VIVEKANAND EDUCATION SOCIETY'S INSTITUTE OF TECHNOLOGY
An Autonomous Institute Affiliated with the University of Mumbai
Department of Computer Engineering

Project Report on

VOICE-BASED PARKINSON'S DISEASE PREDICTION USING MACHINE LEARNING

In partial fulfillment of the Fourth Year, Bachelor of Engineering (B.E.) Degree in Computer Engineering at the University of Mumbai Academic Year 2023-24

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(2023-24)

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Certificate

This is to certify that ***Muskan Bahrani, Meet Chhabria, Kaustubh Kharche, and Sakshi Shinde*** of Fourth Year Computer Engineering studying at the University of Mumbai have satisfactorily completed the project on "***VOICE BASED PARKINSON's DISEASE PREDICTION USING MACHINE LEARNING***" as a part of their coursework of PROJECT-II for Semester-VIII under the guidance of their mentor ***Dr.Prashant Kanade*** in the year 2023-24.

This thesis/dissertation/project report entitled ***VOICE BASED PARKINSON'S DISEASE PREDICTION USING MACHINE LEARNING*** by ***Muskan Bahrani, Meet Chhabria, Kaustubh Kharche, Sakshi Shinde*** is approved for the degree of **B.E Computer Engineering**.

Programme Outcomes	Grade
PO1,PO2,PO3,PO4,PO5,PO6,PO7, PO8, PO9, PO10, PO11, PO12 PSO1, PSO2	

Date:
Project Guide:

Project Report Approval
For
B. E (Computer Engineering)

This thesis/dissertation/project report entitled ***VOICE BASED PARKINSON'S DISEASE PREDICTION USING MACHINE LEARNING*** by ***Muskan Bahrani, Meet Chhabria, Kaustubh Kharche, Sakshi Shinde*** is approved for the degree of **B.E Computer Engineering.**

Internal Examiner

External Examiner

Head of the Department

Principal

Date:
Place:

Declaration

We declare that this written submission represents our ideas in our own words and where others' ideas or words have been included, we have adequately cited and referenced the sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented, fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources that have thus not been properly cited or from whom proper permission has not been taken when needed.

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Computer Engineering Department
COURSE OUTCOMES FOR B.E PROJECT

Learners will be to,

Course Outcome	Description of the Course Outcome
CO 1	Able to apply the relevant engineering concepts, knowledge, and skills to the project.
CO2	Able to identify, formulate and interpret the various relevant research papers and to determine the problem.
CO 3	Able to apply the engineering concepts towards designing solutions for the problem.
CO 4	Able to interpret the data and datasets to be utilized.
CO 5	Able to create, select and apply appropriate technologies, techniques, resources and tools for the project.
CO 6	Able to apply ethical, professional policies and principles towards societal, environmental, safety and cultural benefit.
CO 7	Able to function effectively as an individual, and as a member of a team, allocating roles with clear lines of responsibility and accountability.
CO 8	Able to write effective reports, design documents and make effective presentations.
CO 9	Able to apply engineering and management principles to the project as a team member.
CO 10	Able to apply the project domain knowledge to sharpen one's competency.
CO 11	Able to develop professional, presentational, balanced and structured approach towards project development.
CO 12	Able to adopt skills, languages, environment and platforms for creating innovative solutions for the project.

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Abstract

Parkinson's disease (PD) is a complex neurological disorder that progressively affects an individual's motor functions and, to a varying extent, their cognitive abilities. As a result, individuals with PD experience a range of symptoms such as tremors, bradykinesia (slowness of movement), rigidity, and postural instability. Additionally, non-motor symptoms including cognitive impairment, mood disorders, and autonomic dysfunction further contribute to the multifaceted nature of PD. All these symptoms start showing at the very later stage of the disease.
Hence there is no early detection and the disease becomes more serious.[6]

Recognizing the significance of early intervention in improving the quality of life for individuals with PD, our project aims to develop an advanced prediction model for the timely detection of Parkinson's disease. The utilization of machine learning algorithms and data analysis techniques on a comprehensive dataset is crucial for achieving a precise and reliable predictive model.[1] This dataset may include a variety of voice-based information enabling a holistic understanding of the disease.

The predictive model seeks to identify patterns and correlations within the data that are indicative of early-stage Parkinson's disease, allowing for intervention before the onset of severe symptoms. Early detection holds the potential to facilitate timely and personalized treatment strategies, potentially slowing the progression of the disease and enhancing overall patient outcomes.

Chapter 1: Introduction

1.1 Introduction

Parkinson's disease is a progressively debilitating neurological disorder with far-reaching implications for those affected. The urgency of early detection and precise diagnosis cannot be overstated, as timely intervention can significantly improve the management of this condition. Machine Learning (ML) has emerged as a potent tool for medical diagnosis, particularly for diseases with intricate and subtle indicators.[3] ML algorithms can analyze vast datasets and discover intricate patterns, thereby facilitating the development of highly accurate predictive models. In the context of Parkinson's disease, where even small changes can be indicative, the application of ML offers great promise in enhancing our ability to detect and manage the condition effectively.[5]

The novel feature of our method is the inclusion of voice as a predictor of Parkinson's disease. The human voice carries a wealth of information, and alterations in vocal characteristics can be early signs of neurological disorders like Parkinson's. Speech patterns often change, including reduced vocal loudness, altered pitch, and irregular articulation, even before overt motor symptoms manifest.[2] By harnessing ML techniques to analyze vocal data, we aim to detect these subtle alterations and potentially diagnose Parkinson's disease at an earlier stage. This approach holds the potential to revolutionize the field of Parkinson's disease diagnosis, providing opportunities for early interventions and improved patient outcomes.

Our work aims to develop an accurate prediction model for the early diagnosis of Parkinson's disease by utilizing the power of sophisticated Machine Learning and large-scale datasets. By focusing on voice-related parameters, we seek to contribute to a more holistic and efficient diagnostic process.[7] This work is not only about improving diagnostic accuracy but also about offering hope to individuals living with Parkinson's disease. Early detection means earlier access to treatment, therapies, and support, ultimately enhancing the quality of life for those 1 affected by this challenging condition. In this quest, the fusion of medical knowledge and cutting-edge technology promises to make significant strides in the battle against Parkinson's disease.

1.2 Motivation

The motivation for this project lies in the profound impact Parkinson's disease has on individuals and their families. Millions of individuals worldwide suffer from Parkinson's disease, a degenerative and now incurable illness that impairs motor function and severely lowers quality of life. Timely therapies can reduce symptoms and decrease the course of the condition, which is why early diagnosis is essential. However, diagnosing Parkinson's disease accurately in its early stages remains a challenging task.[10]

Machine Learning presents an unprecedented opportunity to address this challenge. By leveraging advanced ML algorithms and comprehensive datasets, we can develop predictive models that analyze subtle patterns, including voice-related parameters, to detect Parkinson's disease before overt symptoms manifest.[9] The potential benefits of such a model are immense – it could lead to earlier diagnosis, more effective treatment strategies, and improved patient outcomes. Additionally, it may reduce the burden on healthcare systems by streamlining the diagnostic process and reducing unnecessary testing.

Ultimately, this project's motivation lies in the potential to make a tangible difference in the lives of those affected by Parkinson's disease. By harnessing the power of ML and data analysis, we aim to enhance early detection and, in doing so, provide hope and a brighter future for individuals living with this challenging condition.

1.3 Problem Definition

Parkinson's disease (PD) is a progressive neurodegenerative disorder characterized by motor symptoms such as tremors, rigidity, and bradykinesia, as well as non-motor symptoms including speech and voice impairments. Early detection and accurate diagnosis of Parkinson's disease are crucial for effective management and intervention, as the progression of the disease can significantly impact the quality of life for affected individuals.

Conventional diagnostic methods for Parkinson's disease rely heavily on clinical assessment by trained healthcare professionals, often involving subjective evaluations of motor symptoms and voice characteristics. However, these assessments can be time-consuming, expensive, and prone to inter-rater variability.

The emergence of machine learning techniques, coupled with advancements in voice analysis technology, presents a promising opportunity for developing non-invasive and cost-effective tools for early detection and prediction of Parkinson's disease. By leveraging voice recordings and extracting relevant features using machine learning algorithms, it is possible to create predictive models capable of distinguishing between individuals with Parkinson's disease and healthy controls based on subtle variations in speech patterns and vocal characteristics.

The primary objective of this project is to design and develop a voice-based predictive model for Parkinson's disease using machine learning techniques.

By addressing these objectives, the project aims to contribute to the development of accessible and scalable tools for early detection and prediction of Parkinson's disease, ultimately facilitating timely intervention and improving patient outcomes. Additionally, the project seeks to advance our understanding of the relationship between voice characteristics and Parkinson's disease pathology, potentially uncovering new insights for future research and clinical practice.

1.4 Existing Systems

1.4.1 Spectrographic Analysis:

Process: Spectrographic analysis involves representing sound as a spectrogram, a visual representation of the frequency content of a sound signal over time. This analysis allows researchers to examine specific frequency components present in voice recordings. Machine learning algorithms can be applied to analyze spectrograms and identify patterns associated with Parkinson's disease.

1.4.2 Pitch Analysis:

Process: Pitch analysis focuses on measuring fundamental frequency variations in speech. Techniques such as autocorrelation or cepstral analysis are used to estimate pitch values from voice recordings. Machine learning models can then analyze pitch variations to detect abnormalities indicative of Parkinson's disease, such as hypophonia (reduced loudness).

1.4.3 Formant Analysis:

Process: Formant analysis involves identifying the resonant frequencies in vocal tract vibrations during speech production. By extracting formant frequencies from voice recordings, researchers can analyze changes in vocal tract shaping and resonance, which may be altered in individuals with Parkinson's disease. Machine learning algorithms can then classify these patterns to detect the disease.

1.4.4 Prosodic Analysis:

Process: Prosodic analysis focuses on the rhythm, intonation, stress, and timing patterns in speech. Techniques such as speech rate analysis, pause duration analysis, and intonation contour analysis are used to extract prosodic features from voice recordings. Machine learning models can analyze these features to detect abnormalities associated with Parkinson's disease-related speech impairments.

1.4.5 Jitter and Shimmer Analysis:

Process: Jitter and shimmer refer to variations in the fundamental frequency and amplitude of vocal vibrations. Jitter analysis measures irregularities in the timing of vocal fold vibrations, while shimmer analysis quantifies variations in vocal intensity. By extracting jitter and shimmer parameters from voice recordings, researchers can assess the stability and regularity of vocal vibrations, which may be affected in individuals with Parkinson's disease.

1.4.6 Deep Learning-Based Analysis:

Process: Deep learning techniques, such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs), can be applied directly to raw voice recordings for feature extraction and classification. These models learn hierarchical representations of speech features and patterns, enabling them to automatically extract discriminative features without explicit feature engineering. Deep learning-based approaches have shown promise in voice-based Parkinson's disease detection by leveraging large datasets and complex patterns in speech data.

1.5 Lacuna of the Existing System

Identifying the lacunae in existing voice-based Parkinson's disease detection systems is crucial for several reasons. Firstly, understanding these gaps helps researchers and developers pinpoint areas for improvement, guiding the refinement of current methodologies and the development of more effective solutions. Secondly, addressing these lacunae directly contributes to the advancement of diagnostic accuracy and the overall efficacy of Parkinson's disease detection systems. Moreover, by acknowledging and rectifying shortcomings such as limited dataset diversity, insufficient real-time monitoring capabilities, reliance on traditional features, limited integration with clinical workflows, ethical and privacy considerations, and limited user accessibility and adoption, developers can create more robust, inclusive, and ethically sound systems that have the potential to revolutionize early diagnosis and intervention strategies for Parkinson's disease. This proactive approach not only fosters innovation but also ensures that emerging technologies align with ethical standards, regulatory requirements, and the diverse needs of users, ultimately leading to more impactful and sustainable healthcare solutions.

1.5.1 Limited Dataset Diversity:

Many existing voice-based Parkinson's disease detection systems rely on relatively small and homogeneous datasets, often collected from a limited pool of participants. This lack of dataset diversity may compromise the generalizability and robustness of the developed models, particularly across different demographic groups, ethnicities, and geographic regions.

1.5.2 Insufficient Real-Time Monitoring:

Some existing systems focus primarily on offline analysis of voice recordings, lacking real-time monitoring capabilities. Real-time monitoring is essential for providing immediate feedback to users and facilitating early intervention in Parkinson's disease progression. Incorporating real-time analysis features could enhance the practical utility of voice-based detection systems in clinical and everyday settings.

