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Detecting Parkinson's Diseases with MVDP and Ml Classification Algorithms

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Abstract: The motor system is the main target of the neurodegenerative disease known as Parkinson's Disease (PD). Degeneration of brain neurones caused by intricate interplay between genetic and environmental factors, rather than infectious or contagious dissemination, is the cause of this disease's spread. Researchers have begun to use various machine learning techniques to detect and assess Parkinson's disease (PD) utilising audio input and MRI/PET or DAT scans due to the increase in the number of individuals with the disease. In order to identify Parkinson's disease, we need to create a system that can analyse patients' auditory data and identify patterns in their conduct. In order to construct the disease-detecting classifier, the suggested method makes use of Support Vector Machine, random Forest, and a number of other algorithms. A preprocessing step and data analysis are utilised to manage data, guarantee an adequate level of detection error, and optimise training time. This data is later combined with other datasets for use in training and testing. With soft voting, our model achieves a final accuracy of 94.87% and an F1 score percentage of 96.9%.

Keywords: Parkinson’s Disease (PD; Good Level of Detection Error; Degeneration of Neurons; Random Forest.

Introduction

Parkinson’s Disease is a progressive neurodegenerative disorder that primarily affects the motor system. The spread of this disease is not due to contagious or infectious transmission but results from complex interactions between genetic and environmental factors, leading to the degeneration of neurons in the brain [1]. With an increasing number of patients diagnosed with Parkinson’s Disease (PD), researchers have started employing various machine learning methods to detect and analyze the disease using audio input, MRI/PET, or DAT scans [2]. The primary goal is to design and develop a disease detection method for PD by analyzing the audio components of patients and extracting behavioral patterns [3]. The proposed system utilizes Support Vector Machine, Random Forest, and Decision Tree classifiers to build a robust classifier for detecting the disease. A preprocessing step and data analysis are implemented to handle data efficiently, ensuring minimal detection error and optimal training time. The data is then split into training and testing sets to improve model reliability [4-9].

Detecting Parkinson's disease using Machine Learning (ML) techniques aims to develop accurate and reliable models that assist in early diagnosis. The models utilize audio data to differentiate between individuals with and without Parkinson's disease [10]. The key objective is to predict infected and non-infected individuals based on audio jitter, spread, and shimmer, using classification machine learning algorithms. This predictive capability helps in identifying individuals with PD and reporting to healthcare professionals, ensuring timely medical intervention. Parkinson's disease affects millions worldwide, making early detection and accurate diagnosis crucial for timely intervention and treatment [11-15]. The integration of Multi-Voice Data Processing (MVDP) techniques with various Machine Learning (ML) classification algorithms presents a promising approach to enhancing the accuracy and efficiency of Parkinson's disease diagnosis. The primary objective of this study is to develop a robust and accurate Parkinson's disease detection system by leveraging MVDP techniques and multiple ML classification algorithms. The research problem is broken down into several key components, including data collection, data preprocessing, feature extraction, model training, and clinical applicability [16-19].

Data collection involves gathering a diverse dataset consisting of multi-view data sources, including clinical, genetic, and neuroimaging data from individuals with and without Parkinson's disease. The data preprocessing and feature extraction stage implements MVDP techniques to process and extract relevant features from the multi-view data sources [20]. This process involves addressing data integration, noise reduction, feature selection, and dimensionality reduction, ensuring the data quality is optimal for model training. A range of ML classification algorithms, including Support Vector Machines, Random Forest, Logistic Regression, and Deep Learning models, are applied to the pre-processed data to build predictive models [21-24]. These models are trained and evaluated using appropriate training and testing datasets, ensuring reliability. The evaluation metrics include accuracy, sensitivity, specificity, and ROC curves to determine the effectiveness of the models. Additionally, model comparison and selection are conducted to identify the most effective algorithm for Parkinson's disease detection. Cross-validation techniques ensure that the selected model generalizes well to unseen data and does not overfit the training dataset [25-31].

Clinical applicability is an essential aspect of this research, as the developed models must be integrated into real-world Parkinson's disease diagnosis. This may involve implementing the models into clinical practice and validating their performance on new patient data [32-35]. Ethical considerations are also addressed, ensuring patient data privacy and compliance with relevant regulations and guidelines. Machine Learning (ML) is transforming research across various fields by enabling advanced data analysis and predictive capabilities. The current era of data explosion further enhances ML applications as the availability of vast datasets allows for more precise model training. Prediction algorithms now have the potential to solve complex problems by leveraging data more effectively than traditional analytical methods. By correlating datasets and their features, ML models can achieve a level of accuracy that surpasses human capabilities [36-41].

