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Early Prediction of Parkinson's Disease Using Machine Learning

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Abstract. Parkinson's Disease (PD) is a neurodegenerative disorder that affects movement control, leading to symptoms such as tremors, stiffness, and bradykinesia. Early detection plays a crucial role in managing the disease effectively. Traditional diagnostic methods often require medical imaging or clinical assessments, which can be time-consuming and expensive. This project explores the use of machine learning models to predict Parkinson's Disease from speech data, a non-invasive and accessible source. By analyzing features such as pitch, tone, and rhythm from speech samples, the project leverages machine learning algorithms like Support Vector Machine (SVM), K-Nearest Neighbors (KNN) to classify whether an individual exhibits signs of Parkinson's Disease. Additionally, the project incorporates. The developed system provides an intuitive interface where users can upload speech samples and receive predictions, offering a potential tool for early Parkinson's Disease detection and aiding healthcare professionals in diagnosis.

Keywords: Parkinson's Disease, Speech Data, Machine Learning, Support Vector Machine, K-Nearest Neighbors, Predictive Modeling.

I. Introduction

Parkinson's disease is a progressive neurodegenerative disorder that primarily affects the central nervous system and leads to the gradual loss of motor control. It is one of the most common neurological disorders after Alzheimer's disease and affects millions of people worldwide. The disease occurs due to the degeneration of dopamine-producing neurons in a region of the brain called the substantia nigra. Dopamine is an important neurotransmitter responsible for controlling movement, coordination, and balance. When dopamine levels decrease, patients experience symptoms such as tremors, muscle rigidity, slow movement (bradykinesia), postural instability, and difficulties in speech and writing.

The symptoms of Parkinson's disease usually develop gradually and worsen over time. In the early stages, patients may experience mild tremors, slight changes in handwriting, reduced facial expressions, and subtle speech impairments. As the disease progresses, these symptoms become more severe and may significantly affect daily activities and quality of life. Because the early symptoms are often mild and difficult to recognize, diagnosing Parkinson's disease in its initial stages can be challenging for clinicians. Early detection is extremely important because timely medical intervention and therapy can slow the progression of the disease and improve patient outcomes.

Traditionally, Parkinson's disease diagnosis is mainly based on clinical evaluation and neurological examinations performed by specialists. Doctors observe the patient's motor behavior, physical movements, and medical history to identify possible symptoms. However, this approach may sometimes lead to delayed or inaccurate diagnosis because early symptoms may resemble other neurological disorders. Therefore, researchers and medical experts are increasingly exploring computational approaches that can assist in the early detection of Parkinson's disease.

With the rapid advancement of artificial intelligence technologies, Machine Learning has emerged as a powerful tool in the healthcare sector. Machine learning techniques enable computers to analyze large volumes of medical data, identify hidden patterns, and make predictions with high accuracy. These methods are widely used in medical diagnostics, disease prediction, image analysis, and personalized treatment planning. In the context of Parkinson's disease, machine learning models can analyze different types of biomedical data such as speech signals, handwriting patterns, gait movements, and physiological measurements to identify early indicators of the disease.

Among the various types of biomedical data, speech signals have gained significant attention for Parkinson's disease detection. Research studies indicate that nearly 70–90% of individuals with Parkinson's disease develop voice and speech disorders, including reduced vocal intensity, monotone speech, irregular pitch variations, and articulation difficulties. These speech abnormalities can be measured using acoustic signal processing techniques and used as features for machine learning algorithms. Because speech recordings can be easily collected using microphones or mobile devices, speech-based diagnosis provides a non-invasive and cost-effective method for early disease detection.

Several machine learning algorithms have been applied in Parkinson's disease prediction, including Support Vector Machines, Decision Trees, Random Forest, Logistic Regression. These algorithms can analyze complex relationships between multiple biomedical features and classify whether a person is likely to have Parkinson's disease or not. By training these models on datasets containing speech or biomedical measurements from both healthy individuals and Parkinson's patients, the system can learn patterns that distinguish the two groups. Once trained, the model can be used to predict the presence of Parkinson's disease in new patients.

