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Prediction of Parkinson’s Disease using Machine Learning and Deep Transfer Learning from different Feature Sets

Prof. Supriya Kamoji, Research Scholar, Fr. Conceicao Rodrigues College of Engineering, Mumbai, India
Email – supriyas@fragnel.edu.in

Prof. Dipali Koshti, Research Scholar, Fr. Conceicao Rodrigues College of Engineering, Mumbai, India
Email – dipalis@frcrce.ac.in

Valiant Vincent Dmello, B.E. Computer Engineering Student, Fr. Conceicao Rodrigues College of Engineering, Mumbai, India
Email – vvd0927@gmail.com

Alrich Agnel Kudel, B.E. Computer Engineering Student, Fr. Conceicao Rodrigues College of Engineering, Mumbai, India
Email – alrichkudel.ak@gmail.com

Nash Rajesh Vaz, B.E. Computer Engineering Student, Fr. Conceicao Rodrigues College of Engineering, Mumbai, India
Email – vaznash1@gmail.com

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Abstract— **Precursors that appear diminutive hold a world of significance with regard to indicating and diagnosing premature stages of degenerative diseases, especially neurologically concerned ailments like Parkinson's disease (PD). PD usually shows symptoms like spasm in the limbs, jaw or head, rigidness of the limbs and trunk, sluggish movement, etc. and it is crucial to detect Parkinson Disease in early stages by keeping an eye out for these preliminary symptoms. In this paper, various datasets were researched, analyzed and run through certain algorithms to detect several symptoms. The Freezing of Gait dataset was used to predict if there were symptoms related to legs and trunk by analyzing the patient’s gait, the Parkinson Clinical speech dataset to detect deviation in audio frequency and lastly the Parkinson Disease wave and spiral drawing dataset which can help find out impairment in writing due to a tremor in hand or arm. The detection of impairment in handwriting seems to be the most convenient method and Convolutional Neural Network using Transfer Learning is implemented on this image dataset.**

Keywords— Parkinson’s Disease (PD), Freezing of Gait, abnormality in audio, impairment in writing, Transfer Learning, Convolutional Neural Network.

I. INTRODUCTION

Parkinson’s Disease (PD) is associated with the brain which affects a person’s mobility. PD occurs due to the reduction in the production of a chemical referred to as dopamine which plays a most important role within the brain and body. Dopamine controls movement and coordination. PD normally hits at the age of 50 years to 60 years, yet it can likewise be found in an earlier stage of age with marginally low rate Additionally, PD is more frequent in male than in females, on the other hand, the cause for the same is unknown and not visibly recognized [1].

PD is commonly categorized by symptoms which can be motor and non-motor. Motor symptoms can be rigidity, tremors, bradykinesia and instability in posture and these symptoms are considered as fundamental signs of Parkinson’s Disease [2]. Tremors are an uncontrolled, contraction and relaxation which ends up in oscillations of limbs. Rigidity is categorized as an excessive and continuous shrinkage of the muscle which causes stiffness to the movements of joints and may be extremely painful. Bradykinesia is the slowness of the movements and is the major symptom of PD. Postural instability is a balance disorder that may cause a person to feel unsteady. Non-Motor symptoms include Stress, Depression, Fatigue, Eye problems, problems related to Speech and Communication. Machine learning is a concept that allows a computer programme to learn and adapt to new data without the need for human intervention or explicit programming. It learns from previous findings and improves its knowledge, just like a person.

The contribution of our work is threefold:

The first dataset is the Freezing of gait dataset. It is a dataset collected by using sensors. Here we have used various machine learning classification algorithms to identify if there are any symptoms related to legs by analysing a patient's gait.

The second dataset is the Clinical Parkinson’s Dataset, which comprises biomedical voice estimations from the discourse sounds created during the discourse tests. Here a variety of machine learning classification algorithms were used to detect any voice abnormality in individuals suffering from PD.

The third Dataset is the Waves and Spiral Dataset. This dataset is obtained from spiral and wave drawings of the patients. Here we processed the images by using image processing and implemented Convolution Neural Network. This Spiral and Waves dataset helps to identify the impairment in writing due to tremor in hands of the PD patients.

The detection of impairment in handwriting seems to be more convenient among all. We suggest a Deep learning framework which is sensor free and can detect Parkinson’s Disease in a patient by using the images of spirals and waves captured through smartphones.

