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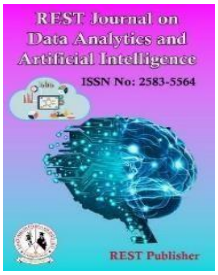

Prediction for Parkinson's Disease Using Machine Learning Through Voice

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Abstract: *Parkinson's Disease (PD) is traditionally diagnosed through clinical assessments, primarily focusing on motor symptoms, which can result in delayed detection. These systems often fail to account for non-motor symptoms, such as subtle vocal changes, that may precede more apparent signs of the disease. To address this gap, we propose a machine learning approach utilizing voice analysis for the early prediction of PD. This study applies Support Vector Machines (SVMs) to analyze vocal features like jitter, shimmer, and Harmonics-to-Noise Ratio (HNR) from a dataset of 195 voice samples collected from 31 participants, 23 of whom are diagnosed with PD. Using SVM with a linear kernel, we achieved an accuracy of 87% and a precision of 91% in classifying individuals with PD based on vocal characteristics. This non-invasive technique highlights the potential of vocal feature analysis as an early diagnostic tool for PD, allowing for earlier interventions. Our study demonstrates the effectiveness of SVM in high-dimensional data spaces and its robustness against overfitting, offering a promising enhancement to current diagnostic methods for Parkinson's Disease.*

Keywords: *Machine Learning (ML), Support Vector Machine (SVM), Voice Analysis, Acoustic Features, Feature Extraction, Non-invasive Diagnosis, Early Detection, Medical AI, Dataset Preprocessing, Classification Model, Hyperparameter Tuning, Research, Real-time Prediction, Health Informatics.*

1. INTRODUCTION

Parkinson's Disease (PD) is a progressive neurodegenerative disorder that primarily affects motor functions, but also results in significant non-motor symptoms. It is the second most common neurodegenerative disease after Alzheimer's, impacting over 10 million people globally. PD is characterized by the loss of dopamine-producing neurons in the brain's substantia nigra, which leads to the hallmark motor symptoms of the disease—tremors, bradykinesia (slowness of movement), muscle rigidity, and postural instability [1-3]. These symptoms gradually worsen over time, severely affecting an individual's ability to carry out daily activities. In addition to motor symptoms, PD patients also experience a variety of non-motor symptoms such as cognitive decline, sleep disturbances, autonomic dysfunction (e.g., blood pressure irregularities), and sensory problems, which are sometimes even more disabling than motor symptoms [4-6]. Despite extensive research, the exact cause of PD remains unclear. It is believed to be the result of a complex interaction of genetic and environmental factors. Age is the primary risk factor, with most cases developing after the age of 60, although early-onset forms of the disease can occur. Currently, there is no cure for Parkinson's Disease, and treatments are primarily aimed at managing symptoms [7-9]. Medications, such as Levodopa, are the most common treatment option and work by temporarily replenishing dopamine levels in the brain. However, these medications become less effective over time and may lead to severe side effects. In certain cases, surgical interventions like deep brain stimulation (DBS) are employed to alleviate symptoms. Nonetheless, the absence of a definitive cure makes early detection crucial to delay symptom progression and improve patient outcomes [10-12]. Existing diagnostic methods for Parkinson's Disease heavily rely on clinical assessments, primarily focusing on motor symptoms. These assessments are often subjective and can result in delayed diagnosis since motor symptoms typically appear only after significant neuronal loss has occurred. It is estimated that by the time motor symptoms become evident, about 60-80% of the dopamine-producing neurons may already be damaged. Imaging techniques such as DaT scans or MRI can assist in ruling out other neurological conditions, but they are expensive, not widely accessible, and