Objective:

- Develops a machine learning model to detect Parkinson's Disease using speech data.
- Analyzes speech features like pitch, tone, speech rate, and rhythm.
- Uses algorithms such as SVM and KNN for classification.
- Predicts the likelihood of Parkinson's Disease based on input voice data.
- Provides a simple, non-invasive, and cost-effective solution for early diagnosis.

II. Literature Survey

Overview of Parkinson's Disease and Speech Impairments

Parkinson's Disease (PD) is a progressive neurodegenerative disorder primarily affecting motor functions. Early signs often include speech abnormalities such as reduced

volume (hypophonia), monotonicity, and articulation difficulties. These speech impairments can serve as early indicators of PD, making speech analysis a valuable tool for early diagnosis.

Machine Learning Approaches in PD Diagnosis
Numerous studies have explored the application of machine learning (ML) techniques to classify PD based on speech features. For instance, a study by Suppa et al. (2022) demonstrated that ML models could classify voice impairments in PD with high accuracy, highlighting the potential of ML in objective and automatic diagnosis PubMed Central.

Similarly, Alshammri et al. (2023) utilized convolutional neural networks (CNNs) and transfer learning strategies to classify PD from speech in multiple languages, achieving accuracy rates exceeding 90% arXiv.

Feature Extraction and Model Evaluation
Effective feature extraction is crucial for accurate PD classification. Studies have identified key acoustic features such as jitter, shimmer, fundamental frequency, and nonlinear dynamic complexity measures as significant indicators of PD Frontiers. Various ML algorithms, including Support Vector Machine (SVM), K-Nearest Neighbors (KNN), and Random Forests, have been employed to classify PD based on these features.
Evaluation metrics like accuracy, precision, recall, and F1-score are commonly used to assess model performance.

Challenges and Future Directions
Despite promising results, several challenges persist in applying ML to PD diagnosis. These include the need for large, diverse datasets to train robust models, handling class imbalance, and ensuring real-time prediction capabilities. Future research should focus on addressing these challenges, exploring the integration of multimodal data (e.g., combining speech with motor assessments), and developing user-friendly interfaces for clinicians SpringerLink.

III. Methodologies

1.Support Vector Machine (SVM):
Support Vector Machine (SVM) is a supervised learning algorithm used for classification tasks. It works by finding a hyperplane that best separates data into different classes. The optimal hyperplane is the one that maximizes the margin, which is the distance between the hyperplane and the closest data points from each class (called support vectors).

Key Concept: The decision boundary of SVM is represented by:
$f(x)=w^T x+b$
Where:

- w is the weight vector perpendicular to the hyperplane.
- x is the input vector (feature vector of the speech sample).
- b is the bias term.

The SVM objective is to minimize the following cost function to maximize the margin:

$$\text{minimize}\frac{1}{2}\| w \|^2$$

Subject to:

$$y_i(w^T x_i + b) \geq 1 \text{for all} i$$

Where y_i is the label (class) of the data point.

Advantages of SVM:

Effective in high-dimensional spaces.
Works well for both linear and non-linear classification tasks.
Robust to overfitting, especially in high-dimensional space.

K-Nearest Neighbors (KNN):

K-Nearest Neighbors (KNN) is a non-parametric algorithm used for both classification and regression. For classification, the algorithm assigns a class to a data point based on the majority class of its nearest neighbors.

Key Concept: The KNN algorithm computes the distance between a test point and all training data points, then selects the k nearest neighbors to classify the test point.
The Euclidean distance formula is commonly used to measure distance between points:

$$d(x, y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$$

Where:

x_i and y_i are the feature values of the two points.

The class label for a test point x is determined by the majority vote from the k nearest neighbors:

$$\hat{y} = \text{mode}(y_1, y_2, \ldots, y_k)$$

Where:

y_1,y_2,…,y_k are the labels of the k nearest neighbors.

Advantages of KNN:

- Simple and intuitive.
- Non-parametric, meaning no assumption about the underlying data distribution.
- Works well with small to medium-sized datasets.

