Voice-Based Parkinson's Disease Prediction Using Machine Learning

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Abstract—
Parkinson's disease (PD) is a complex neurological disorder that progressively affects an individual's motor functions and, to a varying extent, their cognitive abilities. As a result, individuals with PD experience a range of symptoms such as tremors, bradykinesia (slowness of movement), rigidity, and postural instability. Additionally, non-motor symptoms including cognitive impairment, mood disorders, and autonomic dysfunction further contribute to the multifaceted nature of PD. All these symptoms start showing at the very later stage of the disease. Hence there is no early detection and the disease becomes more serious.[6]

Recognizing the significance of early intervention in improving the quality of life for individuals with PD, our project aims to develop an advanced prediction model for the timely detection of Parkinson's disease. The utilization of machine learning algorithms and data analysis techniques on a comprehensive dataset is crucial for achieving a precise and reliable predictive model.[1] This dataset may include a variety of voice-based information enabling a holistic understanding of the disease.

The predictive model seeks to identify patterns and correlations within the data that are indicative of early-stage Parkinson's disease, allowing for intervention before the onset of severe symptoms. Early detection holds the potential to facilitate timely and personalized treatment strategies, potentially slowing the progression of the disease and enhancing overall patient outcomes.

Keywords—
Parkinson's Disease, Machine Learning, Data Analysis, Mel-Frequency Cepstral Coefficient (MFCC).

I. INTRODUCTION

Parkinson's disease is a progressively debilitating neurological disorder with far-reaching implications for those affected. The urgency of early detection and precise diagnosis cannot be overstated, as timely intervention can significantly improve the management of this condition. Machine Learning (ML) has emerged as a potent tool for medical diagnosis, particularly for diseases with intricate and subtle indicators.[3] ML algorithms can analyze vast datasets and discover intricate patterns, thereby facilitating the development of highly accurate predictive models. In the context of Parkinson's disease, where even small changes can be indicative, the application of ML offers great promise in enhancing our ability to detect and manage the condition effectively.[5]

The novel feature of our method is the inclusion of voice as a predictor of Parkinson's disease. The human voice carries a wealth of information, and alterations in vocal characteristics can be early signs of neurological disorders like Parkinson's. Speech patterns often change, including reduced vocal loudness, altered pitch, and irregular articulation, even before overt motor symptoms manifest.[2] By harnessing ML techniques to analyze vocal data, we aim to detect these subtle alterations and potentially diagnose Parkinson's disease at an earlier stage. This approach holds the potential to revolutionize the field of Parkinson's disease diagnosis, providing opportunities for early interventions and improved patient outcomes.

Our work aims to develop an accurate prediction model for the early diagnosis of Parkinson's disease by utilizing the power of sophisticated Machine Learning and large-scale datasets. By focusing on voice-related parameters, we seek to contribute to a more holistic and efficient diagnostic process.[7] This work is not only about improving diagnostic accuracy but also about offering hope to individuals living with Parkinson's disease. Early detection means earlier access to treatment, therapies, and support, ultimately enhancing the quality of life for those 1 affected by this challenging condition. In this quest, the fusion of medical knowledge and cutting-edge technology promises to make significant strides in the battle against Parkinson's disease.

II. MOTIVATION

The motivation for this project lies in the profound impact Parkinson's disease has on individuals and their families. Millions of individuals worldwide suffer with Parkinson's disease, a degenerative and now incurable illness that impairs motor function and severely lowers quality of life. Timely therapies can reduce symptoms and decrease the course of the condition, which is why early diagnosis is essential. However, diagnosing Parkinson's disease accurately in its early stages remains a challenging task.[10]

Machine Learning presents an unprecedented opportunity to address this challenge. By leveraging advanced ML algorithms and comprehensive datasets, we can develop predictive models that analyze subtle patterns, including voice-related parameters, to detect Parkinson's disease before overt symptoms manifest.[9] The potential benefits of such a model are immense – it could lead to earlier diagnosis, more effective treatment strategies, and improved patient outcomes. Additionally, it may reduce the burden on healthcare systems by streamlining the diagnostic process and reducing unnecessary testing.

Ultimately, this project's motivation lies in the potential to make a tangible difference in the lives of those affected by Parkinson's disease. By harnessing the power of ML and data analysis, we aim to enhance early detection and, in doing so, provide hope and a brighter future for individuals living with this challenging condition.

III. LITERATURE SURVEY

The research community is leveraging voice data for PD detection, which suggests that voice characteristics may hold valuable information for early diagnosis.

Preprocessing steps are applied to voice data to improve the quality and efficiency of subsequent analysis.

