Machine Learning based Hybrid model to quickly detect the presence of Parkinson's Disease (PD) using MFCC features of Speech Samples

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Abstract: *Parkinson's Disease (PD) is considered one of the progressive nervous system diseases that affect movement and speech of the individual which causes disability, reduces the life span. Nearly 90% of affected people with this disease have speech disorders. The speech of Parkinson Disease patients will be affected much because of the inherent damage of the motor function. The speech will have monotone pitch and doesn't carry any emotion. It is sometimes hoarse because of heavy breathing of the patients and sometimes is slow because the patients struggle to find the right words during their speech. Stammering and tremor may also be observed in the speech due to the presence of above symptoms, patients with Parkinson disease might undergo depression, therefore it is necessary to early diagnose the disease and start the treatment. Early detection of signs and symptoms also referred to as bio-markers of the Parkinson Disease and the treatment thereof will eventually lead to good quality of life of the patients. Also, it would be helpful for the physicians to treat in a better manner.*

In real-world applications, the speech of PD patients is processed by various Machine learning techniques or algorithms to detect the disease in the early stages and to increase their lifespan.

This work proposes a hybrid model which detects the disease very quickly and accurately. This model covers Multiple Regression (MR) and Association Rule Mining (ARM) techniques. For the development of this model a speech dataset of Parkinson's Disease (PD) patients consisting of only Mel Frequency Cepstral Coefficients (MFCC) or features has been used. The model detected seven MFCC features out of 13 to be affecting the PD disease. Later these seven features are given to the Association Rule Mining model to understand the associations among these features. Later the speech dataset is prepared to consist of these seven MFCC features. Using this dataset HMM and GMM machine learning models have been trained and found to be performing at 88 and 89 percentage levels respectively.

Keywords: *Parkinson's Disease (PD), Speech Disorders, Mel Frequency Cepstral Coefficients (MFCC), Machine Learning, Multiple Regression, Association Rule Mining, Hidden Markov Model (HMM), Gaussian Mixture Model.*

1. Introduction

Parkinson's disease (PD) is a progressive nervous system disease or neurodegenerative disease that affects both motor and non-motor functions resulting in the death of cells in the central nervous system. More than 6 million people worldwide got affected by the disease whose age is above fifty years.

The disease starts with mild tremors and stiffness in the body, gradually worsening over time. As a result, the quality of life of PD patients gets worsened because of the difficulties in speaking, writing, walking and impairment in muscle control.

Despite medical advancements, there are currently no significant remedies for PD. The challenging task is to prevent the progression of the disease. PD patients need to regularly visit the clinics for the treatment of mobility and speech challenges. Therefore detecting the disease early is of the top priority for minimizing its impact, improving the quality of life of the patients, providing timely treatment and thereby reducing their visits to the specialists.

Early detection of symptoms is challenging, particularly for non-specialist physicians. The diagnosis of Parkinson's disease (PD) can be challenging due to subjective assessments of motor symptoms and the overlooked non-motor symptoms that are often caused by other disorders.

Recent advancements in Information Technology have a great impact on medical sciences domain, particularly in the field of neurodegenerative disorders like Parkinson's disease. Machine Learning, Artificial Intelligence, Neural Networks are among so many such popular computational techniques and are being widely used in diagnosing PD.

The techniques are employed on the data collected from the patients and yielded interesting results. The important observation is that the time taken for the diagnosis using these techniques is less when compared to that of the traditional diagnostic examinations.

Presently the research is focused on developing the applications combining the computational techniques and medical sciences for detecting and diagnosing the disease. However, this inter-disciplinary research is very slow on its pace to help the patients in the quick diagnosis of the disease.

As said earlier, the Parkinson's Disease results in speech disorders, thus the speech data of the patients can also be subjected to the computational techniques like Machine Learning (ML) in detecting its presence very quickly. AI technology can accurately and early diagnose Parkinson's disease (PD) using speech data. The computational techniques not only dtects the presence of the disease quickly but also finds its severity level. To address this, machine learning methods have been used to classify PD patients and patients with similar clinical presentations using the speech features dataset.

The paper is organized into seven sections. Section 2 discusses the related work. The features of speech for PD detection are presented in Section 3. The proposed framework of the model and experimental study is elaborated in Section 4. The discussion regarding results is presented in Section 5 and the conclusion remarks are given in Section 6.

