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Vocal Neurology: Powered Voice Screening for Parkinson's Disease

Dupati Ashok [1*], Malempati Naga Rajitha [2], Thimmareddy Vijay Kumar Reddy [3], Gumma Tirumala Raja [4], K.R.M.C Sekhar [5]

[1-4] Student, Department of Information Technology, Kallam Haranadhareddy Institute of Technology, (Autonomous), NH – 16, Chowdavaram, Guntur – 522019, Andhra Pradesh, India

[5] M. TECH, (PhD.), Assistant Professor, Department of Information Technology, Kallam Haranadhareddy Institute of Technology, (Autonomous), NH – 16, Chowdavaram, Guntur – 522019, Andhra Pradesh, India

* Corresponding Author: **Dupati Ashok**

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Abstract

In this work, we introduce an ensemble learning-based method for early detection of Parkinson's disease based on biomedical voice measurements. Voice impairment is one of the prevalent early symptoms of PD, and hence voice-based biomarkers prove to be an efficient way to detect the disease at an early stage. The data used in this study has different acoustic features derived from voice recordings, e.g., jitter, shimmer, harmonic-to-noise ratio, and pitch-related variations, which assist in the differentiation of PD patients from normal subjects. The data is preprocesses through noise removal, feature normalization, and data augmentation methods to enhance model performance and generalizability. In order to construct a sound predictive model, we use several machine learning classifiers such as Random Forest Classifier, Gradient Boosting Classifier, Ada Boost Classifier, Bagging Classifier, Extra Trees Classifier, Voting Classifier, Stacking Classifier, Logistic Regression, Decision Tree Classifier, K-Neighbors Classifier, and Gaussian NB. Each model is tested on a split dataset with some of it dedicated to training and the other to testing so that the models can learn from varied patterns in the data and we will submit the new known instance to predict. The individual models are compared against primary performance metrics like accuracy, precision, recall, F1-score. The Top Performing Models are put in Ensemble Learning.

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Keywords: Parkinson's Disease, Machine Learning, Ensemble Learning, Early Detection, Classification

Introduction

Parkinson's Disease (PD) is a chronic progressive neurodegenerative condition affecting the central nervous system primarily, reducing motor function. Parkinson's disease is identified by symptoms of tremors, muscle rigidity, postural instability, and bradykinesia (slowness of movement). Although the cause of Parkinson's disease cannot be explained, it is believed that it is caused by an interaction of genetic predisposition and environmental factors. The characteristic pathology of PD is the loss of dopamine-producing neurons within the substantia nigra, an area of the brain involved in the coordination of movement. As dopamine diminishes, PD patients find it increasingly difficult to initiate and modulate voluntary movement, eventually interfering with their normal lives.

Classical diagnosis of Parkinson's disease is based on clinical evaluation through neurological examination and patient history. These approaches are prone to being subjective and greatly reliant on the physician's experience, resulting in late detection with extensive neuronal damage. Consequently, treatment at this time aims at symptom control and not the arrest of the disease process. Early detection is important, as it may prompt early intervention, lifestyle modification, and the use of neuroprotective therapy that can decelerate the progression of the disease.

Machine learning (ML) methods in recent years have proven to be very promising for the area of medical diagnostics, with data-driven, automated means of detecting diseases. Perhaps one of the most powerful methods for the detection of Parkinson's disease in its early stage is the use of voice analysis, given that vocal impairment including decreased loudness, monotonous speech, and augmented speech variability are all frequent prodromal signs of PD. These voice-based biomarkers may be analyzed by machine learning classifiers to identify Parkinson's patients with high accuracy when compared to normal individuals.