In this research, the focus is on integrating ML with Database Management Systems (DBMS) to improve predictive accuracy and efficiency. Although ML has achieved significant scientific milestones, the field is still evolving. Integrated ML is particularly useful for SQL developers looking to deploy machine learning models in their work. A SQL syntax provides an efficient interface for communicating with SQL databases, allowing ML algorithms to process input data and generate predictions seamlessly [42-49]. AutoML further simplifies this process by enabling users to create effective ML models without extensive expertise in the field. The integrated ML algorithm utilizes novel internal tuple batching schemes during query processing, enabling efficient query predictions. This approach ensures that predictions are accurate, regardless of the context in which scalar predictions are invoked. Additionally, integrating ML with a relational engine ensures that performance remains optimal, avoiding any negative impact due to abstraction. This method enhances model prediction capabilities based on query plans, allowing for real-time and efficient decision-making in healthcare applications [50-55].

Integrated ML is embedded as a core capability within InterSystems IRIS Data Platform, a multi-model DBMS that supports DDL/DML SQL syntax. By leveraging this platform, researchers and healthcare professionals can integrate ML-driven predictive models directly into database queries, enhancing efficiency and scalability. The ability to process large datasets efficiently is particularly beneficial in the field of Parkinson's disease detection, where timely and accurate diagnosis can significantly impact patient outcomes [56-61]. The proposed methodology involves multiple stages, starting with data acquisition from clinical and publicly available sources. The preprocessing stage applies normalization techniques to clean and standardize the dataset, reducing null values and inconsistencies. Feature selection is a crucial step, where Sequential Ranking Clustering feature analysis is applied to determine the most significant attributes contributing to Parkinson's disease detection. These features include protein, sugar, fat, iron, folic acid, calcium, and immunity levels.

After feature selection, Stratified K-Fold validation is employed to divide the dataset into k subsets of approximately equal size. This method ensures balanced class distribution and improves the robustness of the model. The final classification step utilizes the Naïve Bayes Gradient Boosting (NBGB) algorithm to predict disease occurrence based on extracted features. The NBGB model provides a reliable prediction of Parkinson's disease and evaluates multiple performance metrics, including accuracy, precision, recall, F1-score, error rate, and time complexity. The confusion matrix evaluation confirms that NBGB outperforms previous approaches in terms of efficiency and reliability. Comparative analysis with traditional optimization models such as Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) demonstrates that the proposed approach significantly enhances accuracy and sensitivity. The integration of AlexNet with the Emperor Penguin Optimizer (EPO) further refines the classification process by optimizing feature selection and hyperparameter tuning [62-72]. This combination outperforms conventional deep learning models, ensuring that early-stage Parkinson's disease can be detected with high accuracy. The impact of this research extends beyond technical advancements, as it holds substantial implications for healthcare applications. Early detection of Parkinson's disease allows for timely intervention, potentially improving the quality of life for affected individuals. By leveraging machine learning techniques and integrating them with advanced data processing methodologies, this study contributes to the development of more reliable and efficient diagnostic tools for neurodegenerative disorders.

Literature Review

One approach to predicting Parkinson's disease involves a nonlinear decision tree-based classification model using different voice data features. A model has been developed utilizing a Random Forest classifier with PCA as a nonlinear decision tree [81]. However, the research lacks a feature reduction technique and does not effectively compare different parameters. Another study focuses on classifying Alzheimer's disease and Parkinson's disease using machine learning and neural networks, examining how factors such as age, genetics, diabetes, smoking, and strokes influence early detection [82]. The implementation of Random Forest tree, RBF network, Decision Table, and Multilayer Perceptron was used, but the research requires high computational power to execute effectively [73].

Another method for early detection of Parkinson's disease through voice analysis employs PRAAT and MATLAB to compute MFCC coefficients and voice parameters like pitch, formants, jitter, and shimmer [83]. While the research explores the science behind voice analysis in depth, it does not emphasize the implementation of machine learning models, which limits its applicability. Similarly, a study using nonlinear acoustic analysis to evaluate voice patterns in Parkinson's disease patients employs LFCC, MFCC, and GTCC for feature extraction, combined with KNN and k-cross validation. However, the use of multiple techniques increases the complexity of the model, making it difficult to implement efficiently [84]. In another approach, Parkinson's disease detection is performed using a Random Forest classifier. The model demonstrates effectiveness but is slow in execution. Incorporating ensemble algorithms such as bagging, boosting, and voting could improve performance, alongside expanding the dataset size to enhance predictive accuracy. Brain network analysis between Parkinson's disease and healthy control groups is conducted using rsfMRI and edge functional connectivity. While eFC achieves better results than classification methods, working with MRI scans is highly complex and requires significant resources [74].

