Project Phase II Report On

Health Anomaly Detection using Human Gait Analysis

Submitted in fulfillment of the requirements for the award of the degree of

Bachelor of Technology

in

Computer Science and Engineering

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CERTIFICATE

This is to certify that the project report entitled ***"Health Anomaly Detection using Human Gait Analysis"*** *is a bonafide record of the work done by* ***Mr. Ebin Shibu Nanthalathu (U2003074)****,* ***Mr. Firoz Yoosef (U2003080)****,* ***Ms. Hitha Mathew P. (U2003096)*** *and* ***Ms. Karunya James (U2003116)*** *submitted to the Rajagiri School of Engineering & Technology (RSET) (Autonomous) in fulfillment of the requirements for the award of the degree of Bachelor of Technology (B. Tech.) in Computer Science and Engineering during the academic year 2023-2024.*

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Abstract

Gait analysis, used for motion capture holds significant promise for detecting and monitoring health issues, particularly focusing on Parkinson's disease and arthritis. In the context of Parkinson's, gait abnormalities often precede observable symptoms, serving as early indicators of motor dysfunction. Utilizing sophisticated motion capture, researchers aim to identify and quantify subtle changes in gait patterns. Machine learning algorithms are applied to this data, enabling the development of robust diagnostic and prognostic tools. Early detection of these gait abnormalities not only aids in timely intervention but also facilitates personalized treatment plans for individuals with Parkinson's disease, potentially improving their quality of life.

Gait analysis is similarly valuable in the assessment of arthritis, offering insights into joint function and mobility changes over time. The study investigates correlations between specific gait parameters and arthritis severity, laying the groundwork for targeted rehabilitation strategies. Bio-mechanical measurements play a crucial role, identifying asymmetries and tracking alterations in gait dynamics associated with arthritis progression. The goal is to integrate these findings into routine clinical assessments, considering factors like age and comorbidities, to enhance the applicability of gait analysis across diverse demographic settings.

By collecting gait data from individuals with Parkinson's disease, arthritis, and healthy controls, this research aims to validate the effectiveness of gait analysis in real-world clinical contexts. Ultimately, the integration of gait analysis into clinical practice holds great promise for revolutionizing early detection, personalized treatment strategies, and overall management of individuals with Parkinson's disease and Arthritis.

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Chapter 1

Introduction

1.1 Background

Gait analysis, propelled by advanced technologies such as motion capture and machine learning, has emerged as a transformative avenue in healthcare for the detection and continuous monitoring of health issues. This innovative approach is particularly spotlighted in the context of neurodegenerative disorders, with a specific emphasis on Parkinson's disease, and musculoskeletal conditions like arthritis. The intricate examination of human gait not only offers insights into the early stages of these ailments but also holds the promise of personalized treatment strategies and ongoing monitoring of disease progression.

In this evolving landscape, the research endeavors to unravel the nuanced dynamics of gait abnormalities, showcasing their potential as early indicators of motor dysfunction in Parkinson's disease. Employing cutting-edge motion capture technologies, coupled with the power of machine learning algorithms, the study seeks to discern subtle changes in gait patterns that precede clinical symptoms. Simultaneously, the exploration of gait analysis in the context of arthritis aims to assess joint function and monitor mobility changes over time, laying the foundation for targeted rehabilitation strategies.

This sets the stage for a comprehensive investigation into the multifaceted applications of gait analysis, emphasizing its role as a non-invasive and objective tool for early detection, personalized treatment plans, and continuous monitoring in the realm of Parkinson's disease and arthritis. The fusion of biomechanics, technology, and data-driven approaches propels this research towards transforming clinical practices and enhancing the overall management of individuals facing these health challenges.

1.2 Problem Definition

The objective of this research is to create a comprehensive gait analysis system for early detection and monitoring of health issues related to Parkinson's disease and arthritis. Using non-invasive methods like wearable sensors or motion-capture systems, the study analyzes gait patterns to differentiate between individuals with Parkinson's disease, arthritis, and healthy controls. Demographic and clinical data, including disease duration, severity, and medication history, are collected alongside gait information. Algorithms are developed to scrutinize key gait parameters, and machine learning is employed to train models to distinguish between health conditions. Ethical considerations ensure participant privacy and informed consent. Clinical relevance is established by correlating gait abnormalities with disease severity assessments. Validation involves diverse populations, and collaboration with healthcare professionals aims to integrate the gait analysis tool into routine clinical assessments. The expected outcomes include identifying specific gait patterns, developing accurate machine learning models, and exploring the feasibility of gait analysis as a diagnostic and monitoring tool for Parkinson's disease and arthritis, ultimately contributing valuable insights to improve patient care.