Various machine learning classifiers, including k-NN, SVM, Random Forest (RF), AdaBoost, and Logistic Regression, are employed in PD detection models. These classifiers are tuned and validated to optimize their performance.

Researchers are actively testing different combinations of feature selection methods and classification algorithms to design the most effective PD diagnosis model. This indicates ongoing efforts to refine and optimize the detection process.

IV. PROPOSED IDEA

Data Preparation:

1. Data Collection - Data collection is the procedure of gathering accurate insights, measuring, and analyzing for research via conventional, verified methods.

2. Data Pre-processing - The process of getting raw data ready for a machine learning model is called data preparation.

3. Feature Extraction - Feature extraction is the process of converting raw data into meaningful and relevant features that capture key patterns and traits for analysis or modeling.

MFCCs are used in the model for feature extraction. Mel-Frequency Cepstral Coefficients (MFCCs) are fundamental in audio signal processing and speech recognition, serving as a primary method for feature extraction.[4] They leverage the psychoacoustic properties of the human auditory system and employ the Mel scale to transform frequency representations.

In essence, MFCC computation involves several steps. Initially, the audio signal undergoes a frequency domain transformation, typically via the Discrete Fourier Transform (DFT). Subsequently, Mel filtering is applied to approximate human perception of sound frequency, followed by logarithmic compression to emphasize perceptually relevant details. Finally, cepstral coefficients are derived from the resulting Mel-scaled spectrum.

The significance of MFCCs lies in their ability to compactly represent essential aspects of the audio signal while filtering out extraneous information. The choice of 13 coefficients is empirically determined to strike a balance between computational efficiency and information richness.

The breakdown of the 13 MFCCs is as follows:

- C0 (Zeroth Coefficient): Represents overall signal energy.
- C1 to C12 (First to Twelfth Coefficients): Capture spectral characteristics post Mel-filtering and logarithmic operations. Each coefficient corresponds to a specific frequency band, reflecting energy or magnitude within that band.
- C1: Represents the overall spectral energy distribution.
- C2 to C12: Capture finer spectral details, diminishing in importance with increasing coefficient index.

MFCCs serve as compact representations of audio signals, crucial for various speech processing tasks due to their ability to highlight pertinent features while discarding less relevant information.

Machine Learning process:

1. Model Building - Model Building involves learning and generalization from training data, and then applying that acquired knowledge to make predictions and serve its purpose on new, unseen data.

2. Prediction and Analysis - We forecast future outcomes or trends using this historical data.

3. Testing and Deployment - Testing and deployment involves checking how well a trained ML model works and then putting it to practical use in real situations.

Deployment Process:

1. Front End Development - Building a web application using React.js

2.Integration with ML Model - Finally, we will integrate our web application with Flask, a micro web framework for Python, which facilitates rapid development of secure and maintainable websites.

3. Deployment and Feedback - We will deploy our web application and take feedback from users for further improvement.

The proposed algorithms for the voice-based Parkinson's disease detection project are

1. Decision trees
2. Support vector machines (SVMs)

3. Logistic Regression

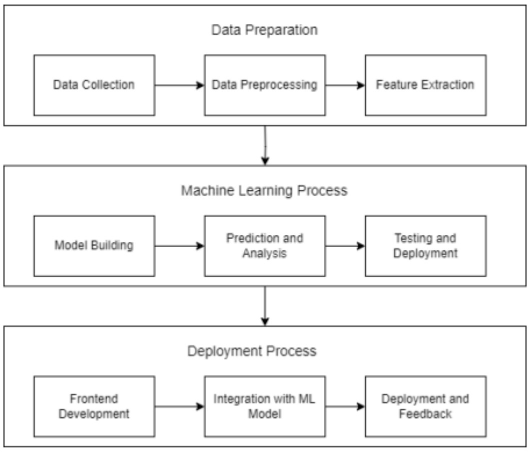
These algorithms are all machine learning algorithms that are effective for various classification tasks, including Parkinson's disease detection.

Decision trees are a form of machine learning method that classifies data using a tree-like structure. The tree's nodes represent decisions, while the leaf nodes indicate class labels. The algorithm learns to categorize data by moving down the tree, making judgments at each node until it reaches a leaf node.

SVMs are a type of machine learning algorithm that learns to categorize data by detecting a hyperplane that divides it into two categories. The hyperplane is chosen to maximize the margin between the two classes. SVMs are very successful with high-dimensional data, such as speech signals.