A study utilizing voiceprint analysis for detecting Parkinson's disease applies MFCC and SVM. While MFCC is a powerful technique for speech analysis, SVMs can be computationally expensive, especially for large datasets, and are sensitive to hyperparameter tuning. Another study comparing machine learning models for Parkinson's disease prediction implements 13 different algorithms [85]. The research faces an overfitting issue of 6-7%, which could be reduced by integrating deep learning and neural networks for improved performance. Machine learning-based detection of idiopathic Parkinson's disease using speech data evaluates various neural network models and machine learning algorithms, concluding that deep neural networks achieve the highest accuracy. However, the complexity of DNN models requires substantial computational resources and precise tuning for optimal results [86]. Another study investigates Parkinson's disease tremor characterization using an iPhone's wireless accelerometer application. The G-Link Wireless Accelerometer Node is utilized, which is widely available in iPhones. However, the major limitation is that not all individuals own an iPhone, restricting the accessibility of the method [75].

A comparison of PDF and PCA for Parkinson's disease classification using structural MRI images involves the use of DICOM scans for generating 3D masks, followed by PCA and SVM classification. While the final accuracy rates are high, working with MRI scans is inherently complex, and the sensitivity of SVM to hyperparameter tuning remains an issue. Another study analyzing tremors in Parkinson's disease employs an Arduino Uno and ADXL335 tri-axial accelerometer [87]. Data collected by the Arduino is processed using MATLAB. However, implementing such a system requires knowledge of IoT, making it challenging for researchers without expertise in the field. A broader neurological study investigates multiple disorders, including Alzheimer's disease, Parkinson's disease detection, anxiety detection, and stress detection, using machine learning algorithms [88]. The model does not have significant limitations but could be updated with more recent Parkinson's disease data to enhance accuracy. Another study applies the Maximal Information Coefficient (MIC) for feature selection in Parkinson's disease classification. The MIC values are used to refine feature selection and train a decision tree classifier. However, computing MIC is complex, and more efficient methods for voice data analysis could be utilized [76].

Overall, while many research studies have made significant advancements in Parkinson's disease prediction and classification, there are still considerable technical gaps. Some models lack proper feature reduction techniques, leading to inefficiencies, while others require extensive computational resources for execution. Certain approaches rely on complex methodologies, making them difficult to implement in real-world applications [89]. Moreover, models based on medical imaging data, such as MRI scans, present additional challenges due to the complexity of handling such datasets. Many studies focus on voice analysis for Parkinson's disease detection, employing techniques like MFCC, PCA, and machine learning classifiers. While these approaches show promise, they often suffer from computational inefficiencies and sensitivity to hyperparameter settings. Improvements can be made by integrating ensemble learning techniques, optimizing feature selection methods, and refining machine learning algorithms to enhance performance and reduce computational demands [77].

Furthermore, leveraging deep learning techniques, particularly neural networks, has demonstrated high accuracy in Parkinson's disease detection. However, the major challenge remains the requirement for high computational power, making these methods less accessible for widespread clinical applications [90]. Future research should focus on optimizing deep learning architectures to reduce computational complexity while maintaining high accuracy levels. Another significant issue in Parkinson's disease research is the reliance on specific hardware, such as accelerometers in smartphones or Arduino-based systems. While these methods are innovative, their applicability is limited due to hardware accessibility and usability constraints. A more universally applicable approach should consider alternative methods that do not require specialized devices, increasing accessibility for a larger population [78].

A key consideration in future research is addressing overfitting issues in machine learning models. Many studies report high accuracy rates, but without proper validation techniques, these models may not generalize well to new data. Implementing rigorous cross-validation techniques and expanding dataset sizes can help mitigate overfitting and improve model robustness [91]. Additionally, integrating multi-modal data sources, such as combining voice data with medical imaging and clinical records, could enhance predictive performance. This approach requires sophisticated data fusion techniques but has the potential to provide a more comprehensive analysis of Parkinson's disease progression and early detection [79].