2. Literature Survey

Parkinson's disease (PD) is a disabling disease that affects the quality of life due to the death of cells in the central nervous system. This leads to difficulties in speaking, writing, and walking. Speech analysis has been widely studied for the detection of PD, as 90% of patients experience speech disorders. Non-invasive treatments for voice analysis can help improve patients' lives.

Various machine learning and deep learning methods, like support vector machines, decision trees, and deep neural networks, have successfully classified PD. The accuracy achieved by the machine learning classifier is significant, with the deep neural network achieving the highest accuracy of 99.49%. Artificial intelligence is proving to be a powerful tool in medical diagnosis, providing valuable insights for neurologists and data scientists [1].

Various studies focused on using Machine Learning algorithms to identify the Parkinson's Disease. Patients with the disease face difficulties in physical visits for treatment and monitoring due to movement and communication impairments. Hence early detection is crucial for a normal life. The study used different Machine Learning techniques and analyzed voice data from 31 individuals, 23 of whom had PD. Using six different classifiers, the accuracy of detection ranged from 85% to 87%. The study is more effective and precise and suggests incorporating machine learning in diagnosing Parkinson's for improved accuracy and systematization [2].

Parkinson's disease affects both motor and non-motor functions and its diagnosis and treatment is more challenging. To achieve this, Gait characteristics were collected using iPhone 5S sensors from 60 participants, with 53 diagnosed with Parkinson's disease. This real dataset was used to classify Parkinson's patients and healthy individuals. Feature selection techniques were employed to simplify the data, and four classification algorithms were tested for accuracy, sensitivity, and specificity. The Support Vector Machine algorithm demonstrated impressive performance, achieving an accuracy of 97.5%, sensitivity of 95.3%, and specificity of 99.8% [3].

The study which aims to comprehensively analyze the evolution, symptoms, treatments, and progression of Parkinson's Disease, focuses on diagnosing voice tremors caused by Parkinson's and explores the impact of medications on the disease's progression. It exploited the use of feature selection and evolutionary algorithms to achieve accurate results. Also it identifies the research gaps, including the potential use of untapped evolutionary algorithms for an efficient diagnosis using multiple types of data, as well as the early symptom of bradykinesia [4].

Despite medical advancements, there are currently no significant remedies for PD. Its early detection improves the patients' quality of life. Artificial Intelligence (AI) has emerged as a promising tool in PD detection due to its ability to handle large amounts of data and generate accurate predictions. The research article provides a comprehensive survey of various AI-based approaches, including machine learning and deep learning, and discusses ongoing research in the field. The integration of AI shows promise in revolutionizing early detection methods and improving the lives of individuals with PD [5].

Recent advancements in machine learning and multimodal data have shown promising potential in improving the diagnosis of Parkinson's Disease (PD). This review discusses recent advancements in multimodal machine learning methods for Parkinson's disease (PD) diagnosis, including gait analysis, clinical assessment, neuro-imaging, genetic data, and wearable sensors. It explores the advantages and difficulties of combining multiple data sources and how these models can be applied in clinical environments. Key findings shed light on the growing use of multimodal machine learning in PD diagnosis and provide suggestions for further investigation [6].

Machine learning techniques have been applied to detect PD at early stages using imaging studies. Comparative studies have demonstrated that machine-learning-based analysis outperforms conventional methods in detecting PD-associated degeneration and thus improves diagnostic accuracy. Integrating multimodal data can enhance PD diagnosis and its early detection. The use of machine learning may reduce the error rate of PD diagnosis, enable early treatment, and alleviate patient suffering [7].

Machine Learning (ML) and neuro-imaging have become important tools for detecting and diagnosing the PD. However, research on their combination is not widely available. This study provides an overview of using neuro-imaging and ML for PD diagnosis. The study reviews various attempts that utilize popular neuro-imaging modalities such as PET, SPECT, and MRI. It also discusses ML approaches, datasets, and findings. The study concludes that ML-based techniques have a high potential for early and effective PD diagnosis when used properly, paving the way for improved clinical diagnosis [8].

Machine learning and deep learning systems help doctors diagnose PD accurately. The research survey covers the use of artificial intelligence in diagnosis, including datasets, algorithms, and approaches [9].