The paper structure is as per the following: Section II describes the Review of the Related work. Section III we have described the Methodology involved with this study. Section IV talks about the results and lastly Section V finishes with the conclusions.

II. RELATED WORK

Several previous studies can be seen based on gait, audio and handwriting features of subjects which were affected with Parkinsonism. From which, features on gait and tremor were obtained from statistical analysis. Algorithms based on threshold having previously given high accuracy on gait dataset. Machine Learning (ML) techniques such as pattern recognition were used for identifying changes in gait. However, limited studies are available which investigates prediction using change from movement to FOG with help of Machine Learning and accelerometer. [1] Also, in this study authors tried to separate healthy people and people suffering from Parkinson's, doing this they achieved accuracy of 68%. They differentiated with help of wrapper feature selection scheme, with this the accuracy obtained was in range of 72 to 92% also, they used vocal features of thirty-one people and got 76% of accuracy.

The authors used various schemes to distinguish between healthy and Parkinson's patients, this was achieved using a variety of traditional techniques.[2]

Doing this, they found that their gyroscope model had a high correlation with the unified PD rating scale. After this they used multiple gyroscopes on Parkinson's patients who went under deep brain stimulation surgery.

By using traditional Machine Learning to detect Parkinson, authors monitored the patients using infrared cameras and used reflective markers to classify them. In this study authors used deep learning techniques for healthcare informatics. This method requires professional motion capturing sensors which are expensive.[3]

Features based on audio were also considered for detecting through speech signals, which were acquired during speech tests records.

These speech signals were then analyzed using a software called as Praat used to remove noise and also characterize distinct factors on vocal records. The Clinical Parkinson data which is based on the audio signals of subjects gave good prediction results but it requires a lot of pre-processing, the audio signals first need to be converted into text format and then need to be pre-processed for further usage. [4] Several research papers have tried to resolve vocal disorders using Machine Learning by focusing on features like dysphonia acoustic measurements to distinguish ordinary from PD cases.

This can be classified into following:

1. Attempting to find the most useful voice factors and produce new datasets.

2. Trying to extract more useful properties from existing data and improve their prediction.[5]

Other authors working on similar studies based on vocal factors for Parkinson's disease Diagnosis and Classification used J48, Naive Bayes, SMO, Bayes Net and MLP algorithms; their outcome was computed using Data Mining Techniques. Doing this, prediction of PD by ML improved their approach and the classifiers gave accuracies of 97.16% and 98.9% under ROC(AUC) for boosted logistic regression.[6]

The wave and spiral datasets are used to develop a two dimensional CNN model and voting ensemble classifier for the detection of PD patients to obtain accuracy of 93.3% [7] The Hand PD dataset was used and a CNN model was proposed for the selection of suitable hyper-parameters (base learning rate, weight decay and penalty parameter) for image classification and the selected parameters were used for image classification. [8]

III. Methodology

In this study, Parkinson's disease was predicted with the help of three different datasets based on three different factors. The data used for predicting was based on the gait, vocal, and handwriting features. Here, we describe more about the datasets we use in this study.

A. Dataset

1.) The Daphnet FOG (Freezing of Gait) dataset: It is obtained from UCI ML Repository [1]. The dataset incorporates information from 10 Parkinson patients. The data collected from wearable acceleration sensors recorded at 64Hz were attached to the legs and hips [shown in fig 1] of the Parkinson's infection patient encountering FOG as an indication. The dataset is collected by using video recorded in the labs which are then analysed by the Therapist.[9] The patients were advised to perform an arrangement of exercises like walking in a straight line, and with various turns, lastly a more sensible action of everyday task. The dataset comprises 1048575 instances and 11 attributes which are shown in table 1.[1] These attributes of Daphnet FOG dataset which were used to identify the PD patients.

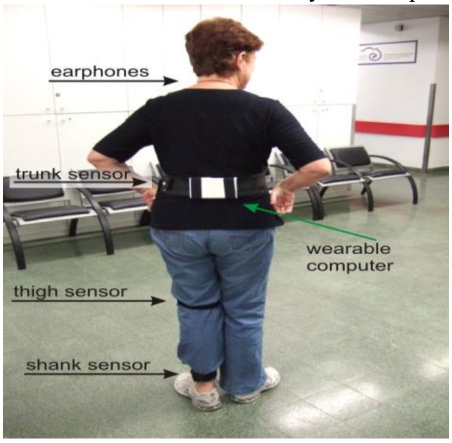

Fig 1: Various wearable acceleration sensors used to obtain the user data

Table 1: Attributes of Freezing of Gait Dataset.