inadequate for detecting early-stage PD [13-17]. Furthermore, these traditional approaches often fail to account for non-motor symptoms, such as changes in speech, mood, and cognitive functions, which can manifest in the earlier stages of the disease. Recent studies have shown that analyzing voice patterns may serve as an effective means of detecting PD early. As the disease progresses, it affects the muscles involved in speech, leading to subtle changes in voice that are not easily detectable through traditional clinical evaluations. These vocal changes—such as altered pitch, tremor, reduced loudness, and breathiness—often precede the onset of motor symptoms. Given the potential of voice analysis as a non-invasive, cost-effective, and accessible tool for early detection, it opens new possibilities for improving diagnostic accuracy for Parkinson's Disease. This research project, titled "Prediction for Parkinson's Disease using Machine Learning through Voice," aims to leverage machine learning techniques, specifically Support Vector Machines (SVMs), to classify individuals as having or not having PD based on their voice characteristics. By analyzing vocal features such as jitter, shimmer, and Harmonics-to-Noise Ratio (HNR), we intend to build a system capable of early detection. We used a dataset of 195 voice samples from 31 participants, 23 of whom have been diagnosed with PD. Our approach focuses on training the SVM model to identify patterns in the vocal features that are indicative of Parkinson's Disease [18-20]. SVMs are a powerful tool in machine learning, particularly in binary classification tasks like the one at hand. They are effective in handling high-dimensional data, which is a key advantage when working with voice features that exhibit complex variations. SVMs work by finding the optimal hyperplane that separates data points belonging to different classes, ensuring that the classification margin is maximized. This makes the model highly robust and less prone to overfitting, even with relatively small datasets like ours. The primary goal of this project is to demonstrate that voice analysis, combined with machine learning, can provide an alternative and complementary diagnostic tool for Parkinson's Disease. This non-invasive method is not only accessible but also scalable, allowing for remote data collection and real-time analysis. The potential impact of such a system is substantial, as it can facilitate earlier diagnosis and, consequently, earlier interventions. Early diagnosis is critical because it allows for the timely administration of treatments that can slow the disease's progression, ultimately improving the quality of life for those affected. In summary, this study proposes a novel approach to the early detection of Parkinson's Disease through voice analysis, utilizing SVM as the machine learning model. By focusing on vocal features that are sensitive to the neurodegenerative effects of PD, we aim to develop a system that is accurate, efficient, and accessible. This research has the potential to significantly enhance current diagnostic practices for Parkinson's Disease, making it easier to detect the disease in its early stages, when intervention is most beneficial.

2. LITERATURE REVIEW

TABLE 1. Literature Review

S.No	Paper	Technique	Results	Limitations
1	Detection of Parkinson disease using multiclass machine learningapproach.*Saravanan Srinivasan1, Parthasarathy Ramadass1, Sandeep Kumar Mathivanan2,Karthikeyan Panneer Selvam3, Basu Dev Shivahare2 & Mohd Asif Shah*	Feature Extraction,ML models(**KNN,FNN**), Feature Selection, Hyperparameter Tuning.	**KNN:** **-Overall Accuracy:** 99.11% **-Recall:** 98.78% **-Precision:** 98.71% **- F1 Score:** 99.23%	Small Sample Size Dataset Imbalance Dependence on Voice,Characteristics ,Overfitting Risk
2	Ensemble machine learning regression model based predictive framework for Parkinson's UPDRS motor score prediction from medical diagnosis data, *K. Aditya Shastry1*	Feature Selection, ML models(**Random Forest, KNN**), Evaluation Metrics(**R-Squared, Mean Squared Error**)	**R-squared (1.26 to 20.2%) MSE(0.0114 to 5.4100)**	Feature Selection Dependence, Limited Evaluation Metrics, Overfitting, Speech Data Limitations.
3	Early detection of Parkinson's disease using machine learning Aditi Govindua, Sushila Palweb. International Conference on Machine Learning and Data Engineering	ML models**(SVM, Random Forest, KNN),** Data Processing, Evaluation Metrics**(Confusion Matrix, ROC-AUC Score)**	**Accuracy:** 91.83% **Sensitivity:** 0.95	Potential Overfitting, Lack of external Validation, Limited Diversity