Machine Learning (ML) systems can use speech data to diagnose Parkinson's disease (PD). In this study, the Parkinson's Progression Markers Initiative (PPMI) dataset and Deep Belief Networks (DBN) were used to predict PD progression. The DBN model, which utilized a Convolutional Neural Network (CNN) with voice inputs from PD patients and healthy controls, outperformed other algorithms. The study demonstrated that DBN-based models can accurately detect PD early, potentially enhancing diagnosis and improving medical therapy [10].

AI technology can accurately and early diagnose Parkinson's disease (PD) using speech data. The study utilized the Parkinson's Progression Markers Initiative (PPMI) dataset and Deep Belief Networks (DBN) to predict PD progression. The DBN model, compared to others, outperformed in detecting PD. The DBN model offers a data-driven and scientific approach. The research suggests using PPMI-sized datasets and speech data to enhance disease management and patient outcomes [11].

Various Supervised Machine Learning models namely Support Vector Machine (SVM), Logistic Regression (LR) and Random Forest (RF) are built on the speech data [21] of PD affected patients and found Random Forest models to be performing well in classifying the PD patients and normal patients [12].

Parkinson's disease (PD) is a progressive nervous system disease that impairs speech, walking, and muscle control. Using a dataset from Kaggle, this study analyzed voice measurements of the patients with PD. Four supervised classification machine learning models were evaluated, with XGBoost achieving the highest accuracy of 0.93 for precise PD classification [13].

The paper explores the use of machine learning algorithms to detect Parkinson's disease by analyzing noise-free speech signals. The Random Forest algorithm used 13 MFCC coefficients for classification and is proved to be the most effective with an accuracy of 95.8% [14].

The researchers are seeking ways to detect PD early to provide timely treatment and also to prevent its progression. Various machine learning models like Naive Bayes, Random Forest, K-Nearest Neighbour, XGBoost, Decision Tree, and Support Vector Machine are employed, with Principal Component Analysis reducing the number of features. Performance analysis shows accuracy ranging from 70% to 90%. Ensemble models are used to improve overall performance, achieving a recognition accuracy of 91% for Parkinson's disease [15].

Diagnosing Parkinson’s disease (PD) at an early stage is more challenging. The research article suggests using deep neural networks and speech signal metrics to automate the PD diagnostic procedure which has a validation accuracy of 94.87% and thus increasing the likelihood of early detection and improving therapy effectiveness [16].

The study aims to evaluate the performance of three supervised AI algorithms (SVM, KNN, and LR) for improving PD diagnosis. Results show that SVM achieved 100% accuracy, while LR achieved 97% accuracy. KNN had the lowest precision at 60% [17].

Diagnosing PD is difficult due to subjective motor symptom assessments and overlooked non-motor symptoms caused by other conditions. To address this, machine learning methods have been used to classify PD patients and the patients with similar clinical presentations. A literature review was conducted, analyzing 209 studies published until February 2020 which highlights the potential of machine learning methods and novel biomarkers in improving the diagnosis and assessment of PD, leading to more systematic and informed decision-making in clinical settings [18].

Parkinson's disease starts with mild tremors and its early detection of symptoms is challenging, particularly for non-specialist doctors. To address this, a predictive analytics framework using K-means clustering and Decision Tree algorithms is proposed. Voice data sets obtained from the UCI Machine Learning repository are analyzed to gain insights. Early detection through this framework can improve patient lifespan and quality of life with proper treatment [19].

Detecting PD early is crucial for enabling patients to live a normal life. The study discusses the application of machine learning in telemedicine to remotely and accurately detect PD in its early stages. Four machine learning models were trained on audio data from 30 PD patients and healthy individuals, with the Random Forest classifier proving to be the most effective, achieving a detection accuracy of 91.83% and sensitivity of 0.95 [20].

The study aims to develop a machine learning system that can accurately classify individuals with PD using their speech signals. The system utilizes four feature selection algorithms, six classifiers, and two validation methods to achieve accurate results. The study highlights the significance of utilizing feature selection methods to improve classification accuracy and explains the medical background behind the selected features and their importance in PD diagnosis [22].

The hybrid model combining Multiple Regression and Association Rule Mining models identified seven MFCC features out of thirteen which got influenced because of the speech disorders arising out of Parkinson's Disease [23].

3. Dataset Information

The data used in this study is reported to have come from 252 individuals, 188 of whom have Parkinson's disease (PD) and the remaining 64 are healthy. The 81 women and 107 men in the PD affected group range in age from 33 to 87 years old. The 41 women and 23 men in the healthy group range in age from 41 to 82. Each subject's sustained phonation of the vowel /a/ was recorded three times during the data collection process, with the microphone set at 44.1 KHz, after a thorough review by the physician [21].