Attributes	Description
Time	Time duration of sample[ms]
acc_trunk_ver	Vertical Acceleration of Trunk[mg]
acc_trunk_hor	Horizontal Acceleration of Trunk(forward)[mg]
acc_trunk_hl	Horizontal Acceleration of Trunk(lateral)[mg]
acc_thigh_ver	Vertical Acceleration of thigh[mg]
acc_thigh_hor	Horizontal Acceleration of thigh(forward)[mg]
acc_thigh_hl	Horizontal Acceleration of thigh (lateral)[mg]
acc_ankel_ver	Vertical Acceleration of Ankle[mg]
acc_ankel_hor	Horizontal Acceleration of Ankle (forward)[mg]
acc_ankel_hl	Horizontal Acceleration of Ankle (lateral)[mg]
Annotation	Target- [0, 1, or 2]

2.) The clinical PD dataset: This dataset contains 195 entries and 22 characteristics. This dataset was collected from speech sounds that were produced during speech test records. These speech signals were then analysed by using Praat software to remove the noise and characterise the signal's unique properties.[10]

Table 2: Attributes of Clinical Parkinson dataset

Attributes	Description
Name	Subject name & recording no. in ASCII
NHR, HNR	Two measures of ratio of noise to tonal voice components: 1 - Parkinson's, 0 – healthy
spread1, spread2, PPE	Three nonlinear measures of fundamental frequency variation
Shimmer:APQ3, Shimmer:APQ5, MDVP:Shimmer, MDVP:Shimmer(dB), Shimmer:DDA, MDVP:APQ	Some measures which shows change in amplitude
MDVP:Fo(Hz)	Fundamental frequency average
MDVP:Jitter(%), MDVP:Jitter(Abs), Jitter:DDP, MDVP:PPQ, MDVP:RAP	Various measures for changes in fundamental frequency
MDVP:Fhi(Hz)	Fundamental frequency – Maximum
MDVP:Flo(Hz)	Fundamental frequency – Minimum
DFA	Signal fractal scaling exponent
RPDE, D2	Two nonlinear dynamical complexity measures[2]

3.) The wave and spiral image dataset: For a Parkinson patient the writing speed and the pressure are reduced, also the tremor in the hands can affect the handwriting of a patient. The hand-written waves and spirals dataset consists of 102 wave images and 102 spiral images shown in fig 2. It includes 72 training images and 30 testing images in each.[7]

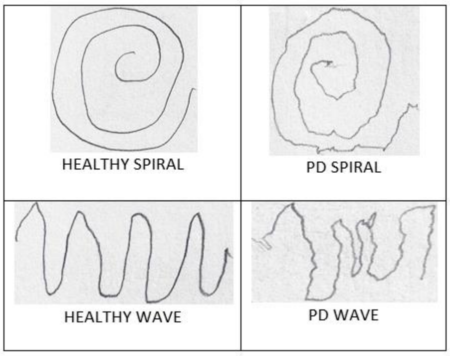

Fig 2: Handwritten waves and spirals obtained from health and parkinon subjects.

B. Methods

FOG Model:

Stages used to determine parkinsonism through Gait features:

The original dataset contained annotations [0,1,2].

The significance of these comments is stated below:

0 – This indicates that it is not part of the investigation.

1 – This indicates that it is part of the experiment, and there is no freeze.

2 – This indicates that it is part of the experiment, and there is freeze.

Here, these annotations 0 were dropped as they cannot be considered as a part of the experiment, annotations 1 were changed to 0 indicating no symptoms of freeze the patient can walk turn and stand properly and 2 to 1 indicating the patient had some symptoms of Parkinson disease that is freeze or freezing of gait. The rest of the data was already preprocessed and hence there was no need to do any preprocessing so kept the data as it is.

After this the data was divided as 80% training data and 20 % as testing data. Later various Classification algorithms were used on the training model. Various algorithms used were: Logistic Regression, KNN, Random Forest Classifier, Naive Bayes, Decision tree Classifier. Comparing the accuracies of these algorithms Decision tree classifier gave highest percentage of accuracy.[11]

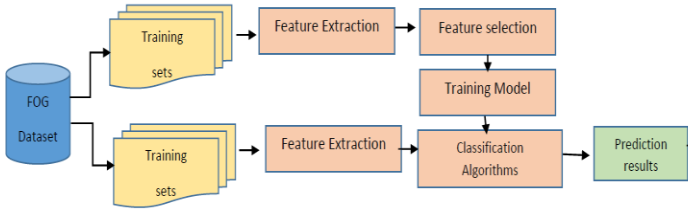

Fig 3: Architecture diagram for FOG dataset.

