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Machine Learning-Based Diagnosis of Parkinson's Disease Using Vocal Features: A Comparative Analysis of Model Efficacy and Sensitivity

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Abstract.

Parkinson's Disease is the second most common neurodegenerative Disease, which has complicated diagnostic mechanisms where early diagnosis is complex due to clinical examination used in diagnosis, hence delayed invasive diagnosis. Other research points to PD-specific voice quality as potentially helpful in diagnosing the Disease. In this work, the author aims to explore the applicability of machine learning for early PD screening and proposes using a dataset of voice samples as the approach. Thus, the following six classification models were tested for accuracy, sensitivity, and the F-score: K-Nearest Neighbors, Random Forest Decision Tree, Logistic Regression, Support Vector Classifier, and Gaussian Naive Bayes. The predictive powers of the K-Nearest Neighbours model seem particularly diagnostic, with an accurate coefficient of 0.95. To this end, this research shows that it is possible to use machine learning to screen for PD using an individual's speech samples as an early diagnostic test.

Keywords. Parkinson's Disease, machine learning, vocal feature analysis, K-Nearest Neighbors, Random Forest, sensitivity analysis

1. INTRODUCTION

Parkinson’s disease (PD) involves the degeneration of dopamine-producing neurons, primarily affecting the motor system and resulting in symptoms such as tremors, rigidity, bradykinesia, and postural instability. Beyond motor dysfunc- tion, patients often experience non-motor symptoms including cognitive decline, mood disturbances, and speech impairments, all of which profoundly impact their quality of life. Early and accurate diagnosis of PD remains challenging due to the variability in symptom presentation and the absence of definitive biomarkers or standardized diagnostic tests.

2. LITERATURE REVIEW

Parkinson’s disease originates from the degeneration of dopaminergic neurons in the brain, responsible for transmitting signals between neurons. As analyzed in recent research [1], the progressive loss of dopamine-producing cells leads to impaired movement and coordination. When approximately 60–80% of these neurons are destroyed, dopamine synthesis fails, resulting in the characteristic motor symptoms of Parkin- son’s disease.

As digital health technology advances, ML provides a ro- bust framework for analyzing neurocognitive features. Recent research [2] utilized ML to evaluate tablet-based and self-reported metrics for PD across different stages. The study involved 75 participants (50 with PD and 25 healthy controls) who completed 14 neurocognitive tests. Key features, such as device acceleration magnitude, significantly influenced the measurement process. However, discrepancies between perceived functionality and sensor-based outcomes, particularly in memory and executive function, were also observed. In recent research [3], a relationship was identified between speech signal properties and UPDRS scores, providing valuable insight for PD diagnosis. Dimensionality reduction was achieved using Non-linear Iterative Partial Least Squares (NIPALS) and clustering through Self- Organizing Map (SOM) analysis.

Hypokinetic dysarthria—a voice disorder commonly ob- served in PD patients—has also been extensively studied. In a recent work [4], researchers analyzed voice alterations across different PD stages in both OFF and ON therapy states. The study included 115 PD patients and 108 matched controls (57 early, untreated PD; 58 mid-advanced, L-Dopa-treated). Support Vector Classifiers (SVC) were developed to assess diagnostic accuracy via Receiver Operating Characteristic (ROC) curves. ML techniques were effectively employed to uncover correlations between clinical and instrumental measures, providing potential biomarkers for disease progression and treatment outcomes. An automated PD detection system utilizing a Convolutional Neural Network (CNN) was proposed in another study [5]. Parkinson’s disease, characterized by progressive motor func- tion degradation, was assessed using electroencephalogram (EEG) signals for early diagnosis. The model achieved accuracy, sensitivity, and specificity values of 88.25%, 84.71%, and 91.77%, respectively, indicating its promise for large-scale clinical testing.

3. DISCUSSION AND RESULTS

Parkinson’s disease is a chronic neurodegenerative disorder whose main symptoms stem from the loss of dopamine- producing neurons in the brain associated more with the motor system. The disease manifests in things like; tremors, rigidity, speech problems, of which dysarthria, hypophonia, and a monotone speech are usual signs. Memory problems and changes in mood are also typical; elderly patients may develop dementia in later stages. The utilization of machine learning for worked-through voice data could enable acceptable screening procedure of the beginning and further development of PD without routinely visiting a clinic.