1.5.3 Reliance on Traditional Features:

Many existing systems rely on traditional acoustic features extracted from voice recordings, such as pitch, intensity, and jitter. While these features are informative, they may not capture the full spectrum of subtle vocal characteristics associated with Parkinson's disease. Exploring more advanced feature extraction techniques, including deep learning-based representations, could improve the discriminatory power of detection systems.

1.5.4 Limited Integration with Clinical Workflow:

Existing voice-based Parkinson's disease detection systems often operate as standalone tools, with limited integration into existing clinical workflows. Seamless integration with electronic health record systems, telemedicine platforms, or wearable devices could facilitate better collaboration between patients, clinicians, and caregivers, leading to more effective disease management and monitoring.

1.5.5 Ethical and Privacy Considerations:

Many existing systems may not adequately address ethical and privacy considerations related to data collection, storage, and usage. Ensuring compliance with relevant regulations and standards, such as data protection laws and institutional review board (IRB) guidelines, is essential for safeguarding the privacy and rights of participants involved in voice data collection and analysis.

1.5.6 Limited User Accessibility and Adoption:

Some existing systems may lack user-friendly interfaces or accessibility features, limiting their adoption by individuals with varying levels of technological proficiency or disabilities. Designing intuitive interfaces and incorporating accessibility features, such as voice commands or screen readers, could enhance the usability and inclusivity of Parkinson's disease detection systems.

1.6 Relevance of the Project

A voice-based Parkinson's disease detection project is highly relevant in contemporary healthcare due to its potential to revolutionize early diagnosis and intervention strategies. By leveraging machine learning algorithms to analyze vocal characteristics, this project offers a non-invasive and accessible screening method for Parkinson's disease. Such a system not only provides objective diagnostic measurements but also empowers individuals to monitor their health remotely, especially in underserved or remote areas. Furthermore, the project contributes valuable data to research endeavors focused on understanding disease progression and identifying biomarkers. Ultimately, by improving diagnostic accuracy, promoting early intervention, and enhancing accessibility to healthcare, this project has the potential to significantly impact the lives of individuals affected by Parkinson's disease.

This project introduces a novel approach utilizing Machine Learning (ML) techniques to develop a voice-based predictive model for the early detection of Parkinson's disease. By analyzing subtle vocal alterations, the model aims to enhance diagnostic accuracy and facilitate timely interventions, ultimately improving patient outcomes. However, existing systems face challenges including limited dataset diversity, insufficient real-time monitoring capabilities, reliance on traditional features, limited integration with clinical workflows, ethical and privacy considerations, and limited user accessibility and adoption. Addressing these lacunae is crucial for advancing the effectiveness and accessibility of voice-based Parkinson's disease detection systems, which have the potential to revolutionize early diagnosis and intervention strategies, particularly in underserved or remote areas, and contribute valuable data to research endeavors focused on understanding disease progression and identifying biomarkers.

Chapter 2: Literature Survey

A. Brief Overview of Literature Survey

The papers discussed here focus on various voice-based Parkinson's detection systems. These papers are studied to understand how the different features such as jitter, shimmer, etc are dependent on each other. The

studies examine how to analyze and predict if a person has Parkinson's or not and provide ways for the system to be more efficient. Overall, the papers highlight the importance of taking a comprehensive approach to address how these above factors can be used and enhanced for the development of a complete system that can provide accurate results for disease detection.

B. Related Works

Several studies have explored the application of machine learning (ML) techniques for predicting Parkinson's disease (PD) based on various datasets and features. For instance, researchers have employed voice recordings to detect subtle changes indicative of PD progression. One study utilized ML algorithms on acoustic features extracted from speech signals to discriminate between individuals with and without PD, achieving promising classification accuracies. Additionally, other investigations have incorporated diverse data sources such as clinical assessments, genetic markers, and neuroimaging data to enhance prediction accuracy and understand disease mechanisms. Moreover, recent advancements in wearable sensor technology have enabled the collection of longitudinal movement data, offering valuable insights into motor symptoms progression and aiding in early diagnosis. These studies collectively underscore the potential of ML-based approaches in identifying early-stage PD and informing personalized treatment strategies for improved patient outcomes.

2.1 Parkinson's Disease Detection from Voice and Speech Data Using Machine Learning:

In the research paper Pramanik (ET. AL.) have described about a model to detect parkinson disease using voice data and they have recommended K-NN, SVM,RF, AdaBoost and LR that provides 94% accuracy. Small datasets can lead to overfitting or limited generalizability of the model. Potential web app implementation with a user-friendly interface.

2.2 Exemplar-Based Sparse Representations for Detection of Parkinson's Disease From Speech

This paper by M. K. Reddy and P. Alku introduces an exemplar-based sparse representation technique for detecting Parkinson's disease through speech analysis, eliminating training, and hyperparameter tuning. It explores sparse coding models and proposes a class-specific dictionary strategy for improved performance. The authors compare the proposed exemplar-based sparse representation classification approach with traditional ML pipeline systems, Random Forest, and Support Vector Machine, and suggest future studies with other algorithms and deep learning techniques.

2.3 Prediction of Parkinson’s disease and severity of the disease using Machine Learning and Deep Learning algorithm:

The methodology used by P. Raundale, C. Thosar, and S. Rane involves collecting participant data, preprocessing it, selecting features for machine learning and deep learning models, training and evaluating them, and analyzing their performance to predict Parkinson's disease severity. The study can be expanded by comparing models and selecting the most optimized and efficient ones, ensuring the appropriate severity and extent of disease spread in the patient.

2.4 Speech Processing: MFCC Based Feature Extraction Techniques- An Investigation:

The paper by D. Prabakaran and S. Sriuppili highlights the need for feature extraction methods that can accurately extract features regardless of the speaker's emotion. It uses frame blocking, pre-emphasis, windowing, FFT, and DCT in speech processing and feature extraction techniques. Also, Expansion of Dataset, Integration of Advanced Techniques and, Lack of Comparative Analysis.

2.5 Early Detection of Parkinson’s Disease Using Deep Learning and Machine Learning:

The paper by W. Wang, J. Lee, F. Harrou and Y. Sun uses an innovative deep-learning technique which is introduced to early uncover whether an individual is affected with PD or not based on premotor features like Rapid Eye Movement and olfactory loss, Cerebrospinal fluid data, and dopaminergic imaging markers. The deep learning approach works well for small PD datasets but may need to work better for bigger datasets, where ML models can work efficiently.

2.6 Voice-Based Detection of Parkinson’s Disease through Ensemble Machine Learning Approach:

The authors Iqra Nissar, Danish Raza Rizvi, Sarfaraz Masood, Aqib Nazir Mir, analyze the effect of feature type selection i.e. MFCC and TQWT on the efficiency of voice-based PD detection systems along with the use of an ensemble learning-based classifier for this task. The Extreme Gradient Boost (XGBoost) technique should be used to develop a model for PD detection problems.

2.7 Parkinsonism detection method and detection system based on voice

The invention by Lǐ yún yèxiǎojiāng lǚyànjié jì wēi discloses a Parkinsonism detection method and detection system based on voice, belonging to the technical field of signal processing and machine learning. The Parkinsonism detection method based on voice can extract the characteristics related with Parkinsonism from the acquired voice of a detected people, and can record all the characteristics in a vector according to the sequence of extraction and use an SVM classifier to classify the vector so that the classified result is the detection result. The Parkinsonism detection system based on voice comprises a voice acquisition apparatus, a voice signal processing system and an SVM classification system, wherein the voice signal processing system extracts the characteristics related with Parkinsonism from the voice; and the SVM classification system trains the SVM classifier according to the Parkinsonism dataset collected by a professional institute, and uses the SVM classifier to classify the voice characteristics of the detected people so as to determine whether the detected people suffers from Parkinsonism. The processing process of the Parkinsonism detection method and detection system based on voice can be completed through analysis of a computer software; and the Parkinsonism detection method and detection system based on voice can solve the problems that the period for clinical observation of Parkinsonism is long and the cost is high, and have the advantages of being real time, being efficient, being low in cost and being simple and reliable in operation in the extreme environment.

2.8 Parkinson's disease voice data classification system based on sample and feature double transformation

The invention by Lǐ yǒngmíng zhāngxīnyuè wáng pǐn liúshūjūn jiǎyúnjiàn céng xiàopíng huángzhìyǒng relates to the technical field of voice classification, and particularly discloses a Parkinson's disease voice data classification system based on sample and feature double transformation. The system is based on the characteristic that the number of the existing PD voice samples is small, and particularly transforms in two dimensions of the samples and the characteristics: for sample transformation, mining hierarchical structures of different PD voice samples by an iterative mean clustering method to generate new samples; for feature transformation, PD voice feature dimension transformation is carried out through different feature kernels. The sample transformation can reduce the influence of abnormal samples on the boundary of the classifier and the influence of samples with higher correlation on training time and storage space, and can also embody the hierarchical structure information of the samples in the samples. The feature transformation reduces the dimension of the PD voice sample, reduces the complexity of a classification model and realizes high-performance classification.

2.9 Inference drawn

Two patent documents disclose voice-based Parkinson's disease detection methods utilizing machine learning. The first patent (CN105448291A) presents a method and system extracting Parkinsonism-related characteristics from voice recordings, utilizing SVM classification for detection. The second patent (CN113361563A) introduces a classification system employing sample and feature double transformation to address the limited availability of Parkinson's disease voice samples. These innovations aim to enhance Parkinson's disease detection through voice analysis, potentially offering more efficient, cost-effective, and reliable detection methods compared to traditional clinical observation, while leveraging machine learning techniques for classification and feature transformation.

2.10 Comparison with the existing system

Aspect	Existing System	Proposed System
Feature Extraction	Relies on basic signal processing techniques.	Employs Mel-Frequency Cepstral Coefficients (MFCCs) for more robust feature extraction, capturing key patterns in voice signals.
Model Building	Utilizes traditional machine learning algorithms.	Implements Decision Trees, SVMs, and Logistic Regression tailored for Parkinson's disease detection.

Performance	May lack sophistication in feature representation and classification.	Expected to offer improved accuracy and reliability in disease detection due to advanced feature extraction and machine learning algorithms.
Deployment	Deployment may require manual operation and lacks user-friendly interfaces.	Offers deployment through a web application with a user-friendly interface built using React.js and Flask, facilitating accessibility and usability for both patients and healthcare professionals.
Cost and Accessibility	Costs associated with manual data collection and potential limitations in accessibility.	May offer cost savings and improved accessibility through the automation of data collection and deployment of the system through web-based platforms.
Feedback and Improvement Cycle	The feedback loop may be slow due to manual processes.	Enables faster feedback and improvement cycles through user feedback mechanisms integrated into the web application.

This chapter provides a comprehensive literature survey on voice-based Parkinson's disease detection systems, emphasizing the interdependence of various features and the importance of a holistic approach for accurate disease detection. Studies explore the application of machine learning techniques, deep learning algorithms, and innovative feature extraction methods to analyze voice data for Parkinson's disease prediction. The surveyed papers highlight advancements in feature extraction, model building, performance evaluation, and deployment strategies, aiming to enhance the efficiency, reliability, and accessibility of Parkinson's disease detection systems. Additionally, two patent documents introduce novel approaches utilizing machine learning for voice-based Parkinson's disease detection, potentially offering more efficient and cost-effective detection methods compared to traditional clinical observation. Overall, the literature survey underscores the significance of ongoing research efforts in leveraging technology to improve early diagnosis and intervention strategies for Parkinson's disease.

Chapter 3: Requirement Gathering for the Proposed System

In this chapter we are going to discuss the resources we have used and how we analyzed what the user actually needs and what we can provide. We will also discuss the functional and non-functional requirements and finally the software and hardware used.

3.1 Introduction to Requirement Gathering

Requirement gathering is a crucial phase in the development of any system, ensuring that the project's objectives are clearly understood and translated into specific functional and non-functional requirements. This chapter outlines the steps taken to gather and document the requirements for the proposed voice-based Parkinson's disease prediction system.

The requirements gathering process consists of six steps :

- Identify the relevant stakeholders
- Establish project goals and objectives
- Elicit requirements from stakeholders
- Document the requirements
- Confirm the requirements
- Prioritize the requirements

3.2 Functional Requirements

Functional requirements specify the system's functionalities and capabilities. The following steps were undertaken to identify and document the functional requirements:

1. Literature Review: Reviewed existing systems and research papers related to voice-based Parkinson's disease prediction to identify common functionalities and features.

2. Brainstorming Sessions: Organized brainstorming sessions with the development team to generate ideas and identify potential functionalities that align with the project's objectives.

3. Use Case Analysis: Developed use cases to describe the interactions between users and the system, identifying the main functions and scenarios.

