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Parkinson's Detection Using Voice Features and Spiral Drawings

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Abstract:- Parkinson's is a dynamic neurodegenerative disease that presents multiple symptoms that advance over time. Our project proposes an innovative Parkinson's discovery machine learning model that combines both voice examination and spiral drawings assessments to capture numerous angles of the disease's symptomatology. Our approach looks for developing a comprehensive Parkinson's detection model over different stages and symptoms of the disease. By integrating voice analysis techniques to discern subtle changes in speech patterns and spiral drawing assessments to evaluate motor function, our method aims to provide a more holistic assessment of PD symptoms. By leveraging the complementary strengths of voice analysis and spiral drawing assessments, our proposed PD detection project aims to overcome the limitations of existing approaches and provide clinicians with a more comprehensive model for early detection, diagnosis and monitoring of Parkinson's Disease. Ultimately, this initiative strives to enhance patient outcomes, improve treatment efficacy, and advance our understanding of PD progression.

Keywords:- *Parkinson's Disease, Feature Selection, Convolutional Neural Network, Healthy Controls.*

I. INTRODUCTION

Parkinson's disease is an age-related neurodegenerative disease that is developed due to the impairment or death of nerve cells in the substantia nigra – an area in the brain responsible for the control of body movement. It is a progressive neurological disorder that primarily affects the movement of the body. Every year, on 11th April, World Parkinson's Day is observed to shed light on this neurological disorder and raise awareness about it.

A. Hoehn and Yahr Scale

The Hoehn and Yahr Scale is an extensively used tool in the field of neurology. It was developed by Margaret Hoehn and Melvin Yahr in 1967 and is used for analysing the progression of Parkinson's disease in a patient. According to The Hohen and Yahr Scale, the progress of Parkinson's disease can be described by the 5 following stages:

- Stage One of Parkinson's Disease: In the first stage of Parkinson's, the symptoms are very mild and may be observed only on one side of the body. The symptoms at this stage include tremor in hands, slowness of movement in the arm or leg on one side of the body. There may be minimal or no functional impairment in the patient's body.
- Stage Two of Parkinson's Disease: In the second stage of Parkinson's, the symptoms can be seen on both sides of the body. The stage two of the disease is developed in months or years after the stage one. The symptoms in this stage may include the loss of facial expressions in both the sides of the face, stiffness of the muscles, general slowness in movement.
- Stage Three of Parkinson's Disease: In the third stage of Parkinson's, the symptoms may include loss of balance and slowness of movement. The third stage of Parkinson's is the middle stage of the disease. In this stage of the disease, falling is common because the body becomes slow in taking actions to prevent from falling.
- Stage Four of Parkinson's Disease: In the fourth stage, the Parkinson's disease has progressed to a severely disabling disease. In this stage, the patient may not be able to walk or stand without any assistance. The patient might need someone's help with some daily activities.
- Stage Five of Parkinson's Disease: The fifth stage of Parkinson's is the most advanced stage and the patient in this stage is restricted to a bed or a wheelchair. The patient may be unable even to rise from the bed or chair without anyone's help. They require assistance all the time to perform their daily activities.

B. Signs and Manifestations of Parkinson's Syndrome

Parkinson's is a gradually advancing neurological disorder whose symptoms keeps evolving with time. During the course of progression of the Parkinson's disease, multiple symptoms could be observed on the patients at the various stages of Parkinson's. It is important to observe these symptoms for early detection, prevention and treatment of the disease. The symptoms of Parkinson's Disease are broadly categorized into motor symptoms and non-motor symptoms.

Motor symptoms are those symptoms that mainly affect the motor functions of the body. The motor symptoms remarkably impact the patient's ability to perform daily activities and becomes worse with the progression of the disease. Some common motor symptoms of Parkinson's Disease are tremor in hands or legs, slowness in movement, difficulties in walking, reduced facial expression.

Non-motor symptoms are those symptoms that does not primarily affect the movement or motor functions, but significantly affect a patient's overall well-being and quality of life. Some common non-motor symptoms of Parkinson's

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Disease are depression, anxiety, sleep disturbances, fatigue, difficulty in speaking and swallowing food.