The use of ensemble learning methods, such as bagging, boosting, and stacking, can also improve model accuracy and stability [92]. These techniques have been successfully applied in other medical domains and could be beneficial in refining Parkinson's disease detection models. Similarly, incorporating automated feature selection methods can enhance the efficiency of models by reducing dimensionality while preserving critical information. Finally, ethical considerations must be addressed in Parkinson's disease research involving machine learning. Ensuring patient data privacy, obtaining informed consent, and adhering to medical data regulations are essential for developing ethical and responsible AI-driven healthcare solutions [93]. Future studies should emphasize transparency in data usage and algorithmic decision-making to build trust among medical professionals and patients. In summary, while significant progress has been made in Parkinson's disease detection using machine learning, several challenges remain. Addressing computational inefficiencies, optimizing feature selection techniques, improving model generalization, and ensuring ethical data handling are critical steps toward developing more reliable and accessible diagnostic tools [94]. By incorporating advanced machine learning techniques and refining existing methodologies, researchers can contribute to early and accurate Parkinson's disease detection, ultimately improving patient outcomes [80].

Methodology

The proposed system aims to facilitate the early detection of Parkinson's Disease (PD) and promptly alert medical professionals about the condition of patients. By analyzing speech patterns, the system can detect irregularities such as increased mean jitter percentage and lower Fo, Fhi, and Flo values, which are common indicators of PD. Once detected, medical professionals receive immediate alerts, enabling them to initiate further diagnostic tests and determine the extent of the condition. The system is designed to be accessible at no cost, benefiting the medical community and potentially contributing to early intervention and better patient care. Furthermore, the underlying principles of this system can be extended to detect other oral or neurological disorders. The ultimate objective is to develop a machine learning (ML)-based tool that aids in diagnosing PD at an early stage, ensuring more effective treatment and improved patient outcomes. The model's effectiveness will be measured based on its accuracy, generalization capabilities, and clinical applicability in real-world settings. Given that over 8.5 million people worldwide are currently living with PD, and its prevalence is expected to rise, the importance of early diagnosis cannot be overstated.

The domain of this research falls under healthcare and medical data analysis, leveraging advanced data processing and ML techniques to enhance diagnosis and patient care. Specifically, it focuses on PD detection using Multi-View Data Processing (MVDP) and classification algorithms, aligning with medical data science, neuroscience, and biomedical informatics. Existing approaches for PD detection have employed various ML algorithms such as Random Forest, Naïve Bayes, Decision Tree, and Multilayer Perceptron. While these techniques have shown varying levels of accuracy, there remains room for improvement in performance and reliability. The system begins with data collection, which involves gathering motor performance data from patients through wearable devices, smartphone applications, or clinical evaluations. This raw data undergoes preprocessing, where noise is filtered, missing values are handled, and normalization techniques are applied to standardize the dataset. Feature extraction is then performed to obtain meaningful parameters, particularly Motor Variability Derived Parameters (MVDP), which capture specific variations in motor movements associated with PD [95].

Once extracted, the dataset is split into training and testing sets to evaluate the performance of the ML models. Feature selection methods are used to identify the most relevant MVDP features for classification [96]. Several ML algorithms are implemented for building predictive models, including Logistic Regression, Support Vector Machines (SVM), Random Forest, Gradient Boosting, and Deep Learning-based neural networks. These models are trained using the selected features, where the presence or absence of PD is treated as the target variable [97]. To ensure optimal model performance, evaluation metrics such as accuracy, precision, recall, F1-score, and ROC-AUC are used. Hyperparameter tuning is conducted to fine-tune the models and improve their predictive capabilities. Cross-validation techniques, such as k-fold cross-validation, are applied to ensure robustness and generalizability. The results are interpreted using confusion matrices and ROC curves to assess classification performance [98-99]. If the model demonstrates strong predictive power, it can be deployed in real-world applications for early diagnosis or disease progression monitoring. Continuous improvement of the system is possible by incorporating additional data and refining the ML models with more sophisticated techniques, ultimately advancing the accuracy and effectiveness of PD detection systems.

Result and Discussion

The proposed system aims to enhance the early detection of Parkinson's Disease (PD) by leveraging machine learning techniques. The system processes patient data, primarily audio recordings and medical imaging scans, to identify patterns indicative of PD. Various ML classifiers, including Support Vector Machine (SVM) and Random Forest, are used to ensure reliable detection, and ensemble learning techniques like soft voting are implemented to enhance prediction accuracy. Data preprocessing ensures that input data is cleaned, normalized, and structured before analysis. Feature extraction techniques are applied to derive meaningful insights from both voice and imaging data, making the system more effective in distinguishing PD symptoms.