3.1. Attribute Information

Various speech signal processing algorithms have been used to voice recordings of Parkinson Disease (PD) patients in an attempt to extract information that is therapeutically helpful for improved patient assessment. Mel Frequency Cepstral Coefficients (MFCCs), Wavelet Transform based Features, Vocal Fold Features, Time Frequency Features, and TWQT features are the methods that make up this set [21].

3.2. MFCC Features

The Mel Frequency Cepstral Coefficients (MFCCs) from an audio signal, we usually end up with a set of features. The number of features can vary depending on the specific implementation, but traditionally, 13 MFCCs are commonly used. Here's a detailed explanation of what these 13 MFCC features talk about:

1. Overall Energy (0th MFCC): The 0th MFCC represents the overall energy of the signal within the frame. It is also known as the "DC" component and is computed as the logarithm of the total energy in the frame.

2. Spectral Envelope (1st MFCC): The 1st MFCC generally captures information about the overall spectral shape or envelope of the audio signal. It reflects how the energy is distributed across different frequency bands. This can give insights into the timbre or quality of the sound.

3. Rate of Change in Spectral Envelope (2nd MFCC): The 2nd MFCC represents the rate of change in the spectral envelope. It captures the dynamics or how quickly the spectral characteristics of the signal are changing from one frame to the next. This can be useful for distinguishing between different phonemes or sounds.

4. Higher Spectral Peaks (3rd to 7th MFCCs): These MFCCs often represent the amplitudes of the peaks in the spectrum. Peaks in the spectrum are important because they correspond to resonances in the vocal tract, which are crucial for speech production. The 3rd to 7th MFCCs can help capture information about the formants of the speech signal, which are the spectral peaks created by the resonant frequencies of the vocal tract.

5. Spectral Bands (8th to 13th MFCCs): The remaining MFCCs (8th to 13th) typically correspond to the amplitudes of the filterbank energies. Signal is passed through Mel scale filters to calculate energies using triangular filters. The 8th to 13th MFCCs provide information about the energy distribution across different frequency bands, reflecting how the energy is distributed in both lower and higher frequencies.

In summary, the 13 MFCC features provide a compact representation of various aspects of the audio signal's frequency content and dynamics. They capture information about the overall energy, spectral shape, rate of spectral change, spectral peaks, and energy distribution across frequency bands. These features are commonly used in speech recognition, speaker identification, and other audio processing tasks because they effectively summarize important characteristics of the speech signal while reducing the dimensionality of the data.

GMM and HMM are popular statistical approaches used for classification in pattern recognition problems such as speech processing. Hence these models have been chosen for classifying the disease data.

Hidden Markov Models (HMMs) are statistical models that describe systems with changing unobservable states. They rely on the notion of an underlying process with concealed states and known outcomes. HMMs model uncertainties and dependencies in sequences by defining probabilities for state switching and symbol emission. They have various applications in finance, bioinformatics, and speech recognition, enabling dynamic system modeling and predicting future states.

The Hidden Markov Model (HMM) is a statistical model that links observed sequences to hidden states. It is useful when the underlying system is unknown. HMMs predict future observations or classify sequences based on the hidden process generating the data. They involve hidden states, generating but not directly observable, and observations, which are measured. Probability distributions model the relationship between the hidden states and observations.

Transition probabilities define the likelihood of moving between hidden states, while emission probabilities define the likelihood of observing an output given a hidden state.

Gaussian Mixture Model (GMM) is a probabilistic model that assumes data points come from a limited set of Gaussian distributions with uncertain variables. It characterizes each distribution with mean and covariance matrix. It extends the k-means clustering technique by considering data's covariance structure and the likelihood of points belonging to each distribution.

GMM Algorithm: GMMs cluster data by detecting similarities and differences for organization. They can classify consumers into subgroups based on demographics and buying habits. GMMs use a soft clustering technique, giving data points the possibility of belonging to multiple clusters. The EM algorithm trains GMMs by iteratively estimating the parameters of the Gaussian distribution.

Steps in GMM algorithm

Initialize phase: Initialize Gaussian distributions' parameters: means, covariances, and mixing coefficients.