II. LITERATURE REVIEW

We studied various research papers to know about the previous works that have been done to detect Parkinson's Disease. After reviewing the research papers, we found that the researchers used a symptom of Parkinson's to detect it. Some used voice features of the patients to detect Parkinson's, while others used spiral drawings or wave drawings to detect Parkinson's in a patient.

The researchers used the bagging method of machine learning to detect the Parkinson's Disease (PD). After preprocessing the data, they used various types of Machine Learning models like Random Forest, Support vector Machine, Multilayer Perceptron and K-nearest neighbour to detect healthy individuals and Person with Parkinson's Disease. Then they compared the results given by the machine learning models. They accuracy of the model, precision, recall and f1-score to determine the best performing machine learning model.

III. PROBLEM IDENTIFICATION

After studying various research papers, we found that the approaches used in the previous works completely rely on a single symptom of the Parkinson's disease. The researchers either used speech as a factor for Parkinson's detection or they used the motor symptom (tremor in hand) as a factor to detect Parkinson's.

This restricts their focus on a single symptom whereas, Parkinson's is a disease which progresses gradually over time. With the progression in time, the symptoms in the patients may be different according to their stage of progression.
Hence, we cannot limit up to a single symptom for Parkinson's detection. There is a need to consider multiple symptoms of Parkinson's for its accurate and reliable detection.

IV. METHODOLOGY

A. Dataset Details

We used the UCI dataset, which is composed of wide a range of voice measurements from 31 people, 23 with Parkinson's disease (PD). It contains 195 records of voice signal features collected from different individuals. The data is in CSV format. The rows of the CSV file contain an instance corresponding to one voice recording. [12]

To detect Parkinson's detection using the spiral drawings, we used the UCI dataset, the database consists of 62 Person with Parkinson's and 15 healthy individuals which was taken at the Department of Neurology in Cerrahpasa Faculty of Medicine, Istanbul University. [13]

TABLE I. VOICE FEATURES USED IN THE UCI DATASET

S. No.	Voice Measure	Meaning
1.	Name	ASCII subject name and recording number.
2.	MDVP: Fo (Hz)	Average vocal fundamental frequency.
3.	MDVP: Fhi (Hz)	Maximum vocal fundamental frequency.
4.	MDVP: Flo (Hz)	Minimum vocal fundamental frequency.
5.	MDVP: Jitter (%)	Measures of variations in fundamental frequency.
6.	MDVP: Jitter (Abs)	
7.	MDVP: RAP	
8.	MDVP: PPQ	
9.	Jitter: DDP	
10.	MDPV: Shimmer	Measures of variations in amplitude.
11.	MDVP: Shimmer (dB)	
12.	Shimmer: APQ3	
13.	Shimmer: APQ5	
14.	Shimmer: DDA	
15.	MDVP: APQ	
16.	NHR	Measures of ratio of noise to tonal components in the voice.
17.	HNR	
18.	Status	Health status of the subject (one) - Parkinson's, (zero) – healthy.
19.	RPDE	Non-linear dynamical complexity measures.
20.	D2	
21.	DFA	Signal fractal scaling exponent.
22.	Spread1	Non-linear measures of fundamental frequency variation.
23.	Spread2	
24.	PPE	

B. Methodology for Parkinson's Detection

Data Preprocessing: The process begins with data preprocessing to ensure uniformity and eliminate noisy data. This involves reading the data from text files, parsing them into arrays, and normalizing the values to reduce variability. Additionally, spectrogram transformation is applied in the spiral drawing dataset to convert the time-domain signal into a frequency-domain representation, which captures relevant features for analysis.

Feature Extraction: Feature extraction is crucial for identifying the features and patterns indicative of Parkinson's disease. In this project, various voice features and spectrograms of spiral drawings are utilized as input features. Spectrograms provide a visual representation of the

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frequencies present in the signal over time, enabling the model to capture complex patterns and variations.