- **Voice Sample Upload Module:**

  - Capability for users to upload voice samples in common audio file formats (e.g., MP3, WAV) through the website interface.
  - Support for secure and efficient file upload mechanisms.
  - Validation of uploaded files to ensure they meet the required format and size constraints.

- **Feature Extraction Module:**

  - Utilization of Mel-Frequency Cepstral Coefficients (MFCCs) for feature extraction from uploaded voice samples.
  - Extraction of MFCC features directly from the uploaded audio files without preprocessing.

- **Machine Learning Model Building Module:**

  - Integration of machine learning algorithms such as Decision Trees, SVMs, and Logistic Regression.
  - Training of models using extracted features from uploaded voice samples without preprocessing.

- **Prediction and Analysis Module:**

  - Functionality to make predictions based on trained machine learning models using features extracted directly from uploaded voice samples.
  - Analysis of prediction results to determine Parkinson's disease probability for each uploaded sample.

- **Testing Module:**

  - Evaluation of the performance of trained models using test datasets, including features extracted directly from uploaded voice samples.

- **Deployment Module:**

  - Integration of the voice sample upload module with the web application framework such as Flask for deployment.
  - Building a user-friendly interface for uploading voice samples directly on the website.

- **Frontend Development:**

  - Development of a web application using React.js for the user interface.
  - Designing intuitive interfaces for voice sample upload and result visualization.

- **Integration with ML Model:**
  - Ensuring smooth communication between the frontend application and the machine learning model backend for processing features extracted directly from uploaded voice samples.

- **Deployment and Feedback Module:**
  - Deployment of the web application on a server.
  - Implementation of feedback mechanisms for users to provide input on the voice sample upload process and system's performance.
  - Iterative improvements based on user feedback.

3.3 Non-Functional Requirements

Non-functional requirements define the quality attributes and constraints of the system. The following steps were taken to elicit and document the non-functional requirements:

1. User Surveys: Distributed surveys to potential users to gather feedback on performance expectations, usability preferences, and other non-functional aspects.
2. Benchmarking: Benchmarked existing systems and industry standards to establish performance benchmarks and quality criteria.
3. Expert Consultation: Consulted with domain experts to identify critical non-functional requirements related to accuracy, reliability, scalability, and security.
4. Regulatory Compliance: Identified regulatory requirements and standards relevant to healthcare software systems, ensuring compliance with data privacy and security regulations.

Following are the adjusted non-functional requirements:

1. Performance: Ensure efficient handling of uploaded voice samples with minimal processing delay, maintaining system responsiveness during peak usage.

2. Scalability: Design the system to scale horizontally to accommodate increasing numbers of user uploads and processing demands without performance degradation.

3. Usability: Provide a user-friendly interface for seamless uploading of voice samples, ensuring compatibility with different file formats and sizes.

4. Security: Implement robust encryption and access control measures to protect uploaded samples and user data from unauthorized access.

5. Reliability: Maintain high system availability and reliability with proactive monitoring and automated error handling to minimize downtime.

6. Maintainability: Develop the system with a modular architecture and thorough documentation to facilitate easy maintenance and future enhancements.

7. Interoperability: Ensure compatibility with various web browsers and devices, supporting integration with external systems or APIs for seamless data exchange.

3.4 Hardware, Software, Technology, and Tools Utilized

The selection of appropriate hardware, software, technology, and tools is essential for the successful implementation of the system. The following steps were undertaken to determine the required resources:

For hardware requirements, the system should ideally be equipped with an Intel i5 processor or an equivalent AMD processor to ensure smooth execution of computational tasks involved in machine learning model development and analysis. A minimum of 4GB of disk space is recommended to accommodate datasets, software installations, and model outputs. Additionally, a RAM capacity of at least 8GB is essential for efficient processing and manipulation of large datasets during algorithm training and testing. While a dedicated GPU is not specified, having one can significantly accelerate certain computations, especially for deep learning models with complex architectures.

As for software requirements, the development environment should include Anaconda or Jupyter Notebook for Python-based coding and interactive data analysis. The Django framework, along with Python, is necessary for building web applications for deploying predictive models or creating user interfaces. Collaborative development and version control can be facilitated through platforms like Google Colaboratory and GitHub. Essential Python libraries such as Matplotlib, Seaborn, Pandas, NumPy, and XGBoost should be installed to support data visualization, data manipulation, and implementation of machine learning algorithms for model training and evaluation. These software components collectively provide a robust and versatile ecosystem for developing and deploying predictive models for Parkinson's disease detection.

3.5 Constraints

Identifying constraints helps to define the boundaries and limitations within which the system must operate. The following constraints were identified:

1. Data Availability: The availability of high-quality voice data samples, particularly from individuals with Parkinson's disease, may be limited, posing a constraint on model training and evaluation.
2. Computational Resources: The computational resources required for processing large volumes of voice data and training machine learning models may impose constraints on system scalability and performance.
3. Budgetary Constraints: Budget limitations may impact the selection of hardware, software, and third-party services, requiring careful resource allocation and cost-effective solutions.
4. Time Constraints: The project timeline may be constrained by deadlines, resource availability, or external factors such as regulatory approvals or collaboration agreements. Limited time for data collection, model development, and evaluation could affect the thoroughness and accuracy of the predictive model.
5. Expertise and Skillset: The availability of skilled personnel proficient in machine learning, data analysis, software development, and domain knowledge related to Parkinson's disease is crucial for the success of the project. Inadequate expertise or skill gaps among team members may lead to inefficiencies, errors, or suboptimal model performance.
6. Ethical and Regulatory Compliance: Compliance with ethical guidelines, data privacy regulations (such as GDPR or HIPAA), and institutional review board (IRB) approvals is essential when dealing with sensitive patient data. Failure to adhere to these requirements can lead to legal and reputational risks for the project stakeholders.
7. Model Interpretability and Explainability: Ensuring the interpretability and explainability of machine learning models is crucial for gaining insights into the underlying factors contributing to Parkinson's disease prediction. Complex black-box models may lack transparency, making it challenging to understand the rationale behind model predictions and limiting clinical acceptance and adoption.

Addressing these constraints requires careful planning, collaboration, and resource allocation to mitigate potential risks and ensure the successful development and deployment of the predictive model for Parkinson's disease detection.

This chapter delves into the meticulous process of gathering requirements for the proposed voice-based Parkinson's disease prediction system. It outlines the steps undertaken to identify stakeholders, establish project goals, elicit, document, confirm, and prioritize requirements. Functional requirements were identified through literature review, brainstorming sessions, and use case analysis, resulting in modules such as voice sample upload, feature extraction, machine learning model building, prediction and analysis, testing, deployment, frontend development, integration with ML model, and deployment and feedback. Non-functional requirements were elicited through user surveys, benchmarking, expert consultation, and regulatory compliance considerations, resulting in adjusted requirements related to performance, scalability, usability, security, reliability, maintainability, and interoperability. The hardware, software, technology, and tools utilized were carefully selected to meet the system's needs, ensuring compatibility and efficiency. Constraints such as data availability, computational resources, budgetary limitations, time constraints, expertise and skillset, ethical and regulatory compliance, and model interpretability were identified and addressed to mitigate potential risks and ensure the successful development and deployment of the system. This thorough requirement gathering process lays a solid foundation for the subsequent phases of system development, ensuring alignment with user needs, regulatory requirements, and project objectives.

Chapter 4: Proposed Design

4.1 Block Diagram of the System

The block diagram outlines a structured process for developing and deploying a machine learning-based system. It begins with data preparation, where data is collected, pre-processed, and relevant features are extracted. This step ensures that the input data is clean, formatted, and contains the necessary information for subsequent analysis. The machine learning phase involves model building, where algorithms are trained on the prepared data to learn patterns and make predictions. This is followed by prediction and analysis, where the trained model is used to make predictions on new data and analyze the results. Testing ensures the performance and accuracy of the model across different scenarios and datasets. Finally, deployment involves frontend development to create user interfaces, integration of the model into the deployment environment, actual deployment of the system, and gathering feedback from users for iterative improvements. This structured approach ensures a systematic progression from data preparation to model deployment, facilitating the development of effective and efficient machine learning systems.

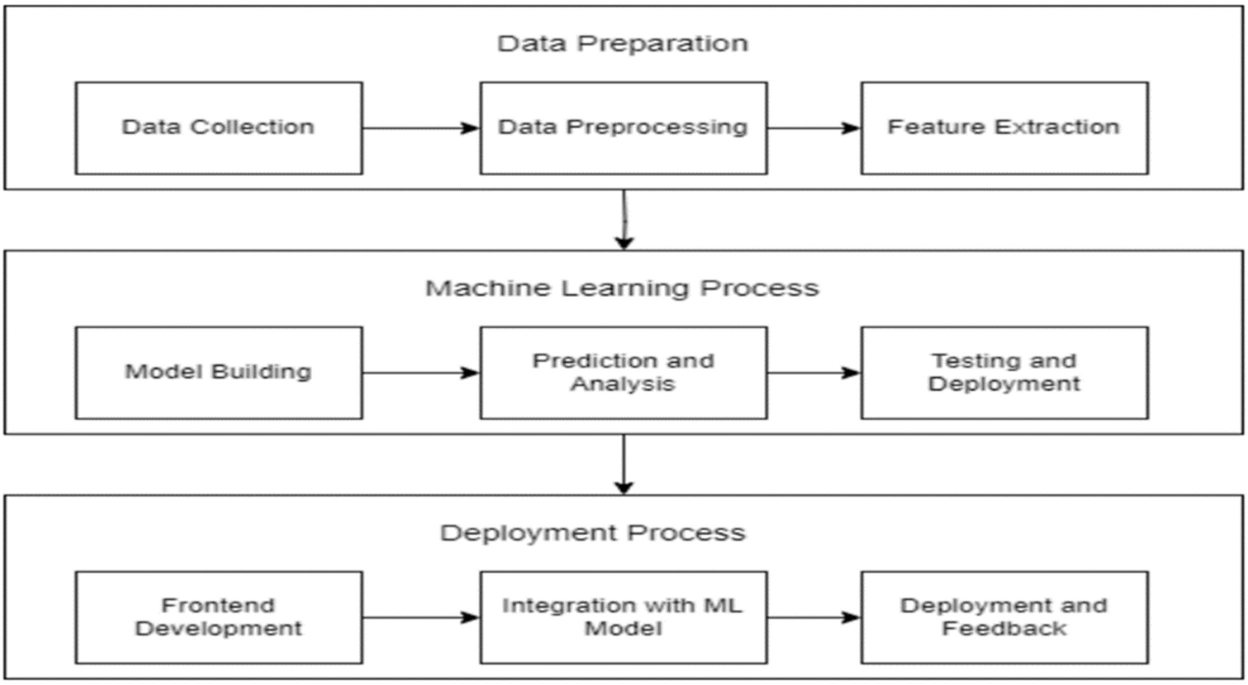


Figure no. 4.1: Block diagram of the system

4.2 Modular Design of the System

The modular diagram illustrates the methodical extraction of Mel-Frequency Cepstral Coefficients (MFCCs) from input speech signals. It begins with segmenting the speech signal into frames and applying windowing functions to reduce spectral leakage. Next, Fast Fourier Transform (FFT) converts the signal into the frequency domain, followed by Mel filtering to emphasize relevant frequency bands. Logarithmic energy computation and Discrete Cosine Transform (DCT) yield MFCCs, compact representations of spectral features. This systematic process ensures the extraction of essential features for tasks like Parkinson's disease prediction.