1.3 Scope and Motivation

Step analysis is the cornerstone of a multifaceted approach to understanding and treating Parkinson's disease (PD). Parkinson's disease is a neuro-degenerative disorder characterized by a complex interplay of motor symptoms, including, rigidity, tremor, and postural instability. The complex nature of PD requires a comprehensive assessment framework, and gait analysis is a key tool in this regard, providing both quantitative knowledge and qualitative observations of the dynamic changes that occur in a person's movement patterns over the course of the disease. The heart of gait analysis is a tool to elucidate the complex picture of movement impairment. By examining various walking parameters such as step length, cadence, speed and variability, doctors can obtain valuable information about the severity and progression of the disease. Longitudinal studies using gait analysis have elucidated subtle but important changes in the walking patterns of PD patients as the disease progresses, providing invaluable markers for disease monitoring and prognosis. Gait analysis holds promise as an early and early sentinel detection and diagnosis. Growing evidence suggests that changes in gait may precede the onset of other overt motor symptoms, offering an opportunity for intervention in the prodromal phase of PD. Using advanced instruments such as wearable sensors and computerized gait analysis systems, researchers are working to discover subtle biomarkers of gait disorders that can predict the early stages of PD, paving the way for timely therapeutic interventions.The therapeutic landscape for PD is vast and multifaceted, including pharmacological, surgical and rehabilitation approaches aimed at improving motor symptoms and improving quality of life. It plays a central role in this therapeutic triangle because it serves as a barometer of therapy effectiveness whether evaluating the effects of dopaminergic drugs on gait dynamics or the results of deep brain stimulation surgery on locomotor function, gait analysis provides clinicians with objective measures to evaluate the effectiveness of interventions, facilitating informed decision-making and individualized treatment planning.In addition to diagnostic and therapeutic benefits, gait analysis also has fall prevention, which is most important in the treatment of PD. Individuals with PD are at increased risk of falling due to gait disturbances and postural instability, underscoring the need for targeted interventions to mitigate this risk. By identifying specific gait abnormalities associated with fall susceptibility, such as shortened stride length or increased gait variability, gait analysis allows clinicians to tailor interventions, from gait training to environmental modifications, to minimize fall-related morbidity and mortality.In addition, gait analysis helps to understand the enigmatic phenomenon of freezing of gait (FOG), which is a disabling symptom characterized by transient periods of gait arrest. By quantifying episodes of FOG and delineating its triggers and mechanisms, researchers are trying to unravel the complexities of this enigmatic phenomenon, paving the way for new treatment strategies aimed at mitigating its effects on mobility and autonomy. Gait analysis exceeds its role. as a purely diagnostic tool, a comprehensive framework for understanding, monitoring and managing the complex interplay of motor dysfunctions in PD. Gait analysis represents a paradigm of individualized care based on objective assessment and tailored interventions, from determining disease progression to therapeutic interventions and fall prevention strategies, offering hope and strength to people navigating the complex landscape of Parkinson's disease.

1.4 Objectives

- Development of Gait Analysis Model:
  - To design and implement a robust gait analysis model capable of extracting relevant features from walking patterns.
- Prediction of Parkinson's Disease:
  - To investigate and identify specific gait parameters indicative of Parkinson's disease progression.
- Prediction of Arthritis:
  - To identify gait abnormalities associated with different types of arthritis for improved diagnostic precision.
- Integration of Machine Learning Algorithms:
  - To evaluate and compare the performance of various machine learning algorithms for predicting health conditions using gait data.
- Validate Models and Enhance Interpretability:
  - Validate the developed models using diverse datasets to ensure generalizability.

1.5 Assumptions and Challenges

The study on gait analysis for health problem detection in Parkinson's Disease and Arthritis operates under key assumptions, including the existence of a discernible link between specific gait abnormalities and these conditions, participant representativeness for generalizing findings, and the validity of selected gait analysis measures. Assumptions also extend to the homogeneity of symptom presentation, stability of gait patterns over time, and the independence of observed patterns from external factors. Challenges in this exploration include the heterogeneity of symptoms, variability and standardization of gait data, addressing population diversity, conducting longitudinal studies, separating disease effects from medication influence, ethical and privacy concerns, integrating gait analysis into clinical practice, generalizing findings to real-world settings, validating machine learning models, and the inherent complexity of identifying specific gait patterns. Overcoming these challenges necessitates a multidisciplinary approach, fostering collaboration between researchers, clinicians, and technologists to advance diagnostic and monitoring tools for Parkinson's Disease and Arthritis.

1.6 Social/ Industrial Relevance

Social Relevance:

1. Enhanced Quality of Life: Gait analysis's early detection improves life quality for those with Parkinson's disease and arthritis, allowing prompt intervention and symptom management.

2. Personalized Healthcare: Gait analysis contributes to personalized healthcare by incorporating individual gait dynamics into treatment plans, tailoring interventions to unique patient needs.

3. Healthcare Accessibility: Non-invasive gait analysis tools enhance accessibility, providing cost-effective diagnosis and monitoring, reducing barriers to healthcare entry.