Model Development: For Parkinson's detection using the voice-features we chose Support Vector Machine (SVM) with a linear kernel. SVM is a powerful supervised learning algorithm capable of handling both linear and non-linear data. In this case, a linear kernel is chosen for its simplicity and interpretability. For Parkinson's detection using the spiral drawings we chose Convolutional Neural Network to effectively process the spatial data such as images and spectrograms. The model comprises multiple convolutional layers followed by dense layers for classification. Each input feature (spectrogram) undergoes convolutional processing to extract relevant features, which are then flattened and concatenated before passing through dense layers for classification. The model is trained using the binary cross-entropy loss and is optimized using the Adam optimizer.
Performance evaluation: The trained model is evaluated using a separate validation dataset to assess its performance on unseen data. Evaluation metrics provide insights into the model's ability to correctly classify individuals with and without Parkinson's disease. To measure the performance, we employed a confusion matrix in this study. The confusion matrix has True Positives (TP), False Positives (FP), True Negatives (TN), and False Negatives (FN).

V. RESULTS

We developed an efficient method to detect Parkinson's by using both voice features and spiral images. The model architecture employed in this project consisted of SVM and convolutional layers followed by dense layers. The convolutional layers were designed to capture features from the spectrogram representations of hand movements. These features were then flattened and passed through dense layers for classification.

Our Parkinson's detection model is trained using the binary cross-entropy loss and is optimized using the Adam optimizer. The model was trained on a dataset comprising recordings from both PD and healthy individuals. While training our model, we have used numerous performance metrics such as binary accuracy, true positives, false positives, true negatives, false negatives, precision and recall to assess the model's performance. Additionally, a validation dataset was used to evaluate the model's generalization ability.

After generating the normalized data points, we plotted the data points on graph, shown in Figure 1.