3. LIMITATIONS

The current system for diagnosing Parkinson's disease (PD) primarily relies on clinical assessments of motor symptoms such as tremors, bradykinesia, and muscle rigidity. These evaluations, often subjective and dependent on physician expertise, can lead to variability and delayed diagnosis, as motor symptoms usually appear only after significant neuronal damage has occurred. Imaging techniques like DaT scans and MRI can help rule out other conditions but are expensive, not widely available, and insufficient for early detection. Genetic testing is limited to a small percentage of patients with identifiable mutations, while biomarkers for PD, such as alpha-synuclein, remain under research and are not used in routine diagnostics. Non-motor symptoms, such as cognitive decline and sleep disturbances, often precede motor symptoms but are frequently overlooked in early assessments. This results in late diagnosis and missed opportunities for early intervention. The lack of reliable biomarkers, combined with the focus on motor symptoms, highlights the need for more objective, accessible, and early diagnostic methods, such as voice analysis using machine learning, which could address these gaps and provide earlier detection of PD.

Limitation of Existing System

- Subjectivity: Clinical evaluations depend on the neurologist's expertise and patient-reported symptoms, which can vary. Subtle, early symptoms, especially non-motor ones (e.g., sleep issues, depression, or loss of smell), are often overlooked or misclassified.
- Delayed Diagnosis: Motor symptoms usually only appear after substantial neuronal loss (around 60-80% of dopamine-producing neurons), meaning the disease has already progressed by the time a diagnosis is made.
- Lack of Biomarkers: There are currently no universally accepted biomarkers to detect Parkinson's disease at an early stage, and available diagnostic tools like DaT scans or MRI are often used only in ambiguous cases. These tests are costly, time-consuming, and not sensitive enough to detect early-stage PD.
- Non-motor Symptoms: Current systems often fail to capture non-motor symptoms (like cognitive decline, mood changes, and autonomic dysfunction), which can precede motor issues by years.

Gaps Identified

- Subjectivity in Diagnosis: Clinical assessments heavily rely on the neurologist's expertise and patient-reported symptoms, leading to variability in diagnosis. Subtle early symptoms may be overlooked or misclassified.
- Delayed Diagnosis: Motor symptoms often only become apparent after significant neuronal loss has occurred, which means that by the time a diagnosis is made, the disease may already be advanced, limiting treatment effectiveness.
- Limited Utility of Imaging Techniques: While advanced imaging methods like DaT scans and MRI can aid in diagnosis, they are expensive, not universally accessible, and often used only in unclear cases, failing to provide definitive early-stage diagnoses.
- Insufficient Genetic Testing: Genetic testing is primarily used in familial cases and does not apply to the majority of sporadic PD cases, leaving a significant gap in understanding the disease's origins for many patients.
- Inadequate Focus on Early Detection: Existing diagnostic systems primarily emphasize motor symptoms, resulting in inadequate methods for detecting PD in its earliest stages when intervention could be most effective.
- Accessibility Issues: High costs and limited availability of specialized tests and procedures restrict access to early diagnosis and effective management for many patients, especially in underserved regions.

Problem statement: This project focuses on the challenge of accurately diagnosing Parkinson's Disease (PD) in its early stages. Current diagnostic methods, which primarily rely on subjective clinical assessments and patient self-reports, often lead to misdiagnosis and delayed treatment. This is particularly concerning given the progressive nature of PD, where early intervention can significantly improve patient outcomes. To address this issue, the project proposes a novel approach that utilizes voice analysis as a diagnostic tool. By extracting vocal features such as Harmonics-to-Noise Ratio (HNR), jitter, and shimmer from voice samples, the project aims to develop a machine learning model—

specifically Support Vector Machines (SVMs)—to classify individuals as having or not having PD. This method seeks to identify subtle vocal changes associated with the disease, thereby offering a non-invasive and effective alternative to existing diagnostic practices