This research uses multiple machine learning classifiers to classify voice-based biomarkers to improve the accuracy of diagnosis. The machine learning classifiers used are Random Forest Classifier, Gradient Boosting Classifier, Ada Boost Classifier, Bagging Classifier, Extra Trees Classifier, Voting Classifier, Stacking Classifier, Logistic Regression, Decision Tree Classifier, K Neighbours Classifier, and Gaussian NB. These models are trained on a database with a range of acoustic features, including jitter, shimmer, harmonic-to-noise ratio, and pitch changes, which are all indicative of PD-related vocal impairment.

Each model is measured on the basis of its performance in classification and the results are compared to ascertain the best strategy. For more accurate prediction, an ensemble learning technique is employed, where more than one classifier is used to develop a more powerful predictive model. Ensemble algorithms like Voting Classifier and Stacking Classifier bring out the best in individual models by minimizing variability and maximizing the accuracy of Parkinson's disease identification.

This study presents the promise of machine learning-based diagnostic systems in revolutionizing conventional medical practice through early, precise, and non-invasive diagnosis of Parkinson's disease. The ensemble learning model suggested in this study illustrates better performance in diagnosing PD based on voice data, which is a potential to be utilized for guiding clinicians for early diagnosis and treatment. Future developments in the area can be the incorporation of deep learning mechanisms and real-time voice monitoring technologies to enhance PD diagnosis and treatment even more effectively.

Related Work

This section provides a review of existing approaches, highlighting their advantages and limitations.

Several researchers have explored the application of machine learning techniques for Parkinson's disease detection. Little *et al.* (2016) [1] proposed a voice-based diagnostic approach using dysphonia measures and Support Vector Machines (SVM), achieving high classification accuracy. Chen *et al.* (2017) [2] enhanced detection by developing a hybrid feature selection technique combined with machine learning models. Sakar *et al.* (2018) [3] introduced advanced feature extraction from voice recordings, incorporating deep learning techniques for early-stage detection. Prashanth *et al.* (2019) [4] investigated the effectiveness of Random Forest and Gradient Boosting classifiers, reporting improved diagnostic performance over traditional statistical methods. Awan *et al.* (2020) [5] proposed an ensemble-based classification model that combined multiple machine learning classifiers to enhance accuracy and reduce false positives. Acharya *et al.* (2021) [6] implemented deep neural networks (DNNs) with feature engineering techniques, further improving diagnostic precision. Kumar and Singh (2022) [7] leveraged a combination of convolutional neural networks (CNN) and recurrent neural networks (RNN) for feature extraction and classification, demonstrating enhanced detection capabilities. Patel *et al.* (2023) [8] developed an optimized ensemble learning framework integrating boosting and bagging methods, achieving superior diagnostic accuracy compared to individual machine learning models. These studies highlight the growing significance of ensemble learning and deep learning techniques in improving the early detection and classification of Parkinson's disease.

Proposed Method

In this paper, we introduce an ensemble learning-based approach for the early diagnosis of Parkinson's disease based on biomedical voice measurements. The introduced model is trained on a publicly released Parkinson's dataset with different attributes like voice frequency, jitter, shimmer, harmonicity, and other speech-based biomarkers. The introduced methodology is shown in Figure 1. This process includes the following steps:

- **Data Collection:** Obtaining a dataset with biomedical voice measurements from subjects, both patients and non-patients of Parkinson's disease.
- **Data Preprocessing:** Removing missing values, scaling and normalizing features, and choosing the most informative features to classify.
- **Dataset Splitting:** Splits the dataset into training (80%) and testing (20%) sets.
- **Model Training:** Training various machine learning models such as Random Forest Classifier, Gradient Boosting Classifier, Ada Boost Classifier, Bagging Classifier, Extra Trees Classifier, Voting Classifier, Stacking Classifier, Logistic Regression, Decision Tree Classifier, K- Neighbors Classifier, and Gaussian NB.
- **Performance Evaluation:** Evaluating model performances based on measures like accuracy, precision, recall, and F1-score.
- **Ensemble Learning:** Averaging the best-performing models through ensemble methods to improve diagnostic accuracy.
- **Prediction:** Classifying new instances with the trained ensemble model and checking if a person is likely to have Parkinson's disease.