One of the primary concerns in developing such a system is data quality and quantity. Insufficient or imbalanced datasets can negatively impact model performance, while noisy or inconsistent data may lead to inaccurate predictions. Careful feature selection is necessary to identify the most relevant Motor Variability Derived Parameters (MVDP) that contribute to the accurate classification of PD. Additionally, models must be designed to prevent overfitting, which can cause them to perform well on training data but fail to generalize to new, unseen cases. Deep learning models, while highly accurate, often lack interpretability, making it difficult for medical professionals to understand the reasoning behind a given diagnosis.

Ethical and privacy concerns also play a crucial role, as handling medical data requires compliance with strict regulations such as HIPAA. Ensuring patient confidentiality and securing sensitive health information is vital for gaining user trust and obtaining regulatory approval. Furthermore, real-time monitoring remains a challenge, as the system may not be capable of continuously tracking disease progression. Integrating clinical expertise into the system could also improve its effectiveness, as healthcare professionals possess valuable insights that may enhance diagnosis accuracy. The implementation of this system involves multiple phases. First, data collection occurs through various sources, including audio-based speech assessments and medical imaging techniques like MRI, PET, and DAT scans. After data collection, preprocessing steps remove inconsistencies and extract essential features from the data. The dataset is then split into training and testing sets to evaluate model performance. Machine learning models are trained using labeled data, allowing them to learn from past cases and improve their ability to detect PD symptoms.

To assess system performance, metrics such as accuracy, precision, recall, and the F1-score are used. The model is optimized to balance these factors, ensuring that it minimizes false positives and false negatives while maximizing detection accuracy. Additionally, training time optimization ensures the system remains practical for real-world applications. The ultimate objective is to contribute to the early detection of PD, making diagnosis more efficient and accessible. However, challenges such as model updates, validation, and regulatory approval remain key considerations. As medical knowledge evolves, continuous improvements to the system will be necessary to keep it relevant. Achieving regulatory approval can also be a lengthy and costly process, requiring extensive validation to ensure that the system meets healthcare standards. Despite these challenges, the proposed system has the potential to significantly impact PD detection, improving patient outcomes through timely intervention (Figure 1).

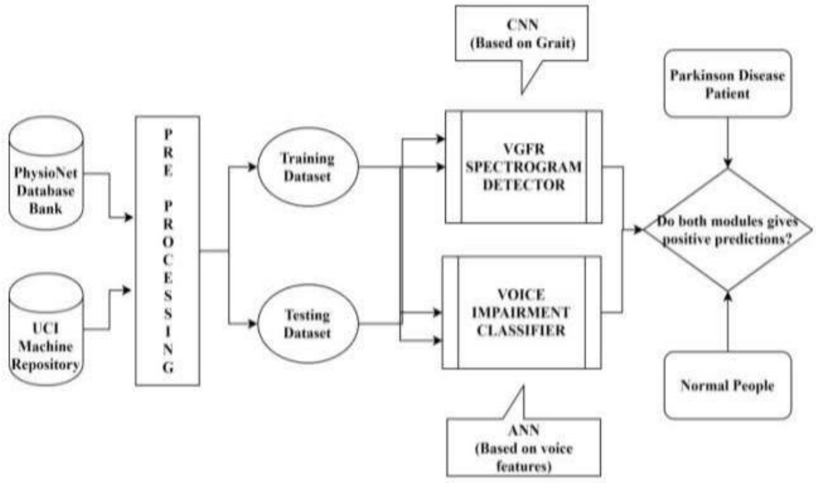

Figure 1: Flow Diagram for Parkinson's Detection

After completing the data analysis, the next step involves splitting the dataset into training and testing subsets. Given the potential imbalance in the data, we will use the train_test_split function from the Scikit-Learn library to ensure a well-structured split. The dataset will be divided into 80% training data and 20% testing data, allowing the model to learn effectively while preserving a portion for evaluation. Once the data is split, the next step is standardization. Standardization ensures that the data is scaled appropriately, preventing certain features from dominating others due to differing scales. The StandardScaler library will be used to transform the data into a normalized format, making it more interpretable for the machine learning algorithms. Standardization is applied by fitting the scaler to the training data, determining the necessary transformations, and then applying these transformations to the testing data as well.