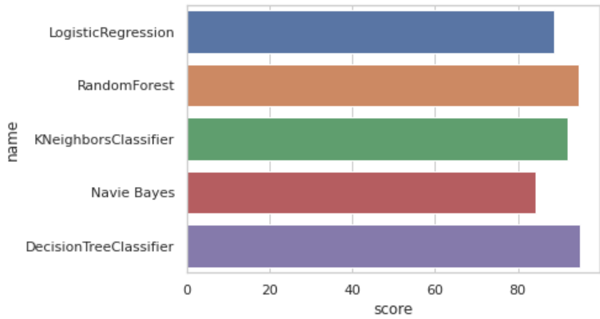

Fig 4: Algorithms for FOG dataset

Speech Model:

The steps used to detect parkinsonism through their vocal signals are:

1.Firstly the vocal frequencies obtained from the user were converted into numerical data.

2. This data was then passed for the training and testing phase where we used 80% for training and 20% for testing the data.

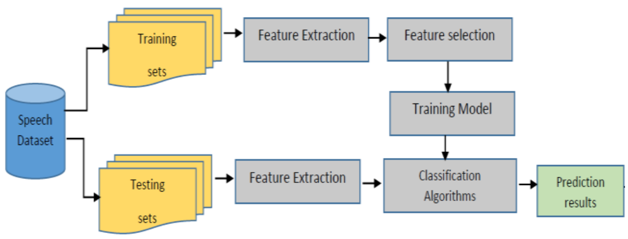

Fig 5: Architecture diagram for speech dataset

3. After acquiring the train and test model various classification algorithms were applied on the training model. Classification algorithms which were used are Extra-tree Classifier, Logistic Regression, KNN, Random Forest Classifier, SVM(Linear and RBF) and Decision Tree Classifier. After obtaining accuracies of all the algorithms,

an algorithm with highest % of accuracy was selected. For this dataset KNN gave the highest percent of accuracy.

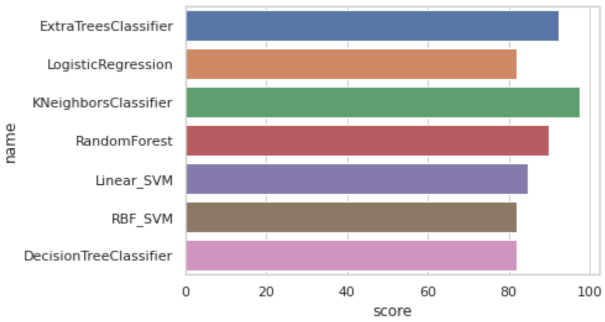

Fig 6: Algorithms for speech dataset

For the ML Classifiers used on FOG and Speech dataset the following steps were performed:

- Import the dataset
- All unnecessary data was removed, in this case we dropped the filename and name column in FOG and Speech dataset respectively, as it was irrelevant to predictions.
- Later we divided the data in X and y. where y contained the target value and X contained the rest of parameters required for prediction.
- We then split the data in training(X_train & y_train) and testing(X_test & y_test) sets as 80% for training and 20% for testing.
- Imported the required classifier
- Trained data on this classifier.
- Predicted values for X_test data.
- Got Accuracy and Confusion matrix by comparing predicted values to y_test values

We performed all these steps using pandas and Sklearn python libraries.

Wave and Spiral CNN Model :

Convolutional Neural Network(CNN) is a Deep Learning technique used to process and classify images, by trying to mimic the actual human neural networks. CNN consists of many layers of nodes(neurons) each assigned with a weight and these weights and inputs are used to get the output. The wave and spiral dataset consisted of only 102 images, which is rather small for training a good CNN model, hence two methods namely Data Augmentation and Transfer Learning were used to deal with this small Dataset.

- Data Augmentation: It is a technique where the images from training data are used to create larger training data by applying various transformations
- Transfer Learning: Transfer Learning is a popular deep learning method where the knowledge of a pretrained model is used in a new Convolutional Network.[12] In this method we use the pretrained model to form initial layers of a CNN model and replace or add a few last layers, hence the new model can learn from the pretrained model and train on the new data for classifying images.