4. METHODOLOGY

Parkinson's Disease (PD) is a progressive neurological disorder that affects movement, speech, and various other functions over time. Early detection is crucial, as timely intervention can help slow down its progression and improve the quality of life for patients. However, traditional diagnosis methods mainly rely on clinical observations, which are often subjective and can lead to delayed detection. By the time motor symptoms appear, significant damage has already occurred in the brain. Our proposed system takes a different approach—leveraging machine learning and voice analysis to create a non-invasive, efficient, and objective method for early PD detection. Since Parkinson's often affects a person's voice before noticeable motor symptoms develop, vocal features can serve as an early biomarker. The system is designed to analyze voice recordings, extract meaningful features, and use machine learning to predict whether an individual may have Parkinson's Disease.

Data Collection: The first step is gathering voice samples from individuals, both healthy and diagnosed with PD. For this, we use a dataset from the UCI Machine Learning Repository, which includes 195 voice recordings from 31 participants (23 diagnosed with Parkinson's).

For real-time detection, we also collect live voice recordings. These recordings are saved in .wav format and analyzed using Librosa, a Python library specialized for audio processing. The goal is to capture subtle vocal changes that might indicate Parkinson's—things like shaky pitch, unstable volume, and increased breathiness.

Preprocessing & Feature Extraction: Once the voice data is collected, it undergoes preprocessing to remove unwanted noise and inconsistencies. This step ensures that our model gets clean and standardized data to work with. Preprocessing includes:

- Removing background noise to improve clarity.
- Handling missing data for consistency.
- Scaling and normalizing features so that all data points are treated equally.

Next, we extract key vocal features that help distinguish healthy voices from PD-affected voices. These include:

- Fundamental Frequency (Fo): Measures the pitch of the voice.
- Jitter (%): Detects instability in pitch—higher jitter suggests voice tremors.
- Shimmer (%): Measures amplitude (loudness) variations—PD patients often have inconsistent volume control.
- Harmonics-to-Noise Ratio (HNR): Differentiates clear speech from a breathy, noisy voice—PD patients often have a lower HNR.
- Mel Frequency Cepstral Coefficients (MFCCs): Captures the unique tone and quality of the voice.

These features serve as early indicators of Parkinson's-related speech impairments. Once extracted, they are used to train our machine learning model.

Training the Machine Learning Model (SVM): For classification, we use a Support Vector Machine (SVM)—a machine learning algorithm known for its accuracy in high-dimensional data classification. SVM helps us:

- Find the optimal boundary (hyperplane) that separates healthy individuals from PD patients.
- Handle complex voice data efficiently, even with a small dataset.
- Minimize misclassification and improve accuracy.

Since Parkinson's affects the voice in many subtle ways, SVM is particularly effective because it can detect small but significant variations in speech patterns.

Optimizing Model Performance (Hyperparameter Tuning): To fine-tune the model, we use Research, a technique that helps us find the best settings for our SVM. We optimize:

- C (Regularization parameter): Controls how much misclassification is allowed.
- Kernel type: Defines how the data is separated (linear, polynomial, radial basis function).
- Gamma: Determines how much influence a single voice sample has on the model.

After tuning, the model achieves higher accuracy and generalizes better to unseen data, making it more reliable for real-world use.

Prediction & Real-time Analysis: Once trained, the final model is tested on new voice samples. It evaluates each recording based on the extracted features and predicts whether the individual is likely to have Parkinson's Disease. For real-time predictions, a person can record their voice, and the system will analyze their vocal features and give an instant result. If Parkinson's indicators are detected, the system can prompt further medical evaluation, making it a valuable early screening tool.