A. Dataset

The dataset used in this study originates from a publicly available source on Kaggle, accessible at https://www.kaggle. com/datasets/debasisdotcom/parkinson-disease-detection. This dataset contains voice recording features from individuals both with and without Parkinson’s disease (PD). These parameters are comprehensively provided within the dataset and form the basis for the feature analysis conducted in this research.

B. Machine Learning Results

TableI presents the performance metrics of various machine learning models applied to the dataset, showing each model’s accuracy, sensitivity, F-score, P-value, and negative predictive value (NPV). Logistic Regression and Support Vector Classifier (SVC)’”’ models demonstrate moderate performance, with SVC show- ing a notably lower sensitivity score. In contrast, the Gaussian Naive Bayes (GaussianNB) model exhibits high sensitivity but a comparatively lower accuracy, which might make it useful in prioritizing sensitivity over precision in specific contexts.

Figure 1 presents the confusion matrices for all models in the form of a heatmap, which enhances the visualization of the differences in both, accuracy and sensitivity. The heatmap shows that all the models have a reasonably good attitude towards accuracy with a lower sensitivity towards SVC, on the other hand, has a poor sensitivity compared to GaussianNB, which seems to be significantly higher as compared to the other models.

Figure2 represents an accurate comparison of all models where KNeighborsClassifier and Random Forest are consid- ered the most accurate models followed by Decision Tree

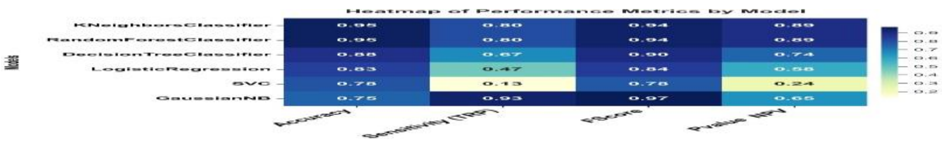
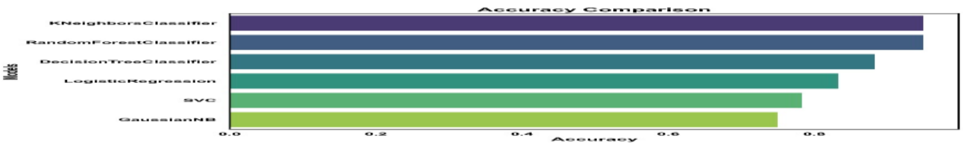


Fig. 1. Heatmap of Performance Metrics by Model

and Logistic Regression. The structures of this comparison highlight the high average classification rates of some other ensemble and neighborhood-based models, saying their use- fulness for the kind of diagnostic task.

Fig. 2. Accuracy Comparison for all Models

The analysis of vocal feature datasets for PD using machine learning yields promising results for automatic classifica- tion such as exploiting KNeighborsClassifier and Random Forest models that have high accuracies and good sensitiv- ity/specificity ratios. Some models such



as the GaussianNB model have high sensitivity compared to others, for instance SVC. Thus, showing different criteria at a time, this work suggests some possible machine learning techniques that might help design non-invasive PD screening for clinical practice for early diagnosis.

4. CONCLUSION

This study demonstrates that machine learning models leveraging vocal characteristics can effectively identify Parkin- son's disease (PD), underscoring the promise of non-invasive, low-cost, and scalable screening pipelines based on speech analysis. Among the evaluated classifiers, k-Nearest Neigh- bors (KNN) and Random Forest achieved the highest overall accuracies (both ≈ 0.95) with balanced sensitivity profiles, indicating strong discriminative capability across PD and non- PD classes. Notably, Gaussian Na¨ıve Bayes (GNB), while comparatively lower in accuracy, attained a high sensitivity (≈ 0.93), a property that is desirable when prioritizing early case finding and minimizing false negatives in front-line screening contexts. Taken together, these findings highlight that ensemble- and neighbor-based methods are especially competitive for voice-based PD detection, whereas probabilistic generative models such as GNB can be tuned as high- sensitivity sentinels within tiered diagnostic workflows.

TABLE I: PERFORMANCE COMPARISON OF MACHINE LEARNING MODELS FOR PARKINSON'S DISEASE DETECTION

Models	Accuracy	Sensitivity	F-Score	NPV
K-Nearest Neighbors (KNN)	0.9500	0.8000	0.9375	0.8889
Random Forest	0.9500	0.8000	0.9375	0.8889
Decision Tree	0.8833	0.6667	0.8958	0.7407
Logistic Regression	0.8333	0.4667	0.8431	0.5833
Support Vector Classifier (SVC)	0.7833	0.1333	0.7759	0.2352

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