Input size of 512 x 512 and 512 x 1024 was used on the spiral and wave images respectively. The data was

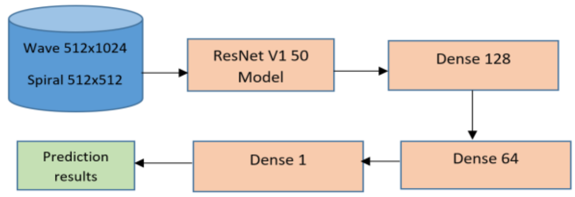

Fig. 7: CNN Architecture for wave and spiral dataset

augmented by applying vertical and horizontal flips and zooming. The pretrained model used for transfer learning is The ResNet V1 50 model from tensorflow hub. Instead of using a conventional CNN model, the transfer learning model will give better outcomes not only because the training dataset is small but also because the pre-trained model consists of deep neural layers additionally, the training speed will be fast. As shown in fig. 7 this pretrained model with a few custom layers is used to train both wave and spiral image datasets individually.

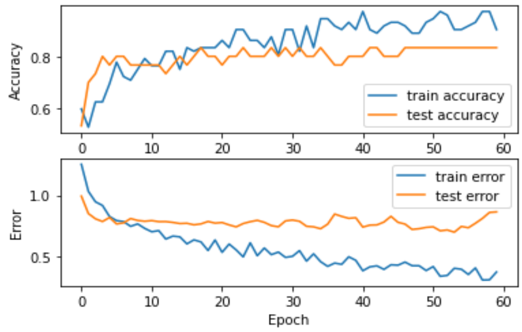

Fig 8: Spiral Accuracy and Loss, overfitting.

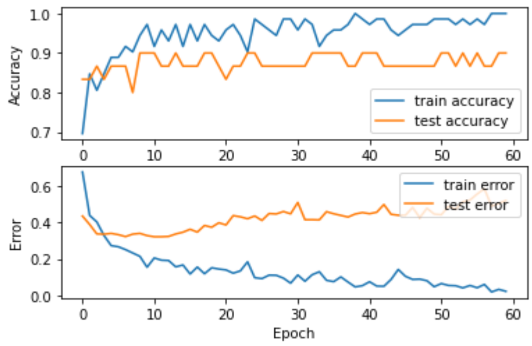

Fig 9: Wave Accuracy and loss, overfitting.

The accuracy and loss on training and validation set for fig 7 can be seen in fig 8 and fig 9, but the model is overfitting. To overcome the overfitting problem the following techniques were used[13]:

- Early Stopping: This method is used to choose the right number of epochs since a large number of epochs can cause overfitting while less epochs can cause underfitting.[14]
- Dropout: In this technique, a few nodes(neurons) of the network are randomly dropped during training, this makes the network more robust and solves overfitting.[15]
- Regularization: It is a very effective technique to overcome the overfitting problem. It is used to lessen

the model complexity and generate a simple model, hence prevent overfitting.[16]