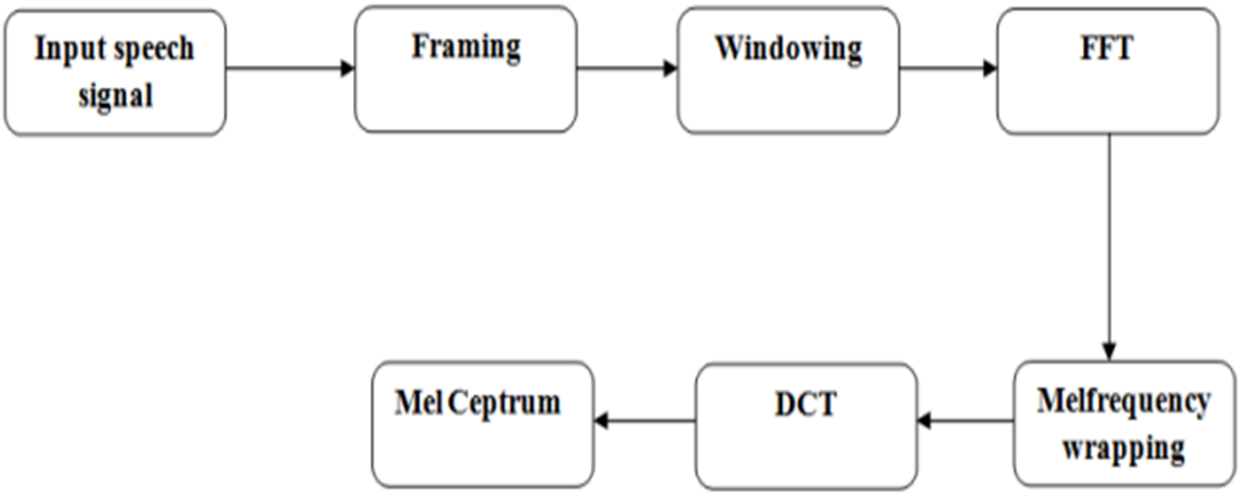


Figure no. 4.2: Modular diagram of the system

4.3 Detailed Design(Storyboard)

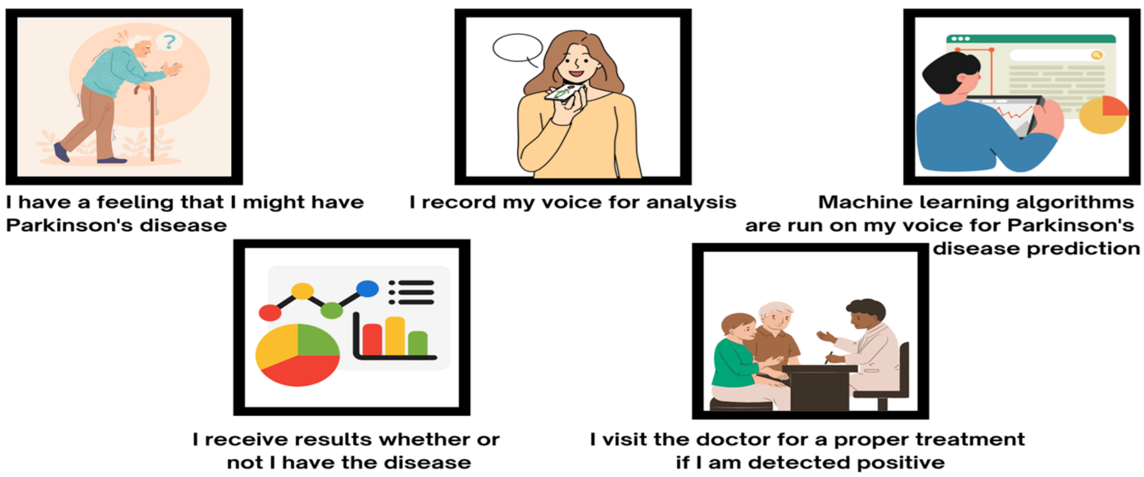
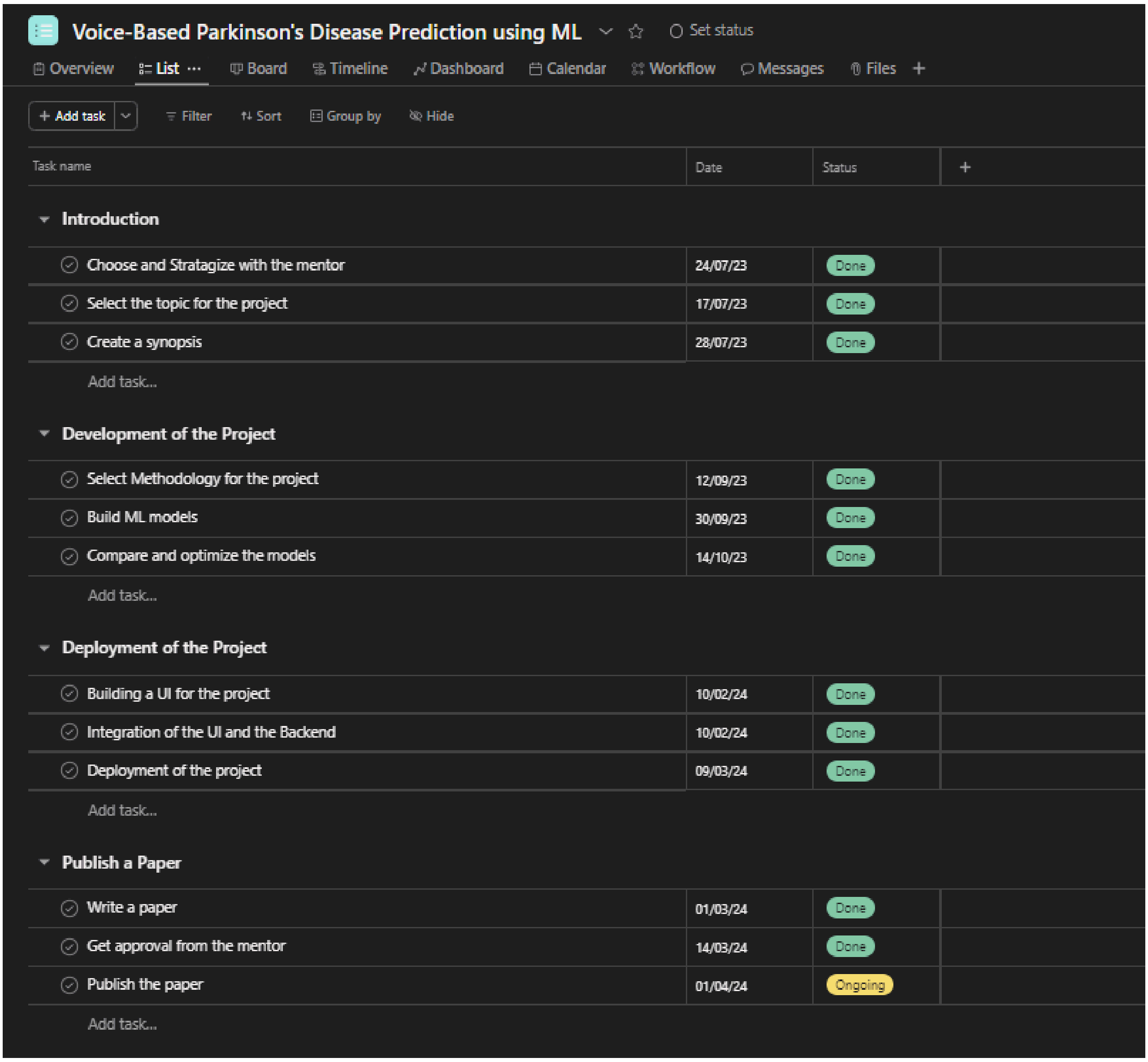


Figure no. 4.3: Storyboard for the project

4.4 Project Scheduling & Tracking using Timeline / Gantt Chart



Task name	Date	Status
Introduction		
Choose and Stratagize with the mentor	24/07/23	Done
Select the topic for the project	17/07/23	Done
Create a synopsis	28/07/23	Done
Add task...		
Development of the Project		
Select Methodology for the project	12/09/23	Done
Build ML models	30/09/23	Done
Compare and optimize the models	14/10/23	Done
Add task...		
Deployment of the Project		
Building a UI for the project	10/02/24	Done
Integration of the UI and the Backend	10/02/24	Done
Deployment of the project	09/03/24	Done
Add task...		
Publish a Paper		
Write a paper	01/03/24	Done
Get approval from the mentor	14/03/24	Done
Publish the paper	01/04/24	Ongoing
Add task...		

Figure no. 4.4: Project Scheduling

Chapter 5: Implementation of the Proposed System

5.1 Methodology employed for development

Data Preparation:

1. Data Collection - Data collection is the procedure of gathering accurate insights, measuring, and analyzing for research via conventional, verified methods.

2. Data Pre-processing - The process of getting raw data ready for a machine learning model is called data preparation.

3. Feature Extraction - Feature extraction is the process of converting raw data into meaningful and relevant features that capture key patterns and traits for analysis or modeling.

MFCCs are used in the model for feature extraction. Mel-Frequency Cepstral Coefficients (MFCCs) are fundamental in audio signal processing and speech recognition, serving as a primary method for feature extraction. They leverage the psychoacoustic properties of the human auditory system and employ the Mel scale to transform frequency representations.

In essence, MFCC computation involves several steps. Initially, the audio signal undergoes a frequency domain transformation, typically via the Discrete Fourier Transform (DFT). Subsequently, Mel filtering is applied to approximate human perception of sound frequency, followed by logarithmic compression to emphasize perceptually relevant details. Finally, cepstral coefficients are derived from the resulting Mel-scaled spectrum.

The significance of MFCCs lies in their ability to compactly represent essential aspects of the audio signal while filtering out extraneous information. The choice of 13 coefficients is empirically determined to strike a balance between computational efficiency and information richness.

The breakdown of the 13 MFCCs is as follows:

- C0 (Zeroth Coefficient): Represents overall signal energy. - C1 to C12 (First to Twelfth Coefficients): Capture spectral characteristics post Mel-filtering and logarithmic operations. Each coefficient corresponds to a specific frequency band, reflecting energy or magnitude within that band.

- C1: Represents the overall spectral energy distribution.

- C2 to C12: Capture finer spectral details, diminishing in importance with increasing coefficient index.

MFCCs serve as compact representations of audio signals, crucial for various speech processing tasks due to their ability to highlight pertinent features while discarding less relevant information.

Machine Learning process:

1. Model Building - Model Building involves learning and generalization from training data, and then applying that acquired knowledge to make predictions and serve its purpose on new, unseen data.

2. Prediction and Analysis - We forecast future outcomes or trends using this historical data.

3. Testing and Deployment - Testing and deployment involves checking how well a trained ML model works and then putting it to practical use in real situations.

Deployment Process:

1. Front End Development - Building a web application using React.js

2.Integration with ML Model - Finally, we will integrate our web application with Flask, a micro web framework for Python, which facilitates rapid development of secure and maintainable websites.

3. Deployment and Feedback - We will deploy our web application and take feedback from users for further improvement.

5.2 Algorithms and flowcharts for the respective modules developed

The proposed algorithms for the voice-based Parkinson's disease detection project are:

1. Decision trees
2. Support vector machines (SVMs)
3. Logistic Regression

These algorithms are all machine learning algorithms that are effective for various classification tasks, including Parkinson's disease detection.

- Decision trees are a form of machine learning method that classifies data using a tree-like structure. The tree's nodes represent decisions, while the leaf nodes indicate class labels. The algorithm learns to categorize data by moving down the tree, making judgments at each node until it reaches a leaf node.
- SVMs are a type of machine learning algorithm that learns to categorize data by detecting a hyperplane that divides it into two categories. The hyperplane is chosen to maximize the margin between the two classes. SVMs are very successful with high-dimensional data, such as speech signals.

●   Logistic regression is a statistical model that estimates the likelihood of a binary event, such as whether or not a patient has Parkinson's disease. Logistic regression works by fitting a linear model to the data and then using that model to estimate the likelihood of the result. The model is trained using a collection of voice recordings from Parkinson's sufferers and those who do not have the condition. The program learns which aspects in speech recordings are most predictive of Parkinson's illness.

Flowchart:

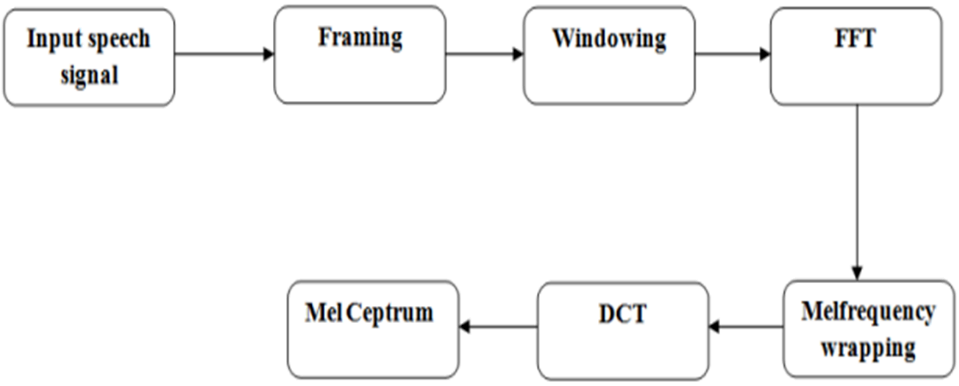


Figure no. 5.1: Flowchart of the Proposed Design

5.3 Dataset source and utilization

Source:

https://ieee-dataport.org/open-access/italian-parkinsons-voice-and-speech

This dataset is associated with the paper, Giovanni Dimauro et al. 2017, which is open source, and can be found here: https://ieeexplore.ieee.org/document/8070308

Utilization:

In order to prepare the dataset for training a predictive model for Parkinson's disease detection, several preprocessing steps were undertaken. Initially, the dataset was segregated into two classes represented by labels 0 and 1, corresponding to individuals without Parkinson's disease and those diagnosed with the condition, respectively. Since the original dataset was partitioned based on these labels, manual concatenation was necessary to merge the data into a unified dataset for subsequent analysis. Additionally, to address class imbalance issues inherent in medical datasets where the number of samples in one class significantly outweighs the other, resampling techniques were employed. Specifically, the minority class, representing individuals with Parkinson's disease, was oversampled or augmented to achieve a more balanced distribution between the two classes. By manually concatenating the segregated data and applying resampling techniques, we aimed to mitigate the effects of class imbalance and ensure that the predictive model would be trained on a representative and equitable dataset, thereby enhancing its generalizability and performance in detecting Parkinson's disease.