Expectation phase: Use Gaussian distributions to determine data point creation likelihood.

Maximization phase: Re-estimate Gaussian distribution parameters with probabilities from expectation step.

Final phase: Repeat the above two steps for parameter convergence.

4. Proposed Methodology

The dataset downloaded from public data repository (kaggle) [1] has the attributes relating to the speech of individuals who got affected by the PD and also of normal persons. The experiment indicated in [23] revealed that ***seven*** MFCC features, namely **MFCC_0th_coef, MFCC_2nd_coef, MFCC_3rd_coef, MFCC_5th_coef, MFCC_6th_coef, MFCC_7th_coef and MFCC_10th_coef** out of thirteen will have influence over the PD.

Therefore the dataset is preprocessed to have only these MFCC features. Also it is to be noted that this modified dataset consist of data tuples of normal persons also along with those of disease affected persons.

On this modified dataset the HMM and GMM models have been built after thorough training and testing activities.

The methodology used for PD identification is as given below:

1. **Data Collection**: The study utilized speech data obtained from a total of 252 individuals, with 188 diagnosed with PD and 64 healthy participants, including both PD patients and healthy subjects.
2. **Feature Extraction**: Mel Frequency Cepstral Coefficients (MFCC) (A total of 13) were extracted which represent the spectral features of the speech signal and are commonly used in speech processing tasks.
3. **Multiple Regression (MR) Analysis**: MR analysis was employed to identify MFCC features significantly associated with PD presence. The MR model was built using the 13 MFCC features as independent variables and PD presence as the dependent variable to analyze the inherent relationship. Coefficients of the MR model were examined to identify features with significant associations with PD.

   Equation of Multiple Regression (MR) for Feature Extraction

   $$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon$$

   where Y represents the PD presence indicator, $X_1, X_2, \ldots, X_n$ denote the MFCC features, $\beta_0, \beta_1, \ldots, \beta_n$ are the regression coefficients and ε represents the error term.

   Algorithm for Feature Extraction using Multiple Regression (MR)

   Input
   1. MFCC dataset (X) with 13 features
   2. Labels indicating PD presence (Y)

   Output
   1. Subset of influential MFCC features for PD detection

   Steps
   a) Perform multiple regression analysis between MFCC features (X) and PD labels (Y).
   b) Compute coefficients (β) representing the relationship between each MFCC feature and PD presence.
   c) Select features with significant coefficients (e.g., p-value < 0.05) as influential features.
   d) Output the subset of selected MFCC features.
4. **Association Rule Mining (ARM)**: ARM was applied to explore associations among the selected MFCC features identified by MR. Frequent featuresets were generated from the subset of influential MFCC features. Association rules were mined from the frequent featuresets to uncover relationships among the features. Rules with high support and confidence values were selected, indicating strong associations among the MFCC features.

   Algorithm for Featureset Extraction using Association Rule Mining (ARM)

   Input

   Subset of influential MFCC features identified by MR

   Output

   Association rules among selected MFCC features

   Steps
   a) Generate frequent featuresets from the subset of influential MFCC features.
   b) Apply association rule mining to the frequent featuresets to discover rules.
   c) Evaluate the strength of association rules (e.g., support, confidence).
   d) Select association rules with high support and confidence values.
   e) Output the selected association rules among the MFCC features.

5. **Classification Model Training**: HMM and GMM models were trained with selected MFCC features for classification. The dataset was preprocessed to include only the identified influential MFCC features for training the models. Both HMM and GMM models were trained and tested on the modified dataset to classify PD presence.
6. **Performance Evaluation**: HMM and GMM models evaluated based on classification accuracy. Accuracy metrics were computed to assess the models' ability to correctly classify PD patients and healthy individuals based on their speech MFCC features.
7. **Results Analysis**: The results of the classification models were analyzed to determine their effectiveness in PD identification. The accuracy of the models was compared, and the performance of the hybrid model combining MR and ARM techniques was assessed.

The below is the Pseudo code in brief for the above methodology and related experimental setup is shown diagrammatically in figure 2.

Pseudo Code used for developing this hybrid model for classifying disease data

1. Download the dataset from Kaggle repository and preprocess it to have only MFCC features.
2. Perform multiple regression analysis to identify significant MFCC features influencing the presence of disease.
3. Prepare the dataset to have the tuples of PD patients only with identified significant MFCC features
4. Convert the continuous data to nominal data to have the labels "high" and "low" on the basis of the average of the concerned feature values.
5. Perform Association Rule Mining experiment to know the relation / association among the identified significant MFCC features.