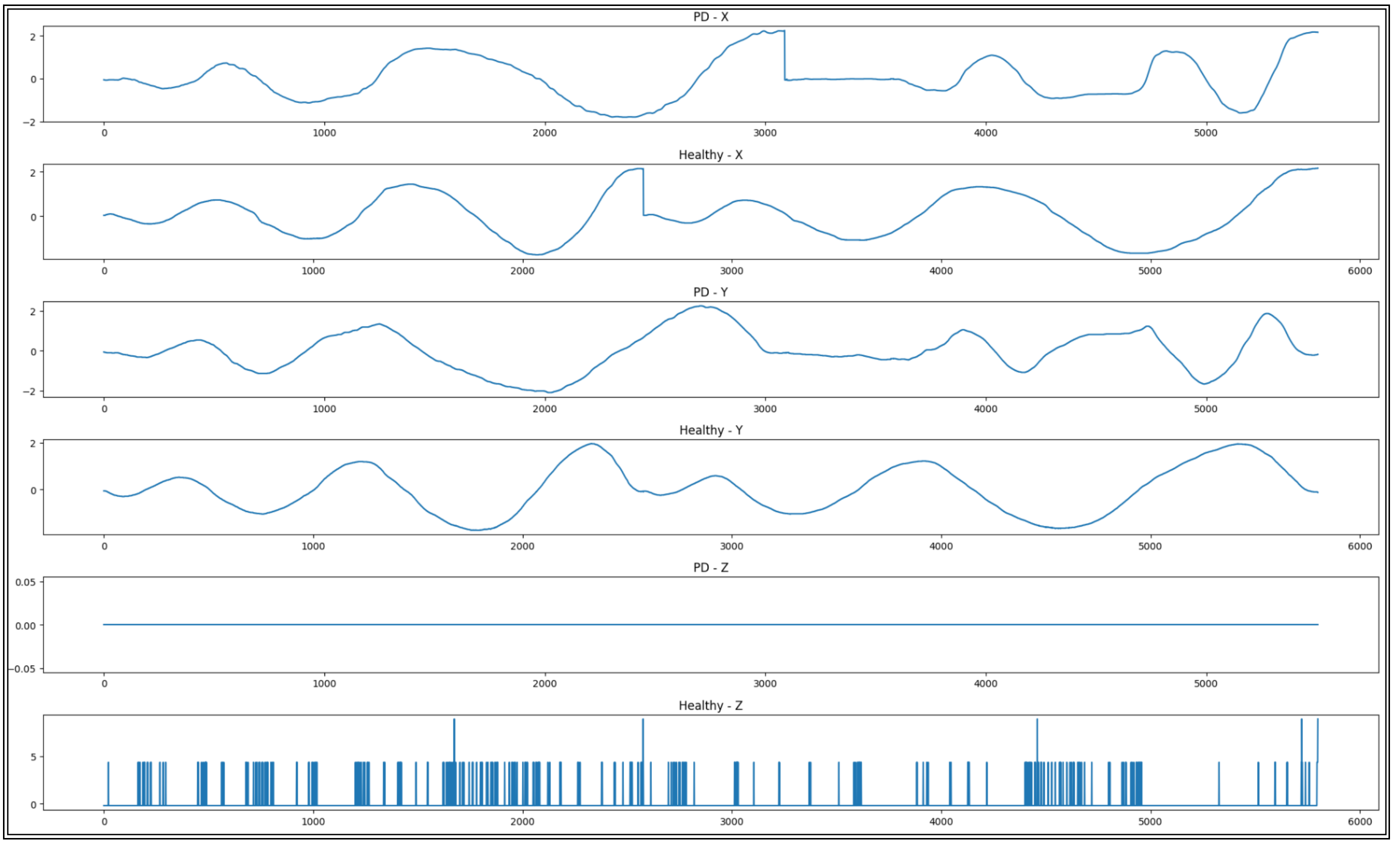

Fig 1. Plot of normalized data points of PD and healthy patients

After training the model for 20 epochs, the following results were obtained:

- Loss: The model achieved a final validation loss of 5.52, indicating good convergence during training.

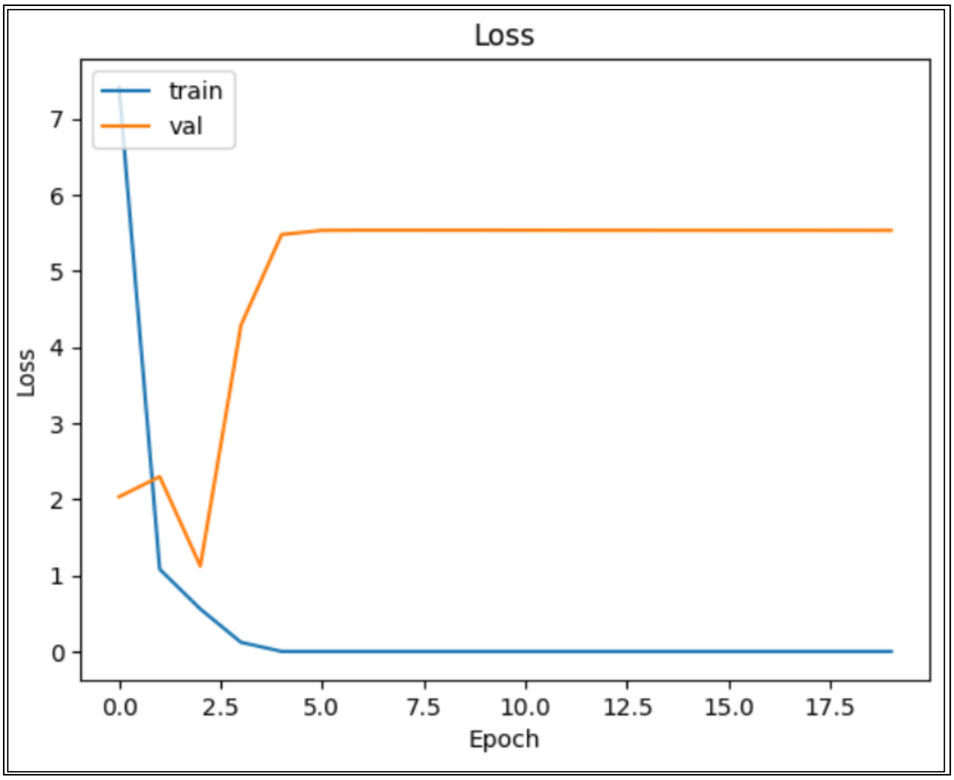

Fig 2. Validation Loss

- Accuracy: The validation binary accuracy reached 85.71%, which indicates the model's ability to correctly identify Person's with Parkinson's Disease and healthy individuals.