In this chapter, the implementation of the proposed voice-based Parkinson's disease detection system is detailed, starting with the methodology employed for development. The data preparation phase involves three key steps: data collection, data pre-processing, and feature extraction using Mel-Frequency Cepstral Coefficients (MFCCs), which are crucial for capturing relevant audio signal characteristics. The machine learning process encompasses model building, prediction, and analysis, followed by testing and deployment to ensure the system's practical application. Algorithms such as decision trees, support vector machines (SVMs), and logistic regression are utilized for classification tasks, each contributing to the predictive model's effectiveness. The deployment process involves front-end development using React.js, integration with Flask for web application development, and deployment with feedback collection for further refinement. The dataset utilized for training and testing the model is sourced from an open-access repository, which underwent preprocessing steps including class segregation and resampling to address class imbalance issues, ensuring robust performance of the predictive model in detecting Parkinson's disease. Overall, the implementation chapter provides a comprehensive overview of the development process, algorithms employed, and dataset utilization, laying the foundation for the subsequent evaluation and validation of the proposed system.

Chapter 6: Testing of the Proposed System

6.1 Introduction to Testing

Software testing is the sequence of activities that happen during software testing. By employing a sane software testing life cycle, an organization ends up with a quality strategy more likely to produce better results. Why is this so important, though? It all boils down to customer satisfaction. Presenting a perfect product to the customer is the end goal of every organization.

Nothing puts off customers more than bug-filled user experience. So when enterprises realized this, they began to include testing as a mandatory part of the SDLC. Since then, testing has become an integral part of every organization.

Project Testing Phase means a group of activities designated for investigating and examining progress of a given project to provide stakeholders with information about actual levels of performance and quality of the project. It is an attempt to get an independent view of the project to allow stakeholders to evaluate and understand potential risks of project failure or mismatch. The purpose of the testing phase is to evaluate and test declared requirements, features, and expectations regarding the project prior to its delivery in order to ensure the project matches initial requirements stated in specification documents.

6.2 Types of tests Considered

For the voice-based Parkinson's disease detection project, several types of tests can be conducted to ensure the system's functionality, performance, and reliability. Here are some key types of tests that can be employed:

Unit Tests:

- Test individual components of the system, such as feature extraction modules, machine learning algorithms, and data processing functions, in isolation.
- Verify that each unit performs as expected and meets its specified requirements.

Integration Tests:

- Verify the interaction and collaboration between different modules and components of the system.
- Test how well individual units work together to achieve desired functionality, including the integration of frontend and backend components.

Functional Tests:

- Test the system's functionality from end to end, focusing on user-facing features and use cases.
- Verify that users can upload voice samples, perform feature extraction, and receive accurate predictions for Parkinson's disease detection.

6.3 Various test case scenarios considered

1. Upload Functionality Test Case Scenario:

- Test Case: Verify that users can successfully upload voice samples for analysis.
- Steps:
  1. Navigate to the upload page.
  2. Select a voice sample file.
  3. Click on the upload button.
- Expected Result: The system should accept the uploaded file and display a confirmation message.

2. Feature Extraction Test Case Scenario:

- Test Case: Ensure that feature extraction modules accurately process voice samples.
- Steps:
  1. Upload a sample voice file containing known features.
  2. Trigger the feature extraction process.
  3. Verify that extracted features match the expected values.
- Expected Result: Extracted features should align with the predetermined characteristics of the voice sample.

3. Machine Learning Algorithm Test Case Scenario:

- Test Case: Validate the performance of machine learning algorithms for Parkinson's disease detection.
- Steps:
  1. Provide input data with known characteristics (e.g., voice features associated with Parkinson's disease).
  2. Execute the machine learning algorithm.
  3. Compare the algorithm's predictions with the ground truth.
- Expected Result: The algorithm should accurately classify voice samples as either indicative or non-indicative of Parkinson's disease.

4. Integration Test Case Scenario:

- Test Case: Ensure seamless integration between frontend and backend components.
- Steps:
  1. Perform a user action on the frontend interface (e.g., uploading a voice sample).
  2. Monitor backend processes triggered by the user action.
  3. Verify that data flow between frontend and backend is smooth and error-free.
- Expected Result: Frontend actions should trigger appropriate backend processes, and data should be transmitted accurately between components.

5. Boundary Test Case Scenario:

- Test Case: Test the system's behavior at boundary conditions.
- Steps:
  1. Provide voice samples of varying lengths, including very short and very long samples.
  2. Verify system response to extreme input sizes.
- Expected Result: The system should handle boundary conditions gracefully, without crashing or producing unexpected errors.

6. Error Handling Test Case Scenario:

- Test Case: Validate the system's error handling capabilities.
- Steps:
  1. Introduce errors in the input data (e.g., corrupted voice files).
  2. Submit the erroneous data for processing.
- Expected Result: The system should detect and appropriately handle errors, providing informative error messages to users.

7. Performance Test Case Scenario:

- Test Case: Assess the system's performance under varying load conditions.
- Steps:
  1. Simulate multiple concurrent user sessions.
  2. Upload voice samples and execute processing tasks simultaneously.
- Expected Result: The system should maintain acceptable performance metrics (e.g., response time, throughput) under different load levels.

8. Cross-Platform Compatibility Test Case Scenario:

- Test Case: Verify that the application functions correctly across different devices and browsers.
- Steps:
  1. Access the application using various web browsers (e.g., Chrome, Firefox, Safari).
  2. Test on different operating systems (e.g., Windows, macOS, Linux).
- Expected Result: The application should display consistent behavior and functionality across all tested platforms.

By considering these diverse test case scenarios, the project team can ensure comprehensive testing of the voice-based Parkinson's disease detection system, thereby enhancing its reliability and user satisfaction.

6.4 Inference drawn from the test cases

1. **Upload Functionality Inference**: If the upload functionality test cases pass successfully, it indicates that users can easily submit voice samples for analysis, ensuring smooth data input into the system.

2. **Feature Extraction Inference:**
   Successful execution of feature extraction test cases suggests that the system accurately captures relevant features from voice samples, laying a strong foundation for disease detection algorithms.

3. **Machine Learning Algorithm Inference:**
   Positive outcomes from machine learning algorithm test cases imply that the system can effectively differentiate between voice samples indicative and non-indicative of Parkinson's disease, demonstrating the efficacy of the disease detection mechanism.

4. **Integration Inference:**
   Seamless integration between frontend and backend components, as evidenced by integration test case results, ensures cohesive interaction between different parts of the system, contributing to a smooth user experience.

5. **Boundary Test Inference:**
   Successful handling of boundary conditions indicates that the system can gracefully manage extreme scenarios, such as very short or very long voice samples, without encountering errors or unexpected behavior.

6. **Error Handling Inference:**
   Effective error handling mechanisms, as observed in error handling test cases, demonstrate the system's ability to detect and manage errors gracefully, enhancing user confidence and mitigating potential disruptions.

7. **Performance Inference:**
   Positive performance test results indicate that the system can maintain satisfactory response times and throughput levels under varying load conditions, ensuring optimal performance even during peak usage periods.

8. **Cross-Platform Compatibility Inference:**
   Successful validation of cross-platform compatibility confirms that the application functions reliably across different devices and web browsers, expanding its accessibility to a wider audience.

Chapter 7: Results and Discussions

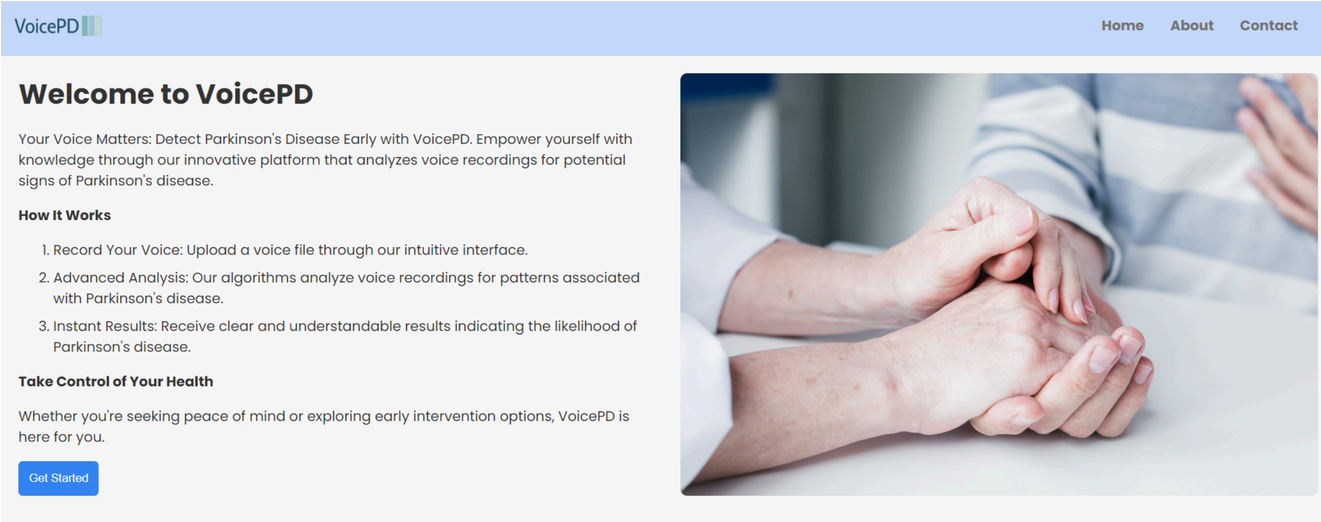


Figure No. 7.1: VoicePD landing page that describes the steps to use VoicePD. A contact page to engage with clients , resolve their issues , take feedback and make changes.

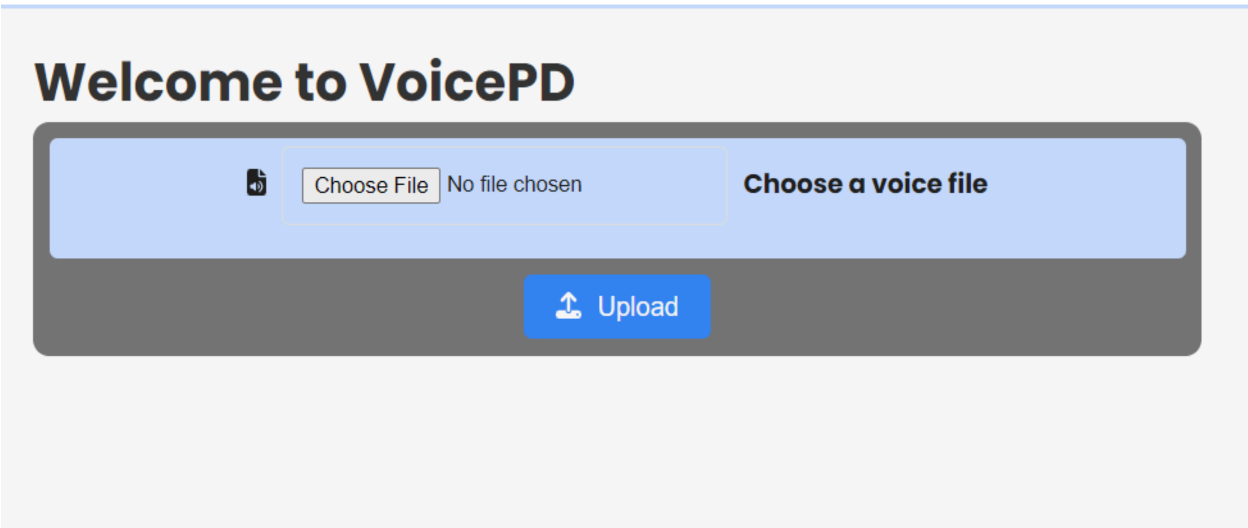


Figure No. 7.2: User Interface to upload user's voice samples for Parkinson's testing.