Building HMM and GMM classification models

6. Pre-process the downloaded dataset to have identified significant MFCC features only. (This dataset is supposed to have both normal and disease affected persons.)
7. Train and test both HMM and GMM models for the classification purpose.
8. Measure the performance of these models on the basis of classification accuracy in identifying the presence of disease.

5. Results and Discussion

The HMM and GMM models, built using the modified dataset, demonstrated their performance at 88% and 89% levels respectively as shown in figure 1.

Model	Confusion Matrix	Precision	Accuracy
GMM	TP = 90, TN = 50, FP = 5, FN = 15	0.85	0.89
HMM	TP = 85, TN = 55, FP = 10, FN = 10	0.89	0.88

Fig 1. Performance metrics of HMM & GMM

The accuracy of 0.89 means the model correctly classified 89% of the total samples in the dataset. It is calculated as the ratio of the sum of the diagonal elements (correctly classified instances) in the confusion matrix to the total number of instances.
As provided confusion matrix in the above diagram,
Total number of instances = 434 (sum of all cells)
Number of correctly classified instances = 150 (No Parkinson), 236 (Severe Parkinson) = 386.
So, the accuracy = (Number of correctly classified instances) / (Total number of instances) = 386 / 434 ≈ 0.89.

Further, the detailed analysis is put forth as under:

1. **Classification Accuracy**: The developed hybrid model using HMM and GMM techniques achieved 88% and 89% classification accuracy respectively, effectively distinguishing between PD patients and healthy individuals based on speech MFCC features.
2. **Effectiveness of Feature Selection**: The combined use of Multiple Regression and Association Rule Mining techniques effectively extracts influential MFCC features, enhancing the accuracy of classification models for speech affected by Parkinson's Disease. These identified features capture essential characteristics, improving the discriminative power of the models.
3. **Utility of Machine Learning Models**: Both HMM and GMM achieve similar results in identifying PD, capturing complex relationships between MFCC features and classifying individuals. The selection between them hinges on factors like computational efficiency and interpretability.
4. **Clinical Implications**: The hybrid model's high classification accuracy suggests its usefulness in clinical settings for early detection and intervention of PD using speech MFCC features. It can serve as a valuable tool for healthcare professionals in diagnosing and monitoring disease progression.
5. **Generalizability**: To evaluate the model's generalizability, assess its results on varied datasets and populations. Cross-validation or independent testing can reveal its robustness in diverse contexts.
6. **Comparison with Baseline**: The achieved accuracies can be compared to baseline metrics to measure the improvement of the proposed approach. Past studies or benchmarks can be used as baselines to evaluate the effectiveness of the developed model.
7. **Future Directions**: Further research can refine the model with more data sources or advanced machine learning techniques. Longitudinal studies can assess its performance and ability to predict disease progression. Collaboration with healthcare practitioners can integrate the model into clinical practice and have real-world impact.

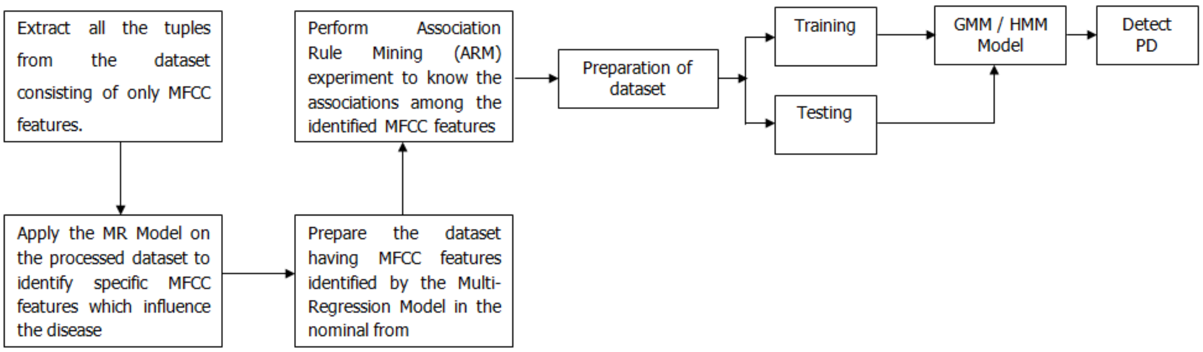

Fig 2. Hybrid Model to detect the presence of PD

6. Conclusion

In this study, we proposed a comprehensive approach for detecting Parkinson's Disease (PD) using Mel Frequency Cepstral Coefficients (MFCC) features extracted from speech data. By leveraging Multiple Regression (MR) and Association Rule Mining (ARM) techniques, we aimed to identify influential MFCC features and explore associations among them to enhance PD detection accuracy.

