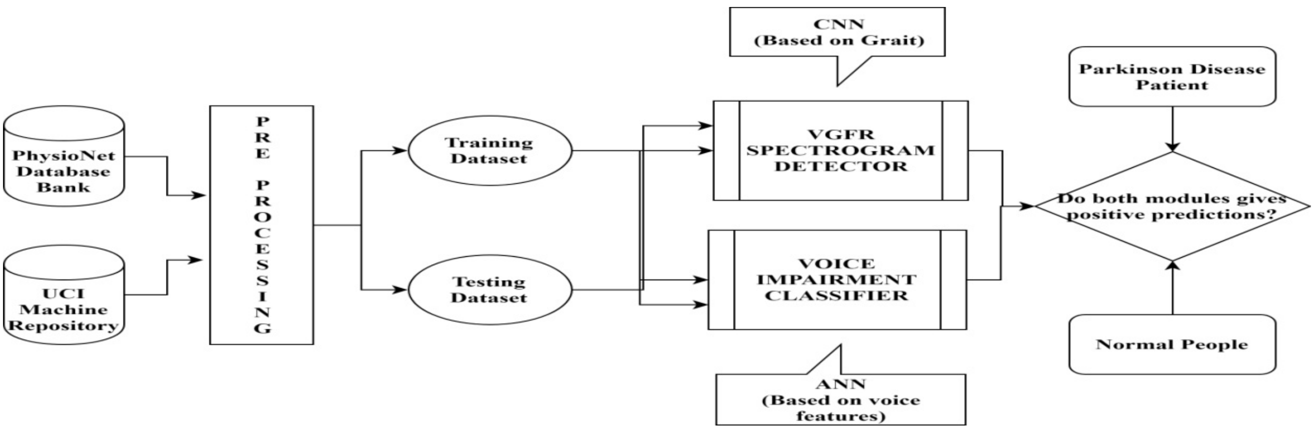


Fig 1. Parkinson Detector Structural Model

## V. IMPLEMENTATION AND RESULTS

This project is divided into two modules, First being "VGFR Gait Analysis using CNN" and the second is "Voice Impairment classifier" based on Voice classification. The first module consists of a dataset containing signals depicting Vertical ground force reaction through 19 features, which were converted into a spectrogram so as to plot these signals respectively in a 2D plane. Now, these 2D Spectrogram images are given as inputs to the neural network to process , First the 2 Convolutional 3D layers and 2 max-pool layer manipulate and reduce the size of the dataset , then 2 Dense layer add non-linearity to the predictions. TensorFlow has been used as backend framework and Keras library is leveraged on the top of TensorFlow to implement CNN.

In the second module, dataset contains the segmented signal values of voices of normal subjects and subjects suffering from PD. The model used in this module is based on ANN, which is again a deep-learning model. It uses 4 layers having 64, 32 and 16 neurons respectively. The CSV file containing dataset is provided as an input, it learned the non-linear patterns in signal values and trained itself based on it. It's also developed using Tensor flow and Keras.

For the testing purpose the dataset has been divided into training & testing sets randomly, implemented the modules on both and calculated the accuracy by tuning various parameters like Learning rate. Then the values of accuracy of VGFR Spectrogram Detector for the generated spectrogram images and Voice Impairment Classifier for detailed features of speech images were evaluated with different epochs. Thereafter, another test was conducted in which three popular machine learning algorithms were applied i.e. XG Boost, Support Vector Machine, and MLP on the two datasets and compared the results with the proposed modules as shown in Table 3.

TABLE III. TRAINING & TESTING RESULTS

| S. No. | Module Name | Data Splitting (Training-Testing) | Training Epochs | Accuracy | Comparisons | | |
|---|---|---|---|---|---|---|---|
| | | | | | SVM | XG Boost | MLP |
| 1. | VGFR Spectrogram Detector | 244-62 | 23 | 88.17% | 86.12% | 78.66% | 87.79% |
| 2. | Voice Impairment Classifier | 157-39 | 35 | 89.15% | 81.16% | 77% | 85.60% |

To the result, it is stated that both the datasets are balanced and have adequate proportion of all the classes, and the proposed modules gives better accuracy as compared to other machine learning algorithms. Hence the model proposed is practically effective and efficient as compared to all other algorithms.

## VI. CONCLUSION

To come up with an efficient way for the detection of Parkinson Disease, different research papers were studied based on Parkinson Detection using various Machine Learning and Deep Learning algorithms to classify subjects into the category of normal and suspicious based on various symptoms. The results obtained by various studies were compared using different techniques and concluded that it is best to implement Deep Learning for the research on two decisive symptoms i.e. distorted walking patterns (gait) & speech impairment. The dataset used have been obtained from UCI ML Repository & PhysioNet Database Bank. Two modules have been implemented i.e. VGFR Spectrogram Detector using CNN and Voice Impairment using ANN to classify PD patients based on two symptoms i.e. gait & speech impairment respectively, with an accuracy of 88.17% & 89.15% for the 2 modules on testing dataset and compared with 3 major algorithms i.e. SVM, XG Boost & MLP and found the proposed model is more efficient and returns better accuracy.

In future, it is planned to merge the results of these 2 modules and try to make the detection more efficient and results more accurate by adding more important decisive features like olfactory sound loss and distortion in handwriting with Deep Learning methodologies to overcome drawbacks of previously researched work/project. Also, new algorithms will be taken into count which could reduce the computation needed and would also make the system lighter.

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