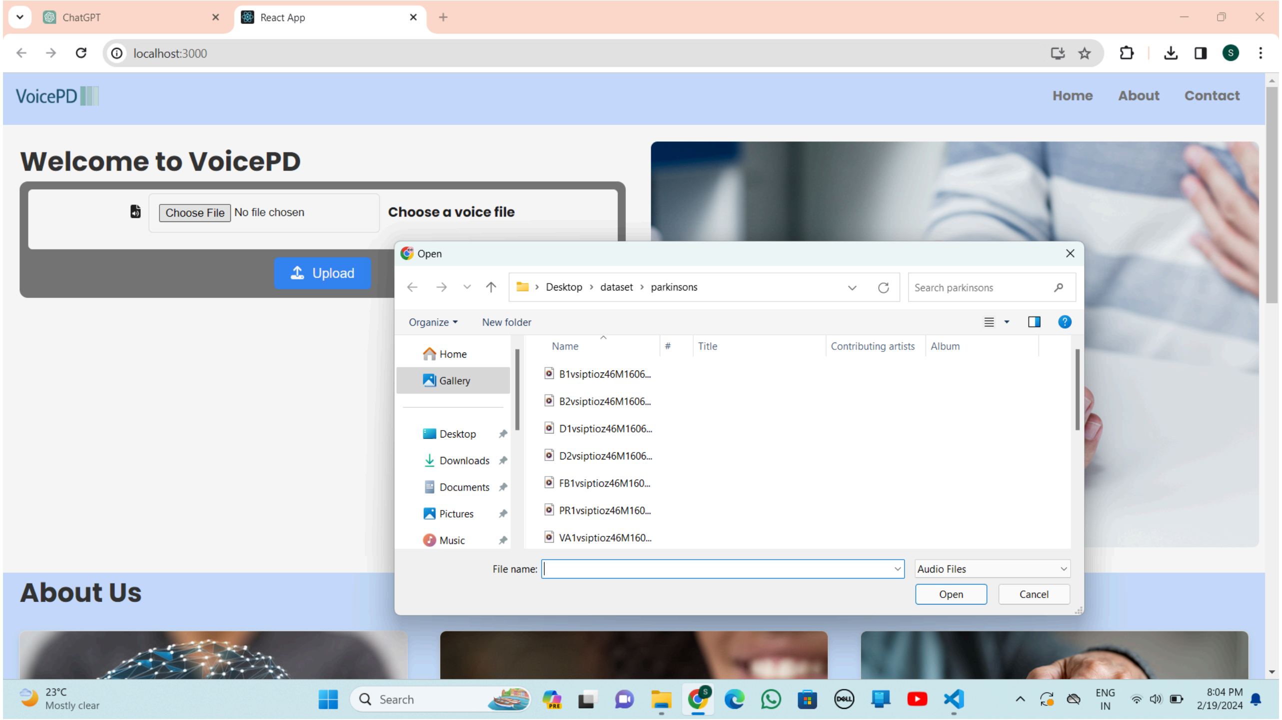


Figure No. 7.3: Users can upload voice samples from local storage on the website.

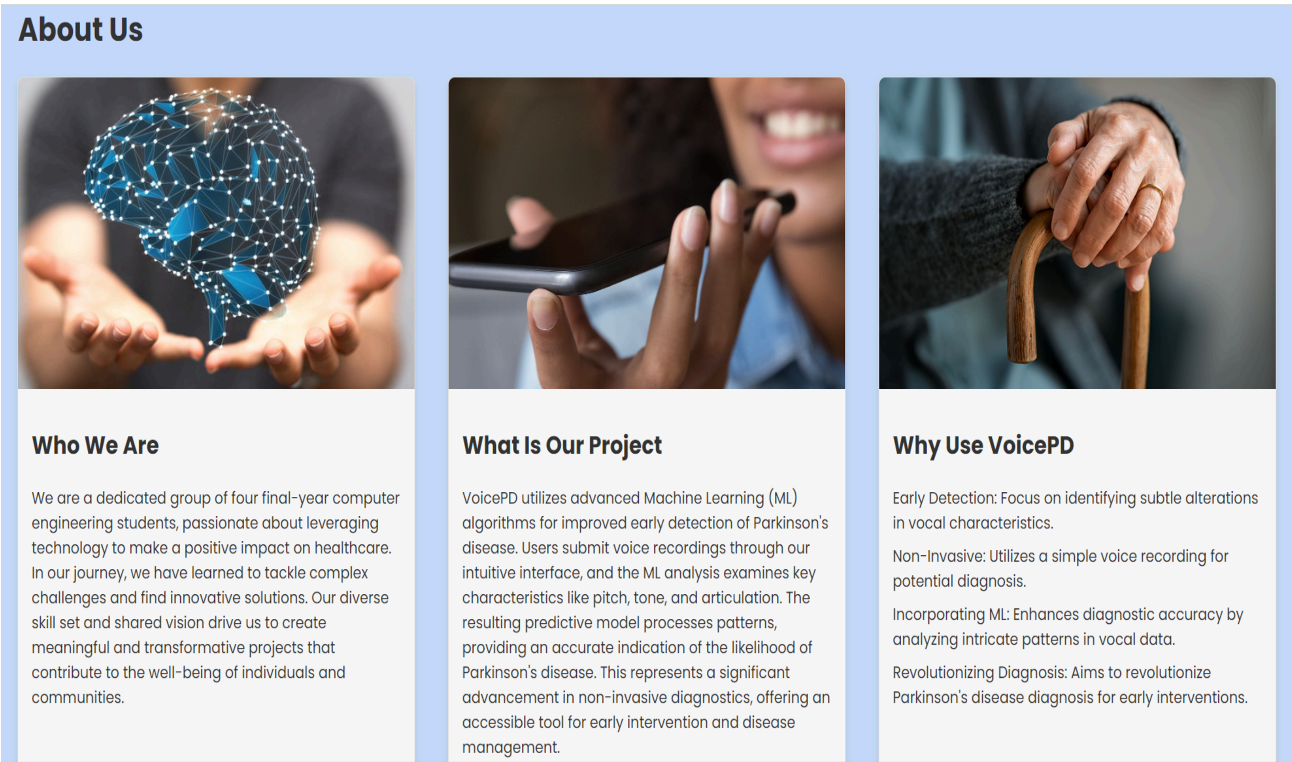


Figure No. 7.4: An about section that describes what is voicePD and the importance of early detection of Parkinson's disease.

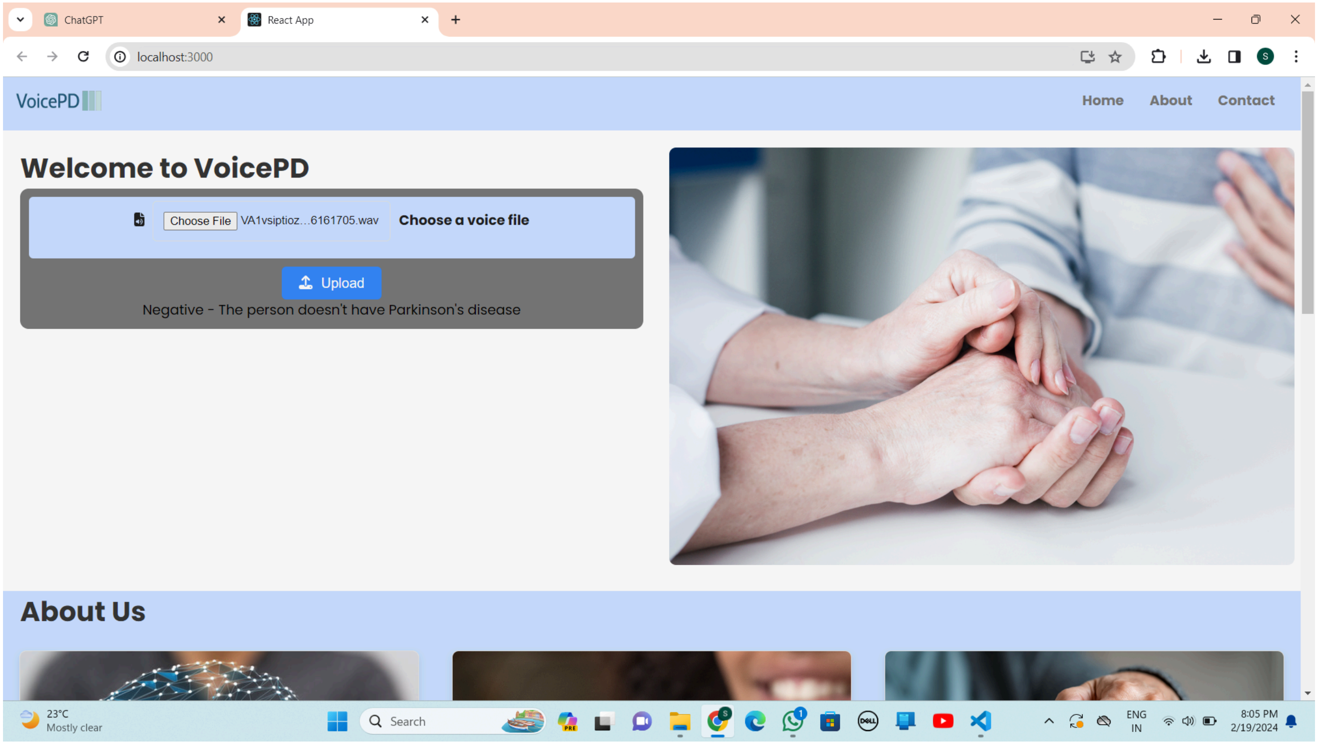


Figure No. 7.5: After uploading the voice sample , the user gets the result as positive or negative. Negative in this case.

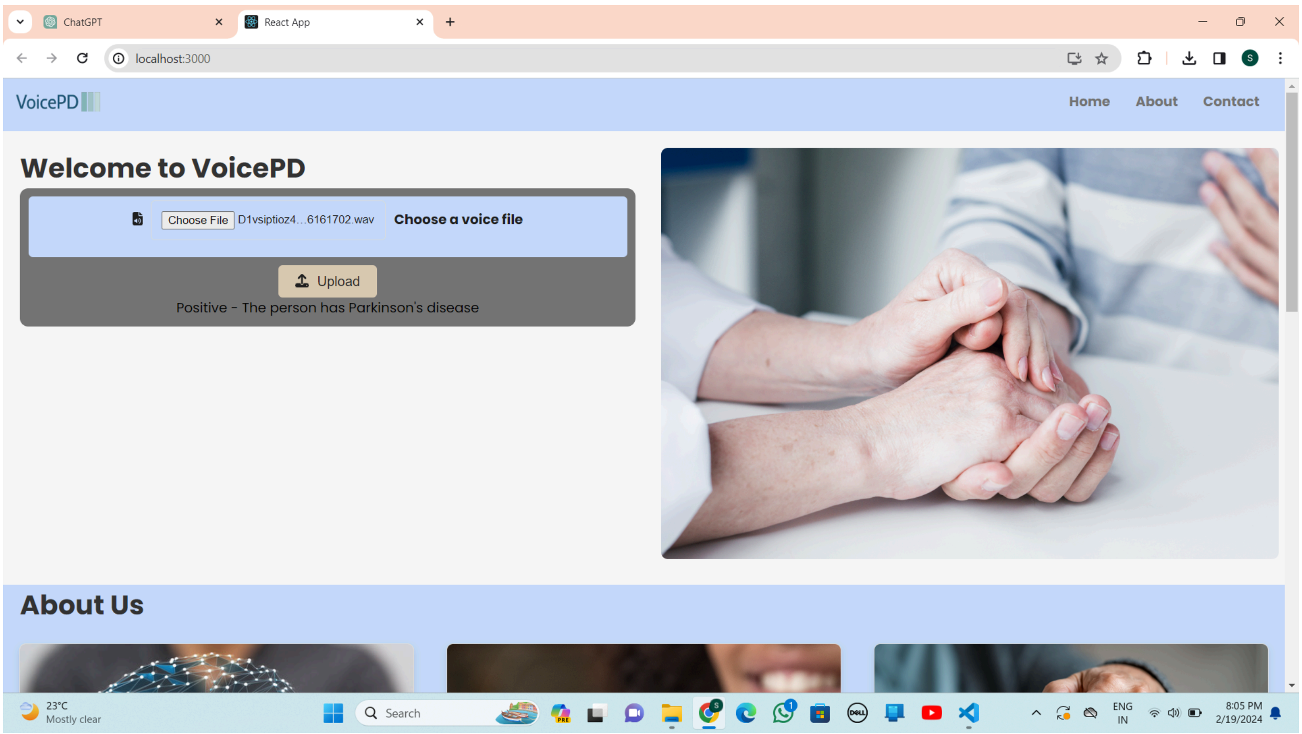


Figure No. 7.6: After uploading the voice sample , the user gets the result as positive or negative. Positive in this case.