Through MR analysis, we identified a subset of seven MFCC features that significantly affect PD presence. These features were selected based on their coefficients indicating a strong relationship with PD. Additionally, ARM was employed to uncover associations among the selected MFCC features, providing insights into their interactions in the context of PD detection.

The developed hybrid model demonstrated promising results, achieving classification accuracies of 88% and 89% for Hidden Markov Model (HMM) and Gaussian Mixture Model (GMM), respectively. These results highlight the effectiveness of our approach in accurately detecting PD using speech MFCC features. This might also be applicable in the case of other models. Also the models built on the datasets having specific MFCC features would definitely reduce the time delay in the classification of the data. Working with healthcare practitioners can help integrate the model into clinical practice, creating real-world results.

References

1. Nissar, W. A. Mir, Izharuddin and T. A. Shaikh, "Machine Learning Approaches for Detection and Diagnosis of Parkinson's Disease - A Review," 2021 7th International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India, 2021, pp. 898-905, DOI: 10.1109/ICACCS51430.2021.9441885.

2. D. Dutta, S. Pahadsingh, S. K. Routray, V. Nikitin, O. Kuziakin and R. Saprykin, "Parkinson's Disease Detection Using Machine Learning Algorithms," 2023 IEEE 4th KhPI Week on Advanced Technology (KhPIWeek), Kharkiv, Ukraine, 2023, pp. 1-6, DOI: 10.1109/KhPIWeek61412.2023.10312853.

3. O. Escamilla-Luna, M. A. Wister and J. Hernandez-Torruco, "Classification Algorithms for Analyzing Parkinson's Disease Patient," 2022 International Conference on Software, Telecommunications and Computer Networks (SoftCOM), Split, Croatia, 2022, pp. 1-6, DOI: 10.23919/SoftCOM55329.2022.9911391.

4. R. Indu and S. Chandra Dimri, "Diagnosing Parkinson's Disease: its evolution to future," 2022 International Conference on Computational Intelligence and Sustainable Engineering Solutions (CISES), Greater Noida, India, 2022, pp. 108-115, DOI: 10.1109/CISES54857.2022.9844353.

5. Keserwani, P.K., Das, S. & Sarkar, N. A comparative study: prediction of parkinson's disease using machine learning, deep learning and nature inspired algorithm. Multimed Tools Appl (2024). DOI: 10.1007 / s11042-024-18186-z

6. Ayus and C. Azad, "Recent Advances in Multimodal Machine Learning for Parkinson's Disease Diagnosis: A Comprehensive Review," 2023 2nd International Conference on Ambient Intelligence in Health Care (ICAIHC), Bhubaneswar, India, 2023, pp. 1-7, DOI: 10.1109/ICAIHC59020.2023.10431435.

7. Zhang, J. Mining imaging and clinical data with machine learning approaches for the diagnosis and early detection of Parkinson's disease. npj Parkinsons Dis. 8, 13 (2022). DOI: 10.1038/s41531-021-00266-8

8. Khanna, K., Gambhir, S. & Gambhir, M. Comparative analysis of machine learning techniques for Parkinson's detection: A review. Multimed Tools Appl 82, 45205–45231 (2023). https://doi.org/10.1007/s11042-023-15414-w

9. Ayaz, Z., Naz, S., Khan, N.H. et al. Automated methods for diagnosis of Parkinson's disease and predicting severity level. Neural Comput & Applic 35, 14499–14534 (2023). https://doi.org/10.1007/s00521-021-06626-y

10. S. R. Burri, D. K. Agarwal, N. Vyas and R. Duggar, "A Machine Learning Framework for Accurate Prediction of Parkinson's Disease from Speech Data," 2023 3rd International Conference on Innovative Sustainable Computational Technologies (CISCT), Dehradun, India, 2023, pp. 1-6, DOI: 10.1109/CISCT57197.2023.10351422.