With the dataset prepared, the implementation of machine learning models begins. Various classification algorithms will be employed to analyze their performance in detecting Parkinson's Disease. The selected models include Support Vector Machine (SVM), which is effective for high-dimensional spaces and finds an optimal hyperplane for classification. K-Nearest Neighbors (KNN) is a non-parametric method that classifies based on the majority class of k-nearest data points. Random Forest Classifier is an ensemble learning method that combines multiple decision trees for improved accuracy. Naïve Bayes is a probabilistic classifier that assumes independence between features, often used for medical predictions. Logistic Regression is a statistical model used for binary classification. Perceptron is a fundamental neural network model used for classification tasks.

In addition to these traditional machines learning models, boosting techniques will be employed to enhance performance. Adaptive Boosting (AdaBoost) will be used to improve the performance of the Random Forest Classifier by focusing more on misclassified instances in each iteration. Extreme Gradient Boosting (XGBoost) is a highly efficient gradient boosting algorithm that utilizes the XGBClassifier to optimize predictions. The final stage involves evaluating the models based on performance metrics. The primary evaluation metric is accuracy, which measures the proportion of correctly classified instances.

$$precision = \frac{true\ positive}{(true\ postive + false\ postive)}$$

Additionally, the F1-score will be calculated, as it balances precision and recall, making it an ideal metric for binary classification tasks. Since our research involves a binary classification problem, the F-beta score is set with β = 1, meaning the F-beta score simplifies to the standard F1-score.

$$recall = \frac{true\ positive}{(true\ postive\ + false\ negative)}$$

By comparing accuracy scores and F1-scores across different models, we can determine which algorithm is best suited for Parkinson’s Disease detection. The integration of boosting methods further ensures that our models achieve higher accuracy and robustness, making the system more effective in real-world clinical applications.

$$F1\ score = 2 * \frac{precision * recall}{precision + recall}$$

With everything in place, we can go on to the outcomes. Prior to moving on to the testing data, we will focus on improving the accuracy core of all the algorithms for the training data. The AdaBoost is not usable due to the fact that the training accuracy is 100%. The issue with achieving perfect accuracy is that it indicates the model has been overfitted, which implies it has picked up on noise or outliers. Hard Voting has a f1 score of 0.955224, Soft Voting of 0.969667, and SVM has a f1 score of 0.952381 (Figure 2).

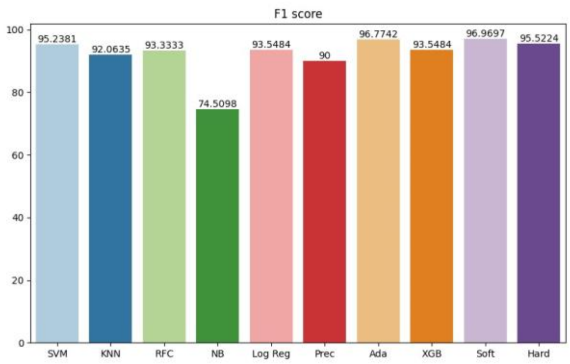

Figure 2: F1 scores of algorithms

Conclusion

The application of machine learning in the detection of Parkinson's disease holds immense promise for improving early diagnosis and treatment outcomes. ML algorithms have demonstrated their ability to analyze large datasets, identify subtle patterns, and provide accurate predictions based on various biomarkers and clinical data. By leveraging these techniques, medical professionals can detect Parkinson’s at an early stage, enabling timely intervention and potentially slowing the progression of the disease. However, despite the effectiveness of the proposed model, certain limitations remain. The classifier’s performance suffers in terms of response time, making real-time application challenging. Additionally, the model does not currently support real-time data processing, which is crucial for continuous patient monitoring and early-stage detection. To address these challenges, future work will focus on enhancing the model’s efficiency while ensuring data security and privacy in real-time applications. Strengthening encryption and access control measures will help protect sensitive patient information. Furthermore, expanding the model’s capabilities beyond acoustic feature-based detection will improve its accuracy and applicability. While this model primarily relies on voice-based biomarkers, Parkinson’s can also be detected using MRI scans and hand tremor analysis. Incorporating these additional diagnostic modalities into the system will create a more comprehensive and accurate detection framework. By integrating multimodal data sources, future research can develop a robust and precise model capable of assisting healthcare professionals in diagnosing Parkinson's disease more effectively and improving patient outcomes through early and reliable detection.

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