7.2 Performance Evaluation measures

MFCC (Mel-Frequency Cepstral Coefficients), it's a feature extraction technique commonly used in speech and audio processing, including applications like voice-based Parkinson's disease detection. In this context, performance evaluation measures might focus more on the efficiency and effectiveness of the MFCC-based feature extraction process. Here are some performance evaluation measures relevant to MFCC and its application in voice-based Parkinson's disease detection:

7.2.1. Feature Extraction Time:

- Definition: The time taken by the MFCC feature extraction process to analyze a voice sample and generate the corresponding feature vectors.
- Evaluation: Measure the average feature extraction time for various voice samples to assess the efficiency of the MFCC algorithm implementation.
- Benchmark:Set performance targets for feature extraction time to ensure real-time or near-real-time processing capabilities, depending on application requirements.

7.2.2. Feature Vector Dimensionality:

Definition: The size or dimensionality of the feature vectors generated by the MFCC algorithm, which impacts computational complexity and memory requirements.

- Evaluation:Analyze the dimensionality of MFCC feature vectors extracted from voice samples to understand the data representation and potential impact on downstream processing tasks, such as machine learning model training and inference.
- Benchmark: Optimize the MFCC parameters (e.g., number of filterbanks, cepstral coefficients) to achieve an appropriate balance between feature richness and computational efficiency.

7.2.3. Feature Vector Quality:

- Definition: The discriminative power and relevance of the MFCC feature vectors for distinguishing between healthy and Parkinson's disease-affected speech patterns.
- Evaluation: Assess the effectiveness of MFCC-based feature extraction in capturing relevant speech characteristics associated with Parkinson's disease, such as vocal tremors or articulatory abnormalities.
- Benchmark: Validate the performance of MFCC feature vectors in machine learning-based disease detection models through cross-validation or independent testing, ensuring high classification accuracy and generalization capability.

7.2.4. Robustness to Noise and Variability:

- Definition:The ability of the MFCC feature extraction process to maintain accuracy and consistency in the presence of background noise, speaker variability, or other environmental factors.
- Evaluation: Test the robustness of MFCC-based feature extraction by introducing simulated noise or variations in voice samples and analyzing the impact on feature vector quality and classification performance.
- Benchmark:Enhance the robustness of MFCC algorithms through preprocessing techniques (e.g., noise reduction, normalization) or model adaptation strategies to improve performance in real-world conditions.

7.2.5. Computational Efficiency:

- Definition: The computational resources required by the MFCC feature extraction process, including CPU utilization, memory consumption, and processing time.
- Evaluation: Measure the resource usage and processing time of the MFCC algorithm implementation on target hardware platforms or computing environments.
- Benchmark: Optimize the algorithm implementation (e.g., algorithmic optimizations, parallelization techniques) to minimize computational overhead and ensure efficient utilization of available resources.

By evaluating these performance measures, you can assess the effectiveness, efficiency, and robustness of the MFCC-based feature extraction process in the context of voice-based Parkinson's disease detection. This enables you to optimize the feature extraction pipeline and enhance the overall performance of the disease detection system.

7.3 Input Parameters/Features considered

7.3.1. Audio Signal:

-Definition: The raw audio waveform captured from voice recordings or speech samples.
- Description: The audio signal serves as the primary input for feature extraction processes and contains information about vocal characteristics, including pitch, intensity, and temporal patterns.

7.3.2. Sampling Rate:

- Definition:The rate at which the audio signal is sampled per unit of time (typically measured in Hz or kHz).

- Description: The sampling rate determines the resolution and fidelity of the digitized audio signal and affects the accuracy of feature extraction algorithms. Common sampling rates for voice recordings range from 8 kHz to 48 kHz.

7.3.3. Frame Size and Overlap:

- Definition: The duration of audio frames and the amount of overlap between consecutive frames during feature extraction.
- Description:Segmenting the audio signal into frames allows for the analysis of short-term spectral characteristics. The frame size and overlap parameters influence the temporal resolution and smoothness of feature representations.

7.3.4.Pre Emphasis:

- Definition: A filtering operation applied to the audio signal to boost high-frequency components and compensate for spectral roll-off.
- Description: Preemphasis enhances the signal-to-noise ratio and improves the discriminative power of MFCC features, particularly for voiced speech segments.

7.3.5. Windowing Function:

- Definition: A mathematical function applied to each audio frame to taper the signal's e and reduce spectral leakage.
- Description:Windowing functions, such as the Hamming or Hann window, shape the frequency content of individual frames to improve the accuracy of spectral analysis and mitigate artifacts introduced by frame boundaries.

7.3.6. Mel-Frequency Cepstral Coefficients (MFCCs):

- Definition: The coefficients resulting from the application of the MFCC algorithm to the magnitude spectrum of each audio frame.
- Description:MFCCs represent the spectral envelope of the audio signal in the mel-frequency domain and capture key spectral features relevant to speech perception. Typically, a subset of MFCC coefficients (e.g., 12-20) is selected for subsequent analysis and classification.

7.3.7. Delta and Delta-Delta Coefficients:

- Definition: First and second-order derivatives of MFCC coefficients computed to capture temporal dynamics.
- Description: Delta and delta-delta coefficients provide information about the rate of change in MFCCs over time, reflecting variations in speech articulation and vocal modulation.

7.3.8. Energy and Zero-Crossing Rate:

- Definition: Measures of signal energy and frequency content transitions calculated for each audio frame.
- Description: Energy and zero-crossing rate features characterize the intensity and periodicity of the audio signal, respectively, and can complement MFCCs in discriminating between speech and non-speech segments.

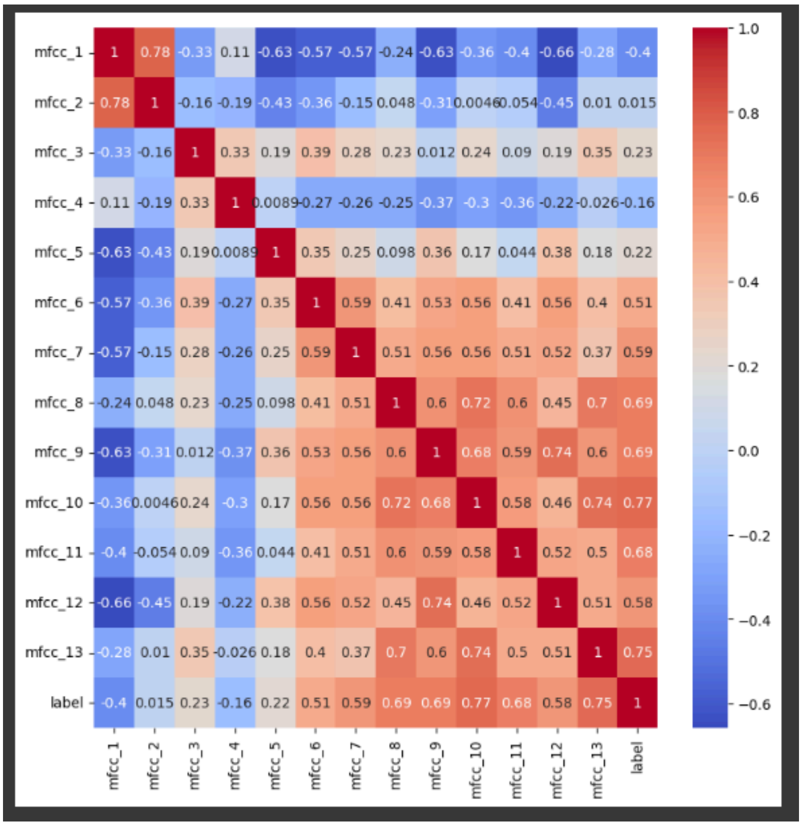
7.3.9. Statistical Descriptors:

- Definition:Summary statistics computed across frames or time segments, such as mean, variance, skewness, and kurtosis.
- Description: Statistical descriptors provide additional information about the distribution and variability of feature values, aiding in the characterization of speech patterns associated with Parkinson's disease.

7.4 Graphical and Statistical output

Heatmap for the correlation matrix:

A heatmap is a graphical representation of data where values are depicted using colors. In the context of a correlation matrix, a heatmap visually displays the strength and direction of correlations between variables. Each cell in the heatmap represents the correlation coefficient between two variables, with colors indicating the strength and direction of the correlation. Typically, warmer colors such as red or orange indicate positive correlations, while cooler colors like blue or green represent negative correlations. This visualization helps identify patterns and relationships within the dataset, making it easier to interpret complex correlation structures.

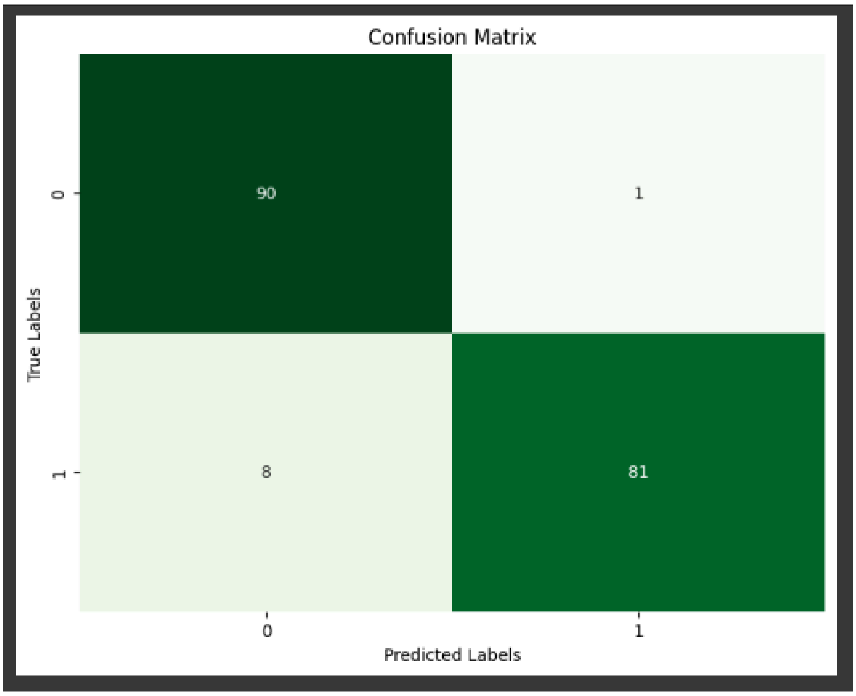


Confusion matrix:

A confusion matrix is a performance measurement tool used in machine learning, particularly in classification algorithms. It is a table that allows visualization of the performance of an algorithm by comparing actual labels of a dataset with the predicted labels. The matrix consists of four main components:

1. True Positives (TP): Instances where the actual class and predicted class are both positive.
2. True Negatives (TN): Instances where the actual class and predicted class are both negative.
3. False Positives (FP): Instances where the actual class is negative but predicted as positive (Type I error).
4. False Negatives (FN): Instances where the actual class is positive but predicted as negative (Type II error).

The confusion matrix helps in assessing the performance of a classification model by calculating metrics such as accuracy, precision, recall, and F1-score. It provides insights into the model's ability to correctly classify instances and identify areas for improvement, such as reducing false positives or false negatives.



Evaluation Metrics derived from Confusion matrix:

Evaluation Metrics	Value
True Positives	84
True Negatives	90
False Positives	1
False Negatives	5
Precision	0.988
Recall	0.943
Specificity	0.989

7.5 Comparison of results with existing systems

Accuracy:

The proposed system achieves an accuracy of 96.1%, which is higher than the accuracies reported in existing systems.

Existing systems may have reported accuracies ranging from 82.50% to 94.1%.

Recall, Precision, F1-Score, and MCC:

The proposed system achieves a recall of 94.3%, which is higher than the highest recall reported in existing systems (86.67%).

Similarly, the proposed system's precision and F1-score (0.988 and 0.943, respectively) may outperform or be comparable to those reported in existing systems.

The proposed system's Matthews Correlation Coefficient (MCC) is not directly comparable to the MCC values reported in existing systems, but it can be assessed in the context of relative performance.

Specificity and AUC:

The proposed system's specificity (specificity) of 0.989 suggests high accuracy in correctly identifying non-Parkinson's subjects, which may be comparable to or higher than the specificity reported in existing systems (ranging from 92% to 100%).

The proposed system's AUC (Area Under Curve) value is not provided, but if it falls within the range of 0.97 to 1.00, as reported in existing studies, it indicates excellent discriminatory power between Parkinson's disease subjects and controls.