Logistic regression is a statistical model that estimates the likelihood of a binary event, such as whether or not a patient has Parkinson's disease.Logistic regression works by fitting a linear model to the data and then using that model to estimate the likelihood of the result. The model is trained using a collection of voice recordings from Parkinson's sufferers and those who do not have the condition. The program learns which aspects in speech recordings are most predictive of Parkinson's illness.[12]

A. Block diagram



Fig(i): A schematic illustrating the flow of data from its collection stage to output.

V. RESULTS

Three classification algorithms were tested for the project i.e. SVM, Logistic Regression, Decision Tree, the best results were obtained when Decision Tree was used with an accuracy of 96.6%

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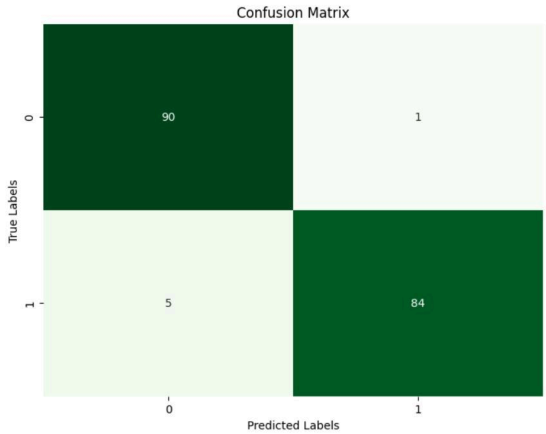
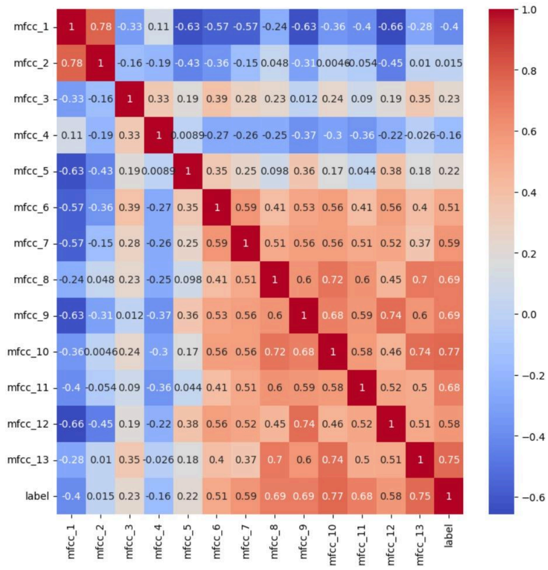


Fig(ii): Confusion Matrix.

Evaluation Metrics	Value
True Positives	84
True Negatives	90
False Positives	1
False Negatives	5
Precision	0.988
Recall	0.943
Specificity	0.989



Fig(iii): Correlation Matrix.

VI. CONCLUSION

In the realm of healthcare, where early diagnosis and effective management are pivotal, our pursuit of predicting Parkinson's disease has been a journey marked by challenges, innovation, and the relentless pursuit of a solution.

The problem we faced was twofold. Firstly, Parkinson's disease is a complex neurological condition that demands early detection for optimal patient care. Secondly, existing diagnostic methods often fall short in providing timely and non-invasive solutions. This gap underscores the critical need for accurate and accessible predictive models.

Our solution, rooted in the power of machine learning and voice analysis, has aimed to address these challenges head-on. Leveraging Support Vector Machine, Logistic Regression, and Decision Tree algorithms, we meticulously crafted predictive models that can analyze diverse voice features, potentially serving as early biomarkers for Parkinson's disease. The choice of technology, including the use of Google Colab for efficient model development, and PyAudio and Librosa for voice extraction, reflects our commitment to robust and practical solutions.

As we prepare to deploy these models on a dedicated system and integrate them with a user-friendly front end, we're not just advancing technology; we're paving the way for accessible and non-invasive Parkinson's disease prediction. Our journey doesn't end here; it extends into the realm of healthcare, offering the promise of earlier diagnoses, improved patient outcomes, and a brighter future for individuals living with Parkinson's disease. Through innovation and collaboration, we aspire to make a meaningful impact on the lives of many, underscoring the transformative power of technology in healthcare.

VII. FUTURE WORK

Here are some potential future works and enhancements that could be considered:

Augmenting the dataset with techniques like pitch shifting, time stretching, or adding noise can help improve model robustness and generalization.
Pre-trained models or transfer learning techniques could be explored, especially if there are similar datasets or tasks available, to leverage knowledge from related domains.
Continuously improve the user interface of the web application to enhance user experience and accessibility for both clinicians and patients.
Integrate a feedback mechanism into the web application to collect user feedback and iteratively improve both the model and the application interface.

By addressing these future works, the project can be further enhanced in terms of model performance, robustness, usability, and ethical considerations, ultimately contributing to improved detection and management of Parkinson's disease.

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