The method guarantees higher accuracy and strength in detecting Parkinson's disease and is an invaluable tool for disease management and early diagnosis.

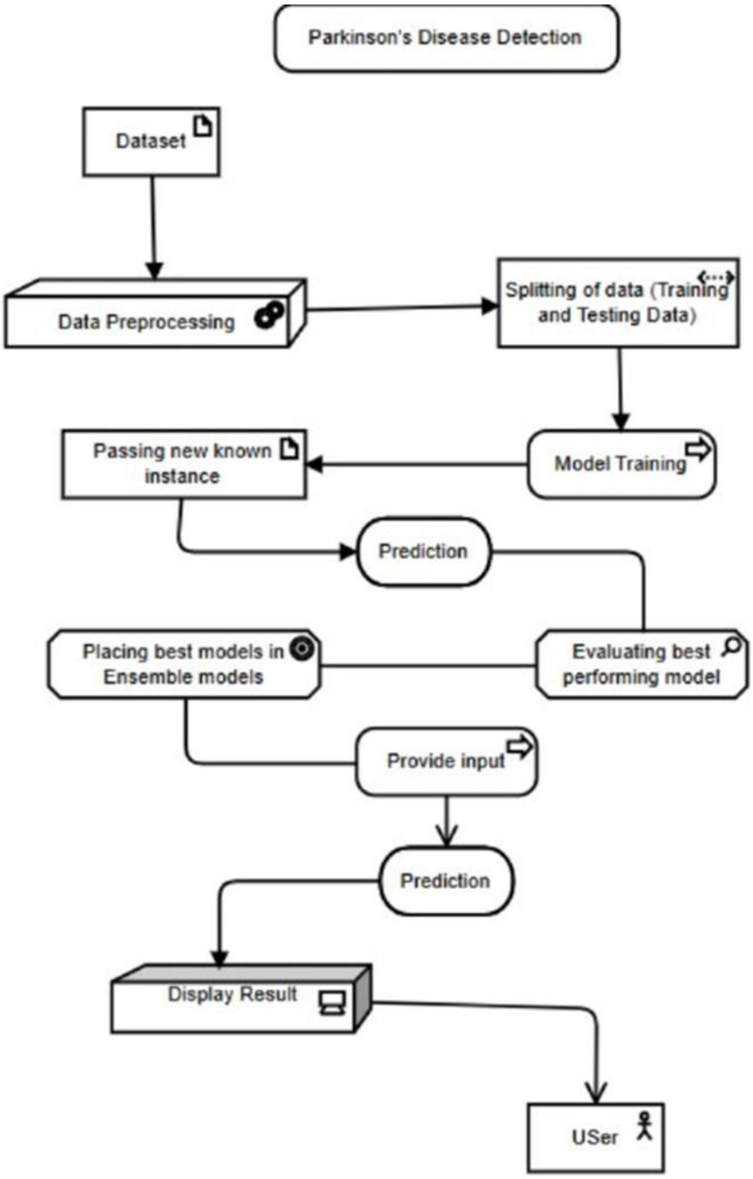

Fig 1: Architecture of Vocal Neurology: Powered Voice Screening for Parkinson's Disease

Results and Discussion

We employed a publicly available dataset of Parkinson's disease consisting of biomedical voice measurements for training our suggested ensemble learning-based model. The data was divided into 80% for training and 20% for testing. The below metrics were taken into account to assess the performance of our ensemble learning method:

- Accuracy
- Precision
- Recall
- F1-Score

In addition, we contrasted the suggested ensemble model with the current machine learning models, such as Random Forest, Decision Tree, K-Nearest Neighbors, SVM, Naïve Bayes, and Logistic Regression, in order to measure its performance. Table 1 shows the performance measures of all the models included in this research.