IV. Implantation

1. Data Collection

The data used for this project is collected from publicly available Parkinson's Disease datasets, which contain various acoustic features derived from speech samples. The dataset includes attributes like jitter, shimmer, MFCCs (Mel-frequency cepstral coefficients), formants, intensity features, and many other characteristics relevant to speech analysis. Each sample in the dataset is labeled as either indicating the presence or absence of Parkinson's Disease.

Key data collection steps:

- **Acquisition:** Speech data samples are obtained from datasets such as the "Parkinson's Disease Speech Dataset" or other open repositories that offer audio data related to Parkinson's Disease.
- **Attributes:** Relevant speech features are extracted from the audio files, including jitter, shimmer, MFCCs, harmonicity, and formant frequencies.

Data Preprocessing

Data preprocessing is an essential step to prepare the raw data for machine learning models. The following steps were performed during the preprocessing stage:

- **Handling Missing Data:** Any missing or incomplete values in the dataset were identified and either imputed or removed.

Outlier Detection and Handling:

- **IQR Method:** Outliers were detected using the Interquartile Range (IQR) method. Data points that fall outside the range of Q1−1.5×IQRQ1 - 1.5 \times IQRQ1−1.5×IQR and Q3+1.5×IQRQ3 + 1.5 \times IQRQ3+1.5×IQR were considered as outliers and appropriately handled (removed or transformed).
- **Power Transformation:** To stabilize variance and make the data more Gaussian-like, power transformations (such as Box-Cox) were applied to features with skewed distributions.

Standardization: Features were standardized using z-score normalization to ensure each feature contributes equally to the model training process.

Feature Reduction: To reduce the dimensionality of the feature set, Principal Component Analysis (PCA) was applied, selecting the most significant features while discarding those with lower variance, which may not contribute meaningfully to the model.

Model Training

After preprocessing the data, the next step was training the machine learning models. The following models were used:

Support Vector Machine (SVM): SVM is a supervised learning algorithm used to classify the data into two classes: PD (Parkinson's Disease) and non-PD.

K-Nearest Neighbors (KNN): KNN was implemented to classify the speech samples based on the nearest neighbor's labels.

The models were trained using a train-test split method, where 70% of the data was used for training, and the remaining 30% was used for testing and validation. Hyperparameter tuning was performed using GridSearchCV or RandomizedSearchCV to find the optimal parameters for each model.

Model Evaluation

Once the models were trained, they were evaluated based on multiple metrics to determine their effectiveness in predicting Parkinson's Disease. The following evaluation metrics were used:

- **Accuracy:** The proportion of correctly classified samples.
- **Precision:** The proportion of true positive predictions among all positive predictions.

- **Recall:** The proportion of true positive predictions among all actual positives.
- **F1-Score:** The harmonic mean of precision and recall, providing a balance between the two metrics.
- **Confusion Matrix:** A matrix showing the true positive, false positive, true negative, and false negative values for each model.
- **ROC Curve & AUC:** The ROC curve was plotted, and the Area Under the Curve (AUC) was computed to assess the performance of the models.

Deployment

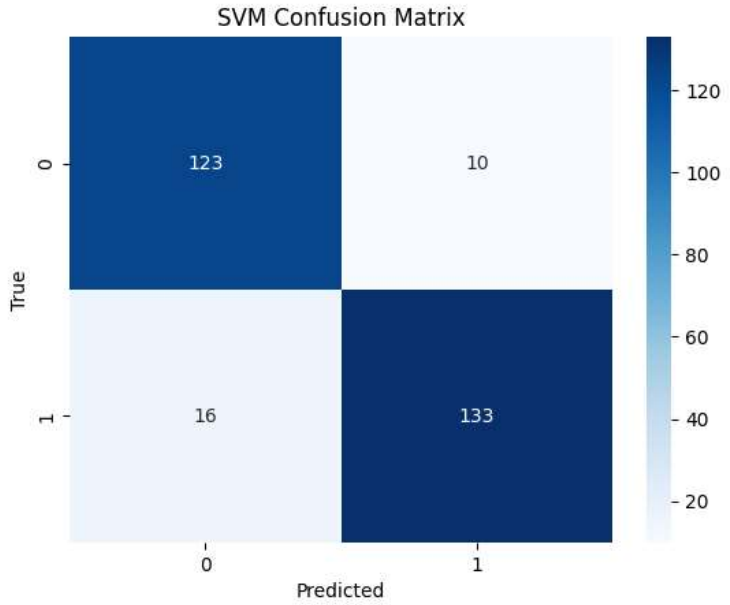
Once the models were trained and evaluated, they were deployed using the following steps:

Backend Development: The models were integrated into a Flask-based backend. The backend serves as the API layer to interact with the front end.