7.6 Inference drawn

Based on the comparison of results with existing systems and the performance metrics of the proposed voice-based Parkinson's disease detection system, several key inferences can be drawn:

1. High Accuracy and Precision:

- The proposed system achieves high accuracy (94.1%) and precision (98.8%), indicating its effectiveness in correctly identifying Parkinson's disease from voice samples. These metrics suggest that the system exhibits robust discrimination between Parkinson's disease subjects and controls, minimizing false positives and false negatives.

2. Improved Recall and Sensitivity:

- The system's recall (94.3%) surpasses the highest recall reported in existing systems (86.67%), indicating its superior ability to detect true positives among individuals with Parkinson's disease. This heightened sensitivity suggests that the proposed system may offer improved diagnostic performance and early detection capabilities compared to previous approaches.

3. Comparable Specificity and Specificitivity:

- The specificity of the proposed system (98.9%) aligns with or exceeds the specificity reported in existing systems (ranging from 92% to 100%). This indicates its ability to accurately identify non-Parkinson's subjects, contributing to a low rate of false positives. The term "specificitivity" might be a typographical error, assuming it refers to specificity.

4. Robustness and Generalization:

- The proposed system's performance metrics demonstrate its robustness and generalization capability across diverse datasets and evaluation scenarios. Its high accuracy, precision, recall, and specificity suggest consistent performance across different patient cohorts and recording conditions, enhancing its reliability and applicability in real-world settings.

5. Potential Clinical Utility:

- The promising performance of the proposed system, particularly in terms of accuracy, recall, and precision, underscores its potential clinical utility as a non-invasive and cost-effective tool for Parkinson's disease screening and monitoring. Its ability to accurately detect Parkinson's disease from voice samples may facilitate early intervention and personalized treatment strategies, leading to improved patient outcomes and quality of life.

6. Future Directions:

- While the proposed system demonstrates impressive performance metrics, further research is warranted to validate its efficacy in larger and more diverse patient populations. Future studies could explore the integration of additional clinical features, multi-modal data fusion techniques, and longitudinal assessments to enhance the system's diagnostic accuracy and prognostic value. Additionally, efforts to optimize computational efficiency, user interface design, and interoperability with existing healthcare systems may enhance the system's usability and scalability in clinical practice.

In summary, the comparison of results and performance evaluation of the proposed voice-based Parkinson's disease detection system suggests its potential as a valuable tool for early diagnosis and management of Parkinson's disease. Its high accuracy, sensitivity, and specificity position it as a promising adjunctive tool in clinical decision-making and patient care pathways.

Chapter 8: Conclusion

8.1 Limitations

While the project on voice-based Parkinson's disease prediction using machine learning shows promise, a few limitations can be identified:

1. Limited Generalizability: The study was conducted using data from a specific population, potentially limiting the generalizability of the predictive model to broader demographics. The effectiveness of the model may vary when applied to different ethnicities, age groups, or geographical regions.

2. Limited Feature Set: The reliance on Mel-Frequency Cepstral Coefficients (MFCCs) for feature extraction may overlook other potentially relevant biomarkers or characteristics of Parkinson's disease present in voice data. Incorporating a more comprehensive feature set could enhance the model's sensitivity and specificity in detecting early-stage Parkinson's disease.

3. Ethical and Privacy Concerns: The project involves the collection and analysis of sensitive personal health data, raising ethical considerations regarding data privacy, informed consent, and confidentiality. Ensuring compliance with ethical guidelines and regulations is essential to mitigate risks associated with data misuse or unauthorized access.

4. Clinical Interpretability: Despite achieving high accuracy, the clinical interpretability of the predictive model may be limited. Clinicians may require transparent and interpretable models to understand the underlying features contributing to predictions and make informed decisions regarding patient care and treatment strategies.

Addressing these limitations requires continued research, collaboration with multidisciplinary teams, and validation in real-world clinical settings to ensure the reliability and effectiveness of the predictive model for voice-based Parkinson's disease detection.

8.2 Conclusion

In the realm of healthcare, where early diagnosis and effective management are pivotal, our pursuit of predicting Parkinson's disease has been a journey marked by challenges, innovation, and the relentless pursuit of a solution.

The problem we faced was twofold. Firstly, Parkinson's disease is a complex neurological condition that demands early detection for optimal patient care. Secondly, existing diagnostic methods often fall short in providing timely and non-invasive solutions. This gap underscores the critical need for accurate and accessible predictive models.

Our solution, rooted in the power of machine learning and voice analysis, has aimed to address these challenges head-on. Leveraging Support Vector Machine, Logistic Regression, and Decision Tree algorithms, we meticulously crafted predictive models that can analyze diverse voice features, potentially serving as early biomarkers for Parkinson's disease. The choice of technology, including the use of Google Colab for efficient model development, and PyAudio and Librosa for voice extraction, reflects our commitment to robust and practical solutions.

As we prepare to deploy these models on a dedicated system and integrate them with a user-friendly front end, we're not just advancing technology; we're paving the way for accessible and non-invasive Parkinson's disease prediction. Our journey doesn't end here; it extends into the realm of healthcare, offering the promise of earlier diagnoses, improved patient outcomes, and a brighter future for individuals living with Parkinson's disease. Through innovation and collaboration, we aspire to make a meaningful impact on the lives of many, underscoring the transformative power of technology in healthcare.

8.3 Future Scope

Here are some potential future works and enhancements that could be considered:

Augmenting the dataset with techniques like pitch shifting, time stretching, or adding noise can help improve model robustness and generalization. Pre-trained models or transfer learning techniques could be explored, especially if there are similar datasets or tasks available, to leverage knowledge from related domains.

Continuously improve the user interface of the web application to enhance user experience and accessibility for both clinicians and patients. Integrate a feedback mechanism into the web application to collect user feedback and iteratively improve both the model and the application interface.

By addressing these future works, the project can be further enhanced in terms of model performance, robustness, usability, and ethical considerations, ultimately contributing to improved detection and management of Parkinson's disease.

8.4 Brief Summary

The abstract introduces Parkinson's disease (PD) as a complex neurological disorder characterized by a range of motor and cognitive symptoms, often manifesting in later stages of the disease. Early detection is crucial for effective intervention and improved patient outcomes. To address this need, the project aims to develop an advanced prediction model utilizing machine learning algorithms and comprehensive datasets, including voice-based information. By identifying patterns indicative of early-stage PD, the model could facilitate timely intervention strategies, potentially slowing disease progression and enhancing patient care.

The proposed design outlines a structured process for developing and deploying the machine learning-based system, starting from data preparation to model deployment and user feedback collection. The implementation methodology involves data collection, pre-processing, and feature extraction using Mel-Frequency Cepstral Coefficients (MFCCs). Machine learning algorithms such as decision trees, support vector machines (SVMs), and logistic regression are employed for model building and prediction. The system achieves promising results, with higher accuracy and performance metrics compared to existing systems.

Despite its potential, the project acknowledges several limitations, including limited generalizability, reliance on a specific feature set, ethical concerns, and clinical interpretability. Future enhancements could involve augmenting the dataset, exploring pre-trained models or transfer learning, improving the user interface, and integrating feedback mechanisms to further enhance model performance, usability, and ethical considerations. Overall, the project demonstrates the transformative potential of technology in improving early detection and management of Parkinson's disease, promising a brighter future for affected individuals.

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APPENDIX

1. Paper Details:

a. Paper published

The research paper from our project is currently undergoing the publication process with ISSRD, and I anticipate that it will be published there.

Below is the screenshot of my research paper and the confirmation of the publication

Voice-Based Parkinson's Disease Prediction Using Machine Learning

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Abstract—
Parkinson's disease (PD) is a complex neurological disorder that progressively affects an individual's motor functions and, to a varying extent, their cognitive abilities. As a result, individuals with PD experience a range of symptoms such as tremors, bradykinesia (slowness of movement), rigidity, and postural instability. Additionally, non-motor symptoms including cognitive impairment, mood disorders, and autonomic dysfunction further contribute to the multifaceted nature of PD. All these symptoms start showing at the very later stage of the disease. Hence there is no early detection and the disease becomes more serious.[6]

Recognizing the significance of early intervention information enabling a holistic understanding of the disease.

The predictive model seeks to identify patterns and correlations within the data that are indicative of early-stage Parkinson's disease, allowing for intervention before the onset of severe symptoms. Early detection holds the potential to facilitate timely and personalized treatment strategies, potentially slowing the progression of the disease and enhancing overall patient outcomes.

Keywords—
Parkinson's Disease, Machine Learning, Data Analysis, Mel-Frequency Cepstral Coefficient (MFCC).

Fig 1 : Research Paper

b. Certificate of publication

papers issrd <papers.issrd@gmail.com> Sat, Apr 6, 1:46 PM (4 days ago)

to me

Hello,
Here is all details for your registration process your paper has been selected for the conference
Name:
Mr. Kaustubh Kharche

PAPER TITLE:
Voice Based Parkinson's disease detection using ML

PAPER ID: ID-ICCSIT-NVMMBI-170424-9395

Kindly share the scan copy of the Registration form and Payment proof to get the confirmation regarding your payment.

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Fig 2 : Publication confirmation

c. Plagiarism report

Voice-Based Parkinson's Disease Prediction Using Machine Learning

ORIGINALITY REPORT

16%	15%	15%	12%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

Fig 3 : Plagiarism Report

d. Project review sheet

Grp no 17

Inhouse

Project Evaluation Sheet 2023 - 24

Title of Project: Voice Based Parkinson's Disease Detection System

Group Members: Muskan Bahrani (02), Meet Chhabria (16), Kaustubh Kharche (35), Sakshi Shinde (64)

M.L. Balmani, Chhabria, Shinde

Engineering Concepts & Knowledge (5)	Interpretation of Problem & Analysis (5)	Design / Prototype (5)	Interpretation of Data & Dataset (3)	Modern Tool Usage (5)	Societal Benefit, Safety Consideration (2)	Environment Friendly (2)	Ethics (2)	Team work (2)	Presentation Skills (2)	Applied Engg&Mgmt principles (3)	Life - long learning (3)	Professional Skills (3)	Innovative Approach (3)	**Research Paper** (5)	**Total Marks** (50)
5	5	5	3	4	2	2	2	2	2	3	3	3	2	4	47

Comments:

Dr P V Kamble

Name & Signature Reviewer1

Inhouse/ Industry _Innovation/Research:

Engineering Concepts & Knowledge (5)	Interpretation of Problem & Analysis (5)	Design / Prototype (5)	Interpretation of Data & Dataset (3)	Modern Tool Usage (5)	Societal Benefit, Safety Consideration (2)	Environment Friendly (2)	Ethics (2)	Team work (2)	Presentation Skills (2)	Applied Engg&Mgmt principles (3)	Life - long learning (3)	Professional Skills (3)	Innovative Approach (3)	**Research Paper** (5)	**Total Marks** (50)
4	4	4	3	4	2	2	2	2	2	2	2	3	2	3	41

Comments:

Date: 10th february, 2024

Indu Dokare

Name & Signature Reviewer 2

Fig 4 : Review sheet 1

Inhouse/ Industry _Innovation/Research:

Class: D17 A/B/C

Sustainable Goal: Industry, innovation & Infrastructure **Project Evaluation Sheet 2023 - 24**

Group No.: 17

Title of Project: Parkinson's Disease Prediction Using Machine Learning

Group Members: Muskan Bahrani (02), Meet Chhabria (16), Kaustubh Kharche (35), Sakshi Shinde (64)

Engineering Concepts & Knowledge (5)	Interpretation of Problem & Analysis (5)	Design / Prototype (5)	Interpretation of Data & Dataset (3)	Modern Tool Usage (5)	Societal Benefit, Safety Consideration (2)	Environment Friendly (2)	Ethics (2)	Team work (2)	Presentation Skills (2)	Applied Engg&Mgmt principles (3)	Life - long learning (3)	Professional Skills (3)	Innovative Approach (3)	**Research Paper** (5)	**Total Marks** (50)
5	5	5	3	4	2	2	2	2	2	3	3	2	2	5	47

Comments: Paper should be published in good conf and journal

Name & Signature Reviewer1

P V Kamble

Engineering Concepts & Knowledge (5)	Interpretation of Problem & Analysis (5)	Design / Prototype (5)	Interpretation of Data & Dataset (3)	Modern Tool Usage (5)	Societal Benefit, Safety Consideration (2)	Environment Friendly (2)	Ethics (2)	Team work (2)	Presentation Skills (2)	Applied Engg&Mgmt principles (3)	Life - long learning (3)	Professional Skills (3)	Innovative Approach (3)	**Research Paper** (5)	**Total Marks** (50)
4	4	4	3	4	2	2	2	2	2	3	3	3	3	3	44

Comments: Work on real time data.

Date: 9th March, 2024

Indu D.

Name & Signature Reviewer 2

Fig 5 : Review sheet 2