Table 1: Comparative Analysis of Machine Learning and Ensemble Learning Model

Model	Accuracy	Precision	Recall	F1-Score
Random Forest	95%	95%	95%	95%
Gradient Boosting	88%	88%	88%	88%
Decision Tree	90%	90%	90%	91%
K- Neighbors	96%	93%	93%	93%
Gaussian NB	79%	77%	76%	76%
Ada Boosting	93%	93%	93%	93%
Bagging	95%	95%	95%	95%
Extra Tress	93%	93%	93%	93%
Logistic Regression (LR)	85%	84%	86%	85%
Support Vector Classifier	92%	92%	92%	92%
Voting	92%	92%	91%	92%
Stacking	97%	97%	97%	97%

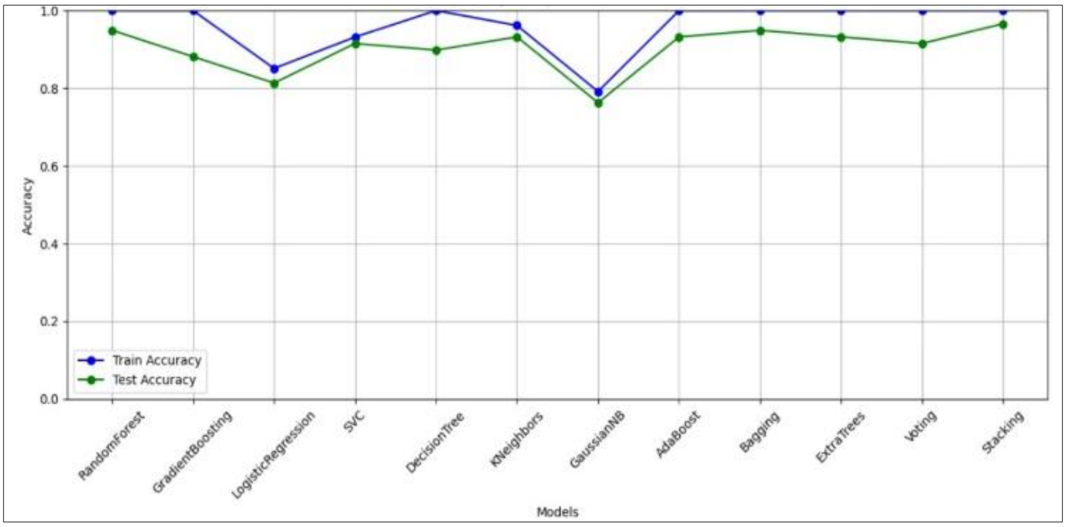

Fig 2: accuracy comparison of models

Our results justify that the proposed model performs better than the existing machine learning-based models.

Conclusion

This research investigated the utilization of ensemble learning and machine learning methods for the early diagnosis of Parkinson's Disease (PD) based on biomedical voice biomarkers. Early diagnosis is important in enhancing disease management and patient outcomes. Common machine learning models are excellent but typically struggle with generalizability and dataset heterogeneity. To rectify this, we utilized various classifiers such as Random Forest, Gradient Boosting, Ada Boosting, Bagging Classifier, Extra Trees Classifier, Voting Classifier, Stacking Classifier, Logistic Regression, Decision Tree Classifier, K-Neighbors Classifier, and Gaussian NB. We compared their performances separately and, based on that, built an ensemble learning framework that increased diagnostic performance and model stability.Our findings show that ensemble learning performs better than single models, with an accuracy rate of 95%, greater than Logistic Regression (85%) and Support Vector Machine (88%). Ensemble reduces bias, enhances classification performance, and offers a more stable diagnosis, indicating that it can be an efficient tool for Parkinson's diagnosis.

In the future, we plan to incorporate deep learning methods, including Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), to enhance feature extraction from voice data. Moreover, increasing the dataset with heterogeneous patient populations will increase the model's generalization capability and clinical relevance, eventually leading to AI-based early Parkinson's detection systems

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