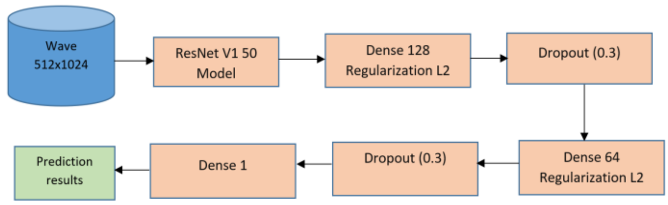

Fig 10: CNN Architecture for wave and spiral dataset to solve overfitting

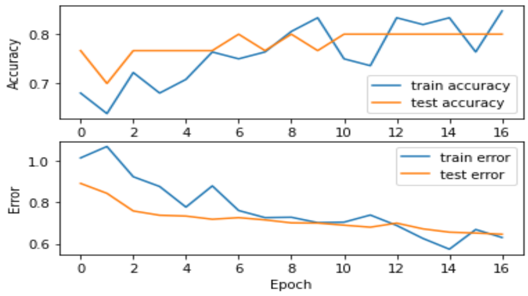

Fig 11: Spiral Accuracy and Loss

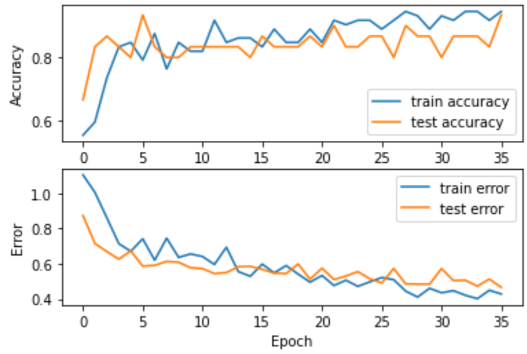

Fig 12: Wave Accuracy and Loss

Fig 10 shows the model used to avoid overfitting. Early stopping with the patience parameter as 10 and 30 for spiral and wave respectively (smaller parameter for spiral because it was over-fitting) is used to fit the model, two dropout layers of probability 0.3 are added after the dense layers and regularization L2 is applied to the dense layer with λ set as 0.001. Fig. 11 and fig 12 shows the accuracy and loss of the spiral and wave model and the overfitting issue was solved.

Table 3: Results of FOG dataset

Classifier	TP	FP	TN	FN	Accuracy (%)	Precision (%)	Specificity (%)	Sensitivity (%)	F-Score (%)
Logistic Regression	322	763	107309	13018	88.65	29.68	99.29	2.41	446.45
Random Forest Classifier	7890	1109	106963	5450	94.60	87.68	98.98	59.15	7063.88
KNN	7566	3840	104232	5774	92.08	66.33	96.45	56.72	6114.93
Naive Bayes	2147	7852	100220	11193	84.31	21.48	92.73	16.09	1839.84
Decision Tree Classifier	10284	3035	105037	3056	94.98	77.21	97.19	77.09	7715.22

Table 4: Results of Audio Dataset

Classifier	TP	FP	TN	FN	Accuracy (%)	Precision (%)	Specificity (%)	Sensitivity (%)	F-Score (%)
Extra Tree Classifier	28	2	8	1	92.31	93.33	80.00	96.55	9491.53
Logistic Regression	28	6	4	1	82.05	82.35	40.00	96.55	8888.89
KNN	28	0	10	1	97.44	100.00	100.00	96.55	9824.56
Random Forest Classifier	27	2	8	2	89.74	93.10	80.00	93.10	9310.34
SVM(linear)	29	6	4	0	84.62	82.85	40.00	100.00	9062.50
SVM(rbf)	28	6	4	1	82.05	82.35	40.00	96.55	8888.89
Decision Tree Classifier	28	6	4	1	82.05	82.35	40.00	96.55	8888.89

Table 5: Results of Spiral and Wave Dataset

Image	Train Accuracy (%)	Train Loss (%)	Train Precision (%)	Train Recall (%)	Train Auc score (%)	Val Accuracy (%)	Val Loss (%)	Val Precision (%)	Val Recall (%)	Val Auc score (%)
Spiral	87.5	52.2	88.57	86.11	96.22	80	64.63	90.91	66.67	90.44
Wave	93.06	41.73	100	86.11	98.8	93.33	46.63	93.33	93.33	97.33

IV. RESULTS

The FOG dataset:

After running various algorithms Decision Tree outputs the best Accuracy of 94.98%. The confusion matrix obtained from all the classifiers was used to calculate the values in table 3.

The Audio Dataset:

Similar to the FOG dataset various algorithms were used on Audio Dataset, the KNN model gave the best accuracy of 97%. The values in table 4 are obtained using the accuracy matrix which was obtained in the section III.

The Hand-written Spiral and Wave Dataset:

The Transfer Learning CNN model was trained and evaluated using metrics parameters as: Accuracy, Precision, Recall and Auc score. Table 5 shows the evaluation results on train and test data, the wave dataset better results than the spiral one.

V. CONCLUSION

The major purpose of this study was to identify healthy individuals and those with Parkinson's disease by identifying three symptoms namely Gait freeze, changes in speech pattern and shiver in arms (impaired handwriting). Freezing of Gait (FOG) Dataset the objective was to detect the FOG events in an individual preceding its beginning by using classification algorithms and to evaluate their performance accuracies. Here, various classification algorithms were used like Logistic Regression, Naive Bayes, K-NN, Random Forest Classifier, Decision Tree Classifier, with Decision Tree classifier giving the highest accuracy of all that is 96.06%. Clinical Speech Dataset, here the focus was to detect any irregularities in the voice of the patient by using Machine Learning classification algorithms and compare their results similar to FOG. Various classification algorithms were used like Logistic Regression, K-NN, SVM-Linear, SVM- RBF, Extra Tree Classifier, Random Forest Classifier, Decision Tree Classifier, with K-NN giving the highest accuracy of 97.43%. For Spiral and Wave Dataset, the motive was identification of tremor in arms by the means of hand-drawn spiral and wave. The transfer learning CNN model was trained on the spiral and wave dataset, furthermore the wave dataset gave better results than the spiral dataset.