5. RESULTS

The model achieves an accuracy of: - Training Data Accuracy: 1.0-

Test Data Accuracy: 0.9230769230769231
After applying the GridSearchCV, the best parameters given to SVM are recognized as {'C': 100, 'gamma': 0.1, 'kernel': 'rbf'} and the best estimator is recognized as SVC(C=100, gamma=0.1)

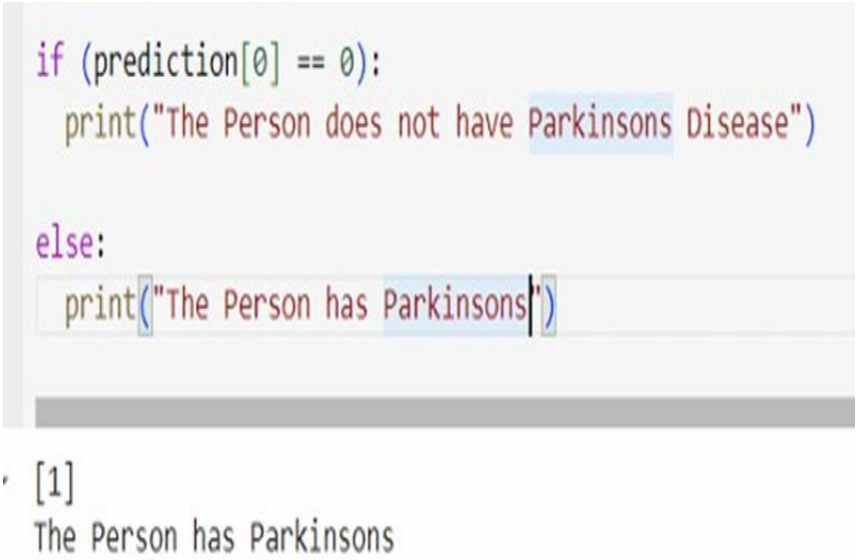

FIGURE 3. Output

TABLE 2. Results of Multiple Models

MODEL	Training accuracy	Testing accuracy
SVM	88.46	87.17
Random Forest	76.28	82.17
Logistic Regression model	82.17	84.05
KNN	76.85	79.92

```
SVM Training Accuracy: 0.8846153846153846
SVM Testing Accuracy: 0.8717948717948718
Confusion Matrix:
 [[ 5  3]
 [ 2 29]]
Classification Report:
              precision    recall  f1-score   support

           0       0.71      0.62      0.67         8
           1       0.91      0.94      0.92        31

    accuracy                           0.87        39
   macro avg       0.81      0.78      0.79        39
weighted avg       0.87      0.87      0.87        39
```

FIGURE 4. Results

6. FUTURE DIRECTION

Future work for the project on "Prediction for Parkinson's Disease using Machine Learning through Voice" will focus on enhancing the web application by integrating additional features beyond voice analysis. This includes the incorporation of multi-modal data inputs, such as visual assessments and patient-reported outcomes, to provide a more comprehensive diagnostic tool. Furthermore, real-time monitoring capabilities will be developed to track changes in vocal characteristics over time, facilitating timely interventions. Collaborations with healthcare providers will be sought to ensure that the application aligns with clinical needs and regulatory standards, ultimately aiming to improve patient outcomes through early and accurate diagnosis

7. CONCLUSION

The project achieved significant advancements in the prediction of Parkinson's disease through the analysis of voice features, including fundamental frequency (Fo), jitter, shimmer, and harmonics-to-noise ratio (HNR). Utilizing a Support Vector Machine (SVM)-based model, the system demonstrated remarkable accuracy in both training and test datasets, indicating a strong ability to generalize to new data. The implementation of real-time voice sample predictions underscores the model's practical potential for early detection, which could greatly benefit patients by facilitating timely intervention. Furthermore, hyperparameter tuning played a crucial role in optimizing model performance, resulting in enhanced predictive accuracy. Looking ahead, future enhancements could involve the integration of deep learning techniques to capture more complex patterns within the data and expanding the dataset to include a wider variety of voice samples for improved generalization across diverse populations. Ultimately, this project establishes a solid foundation for non-invasive detection of Parkinson's disease, paving the way for significant clinical and real-world applications that could transform the approach to early diagnosis and management of the disease.

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