11. S. Chandrasekaran, V. Dutt, N. Vyas and A. Anand, "Fuzzy KNN Implementation for Early Parkinson's Disease Prediction," 2023 7th International Conference on Computing Methodologies and Communication (ICCMC), Erode, India, 2023, pp. 896-901, DOI: 10.1109/ICCMC56507.2023.10083522

12. M. Venugopal Reddy, M. Sadanandam, Effective Machine Learning Models Using Dynamic MFCC Features to detect the Parkinson's Disease, Journal of Technology, Volume 9 Issue 6, 152-158, 2021

13. Rohit Surya, A.T., Yaswanthram, P., Nair, P.R., Rajendra Prasath, S.S., Akella, S.V. (2022). Prediction of Parkinson's Disease Using Machine Learning Models—A Classifier Analysis. In: Bianchini, M., Piuri, V., Das, S., Shaw, R.N. (eds) Advanced Computing and Intelligent Technologies. Lecture Notes in Networks and Systems, vol 218. Springer, Singapore. https://doi.org/10.1007/978-981-16-2164-2_35

14. K. P. Faseela and P. Supriya, "Machine Learning Based Parkinson's Disease Detection from Enhanced Speech," 2023 IEEE 4th Annual Flagship India Council International Subsections Conference (INDISCON), Mysore, India, 2023, pp. 1-6, doi: 10.1109/INDISCON58499.2023.10270365.

15. G. Tallapureddy and D. Radha, "Analysis of Ensemble of Machine Learning Algorithms for Detection of Parkinson's Disease," 2022 International Conference on Applied Artificial Intelligence and Computing (ICAAIC), Salem, India, 2022, pp. 354-361, doi: 10.1109/ICAAIC53929.2022.9793048

16. P. Deepa and R. Khilar, "Parkinson's disease Classification from Speech Signal Parameters using Deep Neural Network," 2022 IEEE 4th International Conference on Cybernetics, Cognition and Machine Learning Applications (ICCCMLA), Goa, India, 2022, pp. 44-48, DOI: 10.1109/ICCCMLA56841.2022.9989106.

17. F.M. Javed Mehedi Shamrat, Md. Asaduzzaman, A.K.M. Sazzadur Rahman, Raja Tariqul Hasan Tusher, Zarrin Tasnim, "A Comparative Analysis Of Parkinson Disease Prediction Using Machine Learning Approaches", International Journal of Scientific & Technology Research, Volume 8 - Issue 11, November 2019, ISSN 2277-8616.

18. Mei Jie, Desrosiers Christian, Frasnelli Johannes,"Machine Learning for the Diagnosis of Parkinson's Disease: A Review of Literature", Frontiers in Aging Neuroscience, Volume 13, 2021, ISSN: 1663-4365, DOI: 10.3389/fnagi.2021.633752

19. Anitha R, Nandhini T, Sathish Raj S, Nikitha V, "Early Detection of Parkinson's Disease Using Machine Learning" , International Journal of Advance Research and Innovative Ideas in Education(IJARIIE), Vol-6 Issue-2 2020, ISSN(O) : 2395-4396.

20. Aditi Govindu, Sushila Palwe, "Early detection of Parkinson's disease using machine learning", Procedia Computer Science, Volume 218, 2023, Pages 249-261, ISSN: 1877-0509, DOI: 10.1016/j.procs.2023.01.007.

21. Sakar, C.O., Serbes, G., Gunduz, A., Tunc, H.C., Nizam, H., Sakar, B.E., Tutuncu, M., Aydin, T., Isenkul, M.E. and Apaydin, H., 2018. A comparative analysis of speech signal processing algorithms for Parkinson disease classification and the use of the tunable Q-factor wavelet transform. Applied Soft Computing, DOI: https://doi.org/10.1016/j.asoc.2018.10.022

22. Cantürk, İ., Karabiber, F. A Machine Learning System for the Diagnosis of Parkinson's Disease from Speech Signals and Its Application to Multiple Speech Signal Types. Arab J Sci Eng 41, 5049–5059 (2016). https://doi.org/10.1007/s13369-016-2206-3

23. M. Venugopal Reddy, M. Sadanandam, Identifying MFCC Features Influencing Parkinson's Disease Using Multiple Regression Analysis and Association Rule Mining, Journal of Transportation Systems Engineering and Information Technology, Volume. 10 Issue 4, 138-145, 2022.