When comparing the dataset with each other, the FOG and Speech dataset performed really nice. But if we were to compare the process of obtaining data wave and spiral data is very easy to obtain. The data collection in the FOG dataset is done by using sensors which is quite expensive and the Clinical speech dataset also requires a software to convert audio into biomedical voice measurements also a lot of pre-processing is needed. Comparatively the Spiral and Waves seem to be more convenient and cheaper, the only thing needed is to draw a wave and spiral image with a pen and paper. When, this application is deployed in real world, it will be impossible for normal patients to get expensive sensors and very hard to use the Praat software. The early detection of disease symptoms can make patients aware and they may start the cure while the disease is in early stage. The hospitals that have sensors and software required for inputs available, then hospitals can use this system to get a rough estimate of the patient's condition by analysing all the symptoms. Normal users can easily use this system, all they have to do is draw an image of a wave and upload it for prediction.

REFERENCES

[1] Predicting Freezing of Gait in Parkinsons Disease Patients using Machine Learning by Natasa K. Orphanidou, Abir Hussain, Robert Keight, Paulo Lisboa, Jade Hind, Haya Al-Askar.

[2] SVM Based Machine Learning Approach to Identify Parkinson's Disease Using Gait Analysis by Sachin Shetty and Dr. Y. S. Rao.

[3] A Pervasive and Sensor-Free Deep Learning System for Parkinsonian Gait Analysis Jerry Ajay, Chen Song, Aosen Wang, Jeanne Langan, Zhinan Li and Wenyao Xu.

[4] New machine-learning algorithms for prediction of Parkinson's disease by Dr. Indrajit Mandal, N. Sairam.

[5] A Multiple-Classifier Framework for Parkinson's Disease Detection Based on Various Vocal Tests by Mahnaz Behroozi and Ashkan Sami.

[6] Performance Evaluation of Machine Learning Algorithms in the Classification of Parkinson Disease Using Voice Attributes by J. Sujatha, Dr. S.P. Rajagopalan.

[7] Parkinson's Disease Detection from Spiral and Wave Drawings using Convolutional Neural Networks: A Multistage Classifier Approach by Sabyasachi Chakraborty, Satyabrata Aich, Jong-Seong-Sim, Eunyoung Han, Jinse Park, Hee-Cheol Kim.

[8] Convolutional Neural Networks Applied for Parkinson's Disease Identification by Clayton R Pereira, Danillo R Pereira, Joao P Papa, Gustavo H Rosa and Xin-She Yang.

[9] Wearable assistant for Parkinson's disease patients with the freezing of gait symptom Marc Bachlin, Meir Plotnik, Daniel Roggen, Inbal Maidan, Jeffrey M ¨ Hausdorff, Nir Giladi and Gerhard Troster.

[10] Exploiting Nonlinear Recurrence and Fractal Scaling Properties for Voice Disorder Detection Max A Little, Patrick E McSharry, Stephen J Roberts, Declan AE Costello and Irene M Moroz.

[11] Feature Selection Techniques for Prediction of Neuro-Degenerative Disorders: A Case-Study with Alzheimer's And Parkinson's Disease by Tejeswinee. Ka, Shomona Gracia Jacob , Athilakshmi. R

[12] Refining Parkinson's neurological disorder identification through deep transfer learning by Amina Naseer, Monail Rani, Saeeda Naz, Muhammad Imran Razzak, Muhammad Imran, Guandong Xu

[13] An Overview of Overfitting and its Solutions by Xue Ying

[14] Early Stopping - But When? by Lutz Prechelt.

[15] Dropout: A Simple Way to Prevent Neural Networks from Overfitting by Nitish Srivastava, Geoffrey Hinton, Alex Krizhevsky, Ilya Sutskever, Ruslan Salakhutdinov

[16] Regularized Deep Convolutional Neural Networks for Feature Extraction and Classification by Khaoula JAYECH