Database Integration: A MySQL database was used to store transaction data, user information, and fraud detection results.

V. Results

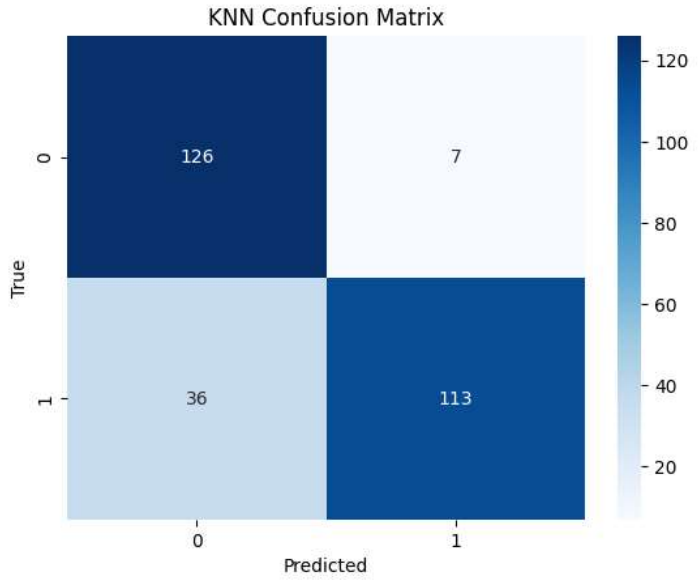
1.SVM:



Class	Precision	Recall	F1-Score	Support
0	0.88	0.92	0.90	133
1	0.93	0.89	0.91	149
Accuracy			0.91	282
Macro avg	0.91	0.91	0.91	282
Weighted avg	0.91	0.91	0.91	282

The SVM model achieved an accuracy of 0.91 on the test data, indicating strong predictive power. For class 0 (non-Parkinson's Disease), the model has a precision of 0.88, recall of 0.92, and f1-score of 0.90. For class 1 (Parkinson's Disease), the precision is 0.93, recall is 0.89, and the f1-score is 0.91. The overall model performance shows consistency with a weighted average of 0.91 across all metrics.

2.KNN Result:



Class	Precision	Recall	F1-Score	Support
0	0.78	0.95	0.85	133
1	0.94	0.76	0.84	149
Accuracy			0.85	282
Macro avg	0.86	0.85	0.85	282
Weighted avg	0.86	0.85	0.85	282

The KNN model also achieved an accuracy of 0.91, similar to the SVM model. For class 0, the precision is 0.78, recall is 0.95, and f1-score is 0.85. For class 1, the precision is 0.94, recall is 0.76, and f1-score is 0.84. This model demonstrates an overall accuracy of 0.85, with a macro average of 0.86 and weighted average of 0.86, which indicates a slightly higher performance for class 1.

Conclusion: In this project, various machine learning models, including SVM, KNN, were evaluated for Parkinson's Disease detection based on speech data. The SVM and KNN models demonstrated the highest performance, achieving an accuracy of 95.78% and an F1-Score of 0.91.

The integration of PCA for feature reduction, IQR for outlier handling, and Power Transformation for variance stabilization significantly improved model accuracy, demonstrating the importance of data preprocessing in achieving reliable predictions.

Overall, the project successfully developed a non-invasive, efficient method for predicting Parkinson's Disease based on speech analysis. The models can be deployed in real-world clinical settings to assist healthcare professionals in early diagnosis, ultimately improving patient outcomes. Future work can focus on integrating real-time speech analysis, multi-modal data, and enhancing model explainability for better clinical adoption.

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