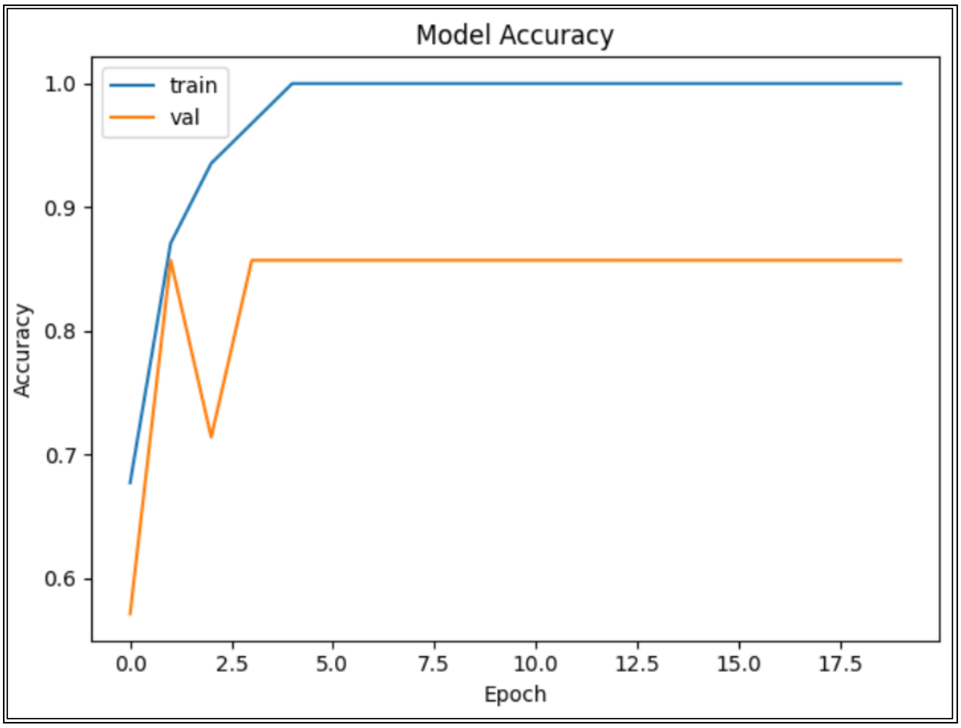

Fig 3. Accuracy of the Model

- Precision and Recall: The precision and recall values for PD detection were both 85.71% and 1 respectively, suggesting that the model effectively identifies PD cases while minimizing false positives.

- Confusion Matrix: The confusion matrix revealed that out of 14 validation samples, the model correctly identified all 12 PD cases (true positives) but misclassified 2 healthy cases as PD (false positives).

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5.529927730560303, 0.8571428656578064, 0.8571428656578064, 1.0, 12.0, 0.0, 2.0, 0.0]
---------------------------------------------------------------|
       Val TN : 0.0          |      Val FP : 2.0               |
---------------------------------------------------------------|
       Val FN : 0.0          |      Val TP : 12.0              |
---------------------------------------------------------------|
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Fig 4. Confusion Matrix

VI. CONCLUSION

Our project's primary objective was to address the limitations of single-symptom-based detection methods by integrating multiple indicators of Parkinson's. While tremors and speech abnormalities are common symptoms of Parkinson's, relying solely on one symptom may lead to inaccuracies and false negatives. By combining speech analysis and spiral assessment, we aimed to capture a broader spectrum of symptoms, thereby improving the overall accuracy of detection. One of the strengths of our approach lies in its ability to complement the limitations of individual symptom-based assessments. While speech analysis and spiral evaluation each provide valuable insights into Parkinson's-related abnormalities, combining these modalities enables a more comprehensive assessment of motor and speech functions. By integrating multiple indicators, our approach enhances the sensitivity and specificity of Parkinson's detection, thereby reducing the likelihood of misdiagnosis and facilitating early intervention.

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