4. Public Health Impact: Emphasis on early detection and monitoring supports public health by identifying at-risk individuals and reducing the overall burden of neurodegenerative and musculoskeletal disorders.

Industrial Relevance:

1. Advancements in Medical Technology: The research propels medical technology advancements in motion capture and machine learning, positioning industries at the forefront of healthcare innovation.

2. Healthcare Innovation: Integrating gait analysis into healthcare systems fosters innovation in diagnostics and treatment planning, offering novel solutions for precise and targeted interventions.

3. Rehabilitation Solutions: Gait analysis provides invaluable insights for healthcare and rehabilitation industries, facilitating the development of targeted solutions for individuals with arthritis and musculoskeletal conditions.

4. Data-Driven Healthcare: The research aligns with the trend of data-driven healthcare, enhancing diagnostic accuracy and contributing to evidence-based decision-making for a more efficient healthcare ecosystem.

1.7 Organization of the Report

The project report on Gait Analysis for Health Problems Detection, focusing on predicting the probability of Parkinson's disease and arthritis, follows a systematic structure to convey comprehensive information. The introduction provides background on gait analysis, project motivations, and specific objectives. It emphasizes the need for a diagnostic system using gait analysis, outlining its scope and potential social and industrial impact. The literature survey critically examines relevant knowledge, and the existing system section evaluates current approaches. The proposed system is detailed with an architectural diagram, sequence diagram, and module-wise diagrams. Assumptions, challenges, work breakdown, and responsibilities are discussed, providing insights into contextual nuances and project hurdles. Hardware and software requirements, project milestones, and schedules are outlined for system implementation. Budget estimates cover equipment and software costs, while risk identification and mitigation strategies ensure project resilience. The conclusion summarizes key findings, contributions, and future scope of this project.

Chapter 2

Literature Survey

2.1 Base Paper: Gait Spatiotemporal Signal Analysis for Parkinson's Disease Detection and Severity Rating [1]

The exploration of Gait Spatiotemporal Signal Analysis for Parkinson's Disease Detection and Severity Rating focuses on employing deep learning models to process raw gait-induced ground reaction force (GRF) data. This innovative research targets both Parkinson's disease (PD) patients and individuals without PD, aiming to automatically learn spatiotemporal GRF signals for end-to-end PD severity classification. An integral part of this approach involves the use of layer-wise relevance propagation (LRP) to interpret the models' output, identifying crucial features within spatiotemporal gait GRF signals for effective PD severity classification. One notable feature of the proposed models is their resilience to noise and computational efficiency. These models demonstrate robustness in processing and classifying extensive longitudinal datasets of gait-induced GRF signals. The assessment of model performance, measured through the F1-score metric, emphasizes their commendable efficacy, achieving a mean performance of 95.5% with remarkably low standard errors of 0.28%.

Beyond the technical aspects, the study highlights the practical implications of deploying deep learning models in gait analysis for PD detection and severity rating. The high mean F1-score and low standard errors affirm the accuracy and reliability of these models, positioning them as viable tools for handling substantial datasets in a clinical context. The interpretability of the models' output, facilitated by LRP, is particularly noteworthy, allowing for the identification of significant gait features indicative of PD severity. This information is invaluable for detecting postural balance deterioration and monitoring the progression of PD over time.

In conclusion, the integration of deep learning models into gait analysis for PD detection and severity rating represents a promising advancement with far-reaching implications for clinical practice. The models' ability to offer accuracy, resilience, and efficiency in handling substantial datasets, coupled with their capacity to unveil nuanced insights into gait dynamics at different stages of Parkinson's disease, underscores their potential significance in enhancing our understanding and management of this health condition.

2.2 A Strong and Robust Skeleton-Based Gait Recognition Method with Gait Periodicity Priors[2]

The research here describes a method for recognizing individuals based on their walking patterns using information extracted from their skeletal movements. It focuses on understanding and utilizing the recurring elements or cycles within a person's gait, aiming to create a robust and accurate recognition system. The key components of this method involve extracting meaningful data from the skeletal representation, considering factors like joint angles, step length, and phase relationships between joints. These extracted features are then used to model the periodic nature of human gait, employing statistical or mathematical techniques to capture and leverage these periodicities effectively.
Machine learning or pattern recognition algorithms are employed to match these features to specific individuals, potentially using methods like Support Vector Machines or neural networks for classification.
The paper likely discusses how this approach improves upon existing gait recognition methods, highlighting its advantages in accuracy, resilience under various conditions, and potential applications in security, surveillance, healthcare, and human-computer interaction. It's expected that the paper includes experimental results to validate the proposed method, demonstrating its accuracy, robustness, and efficiency compared to other state-of-the-art approaches in gait recognition. This research holds significance in enhancing the reliability and applicability of gait recognition systems across different domains.

2.3 Multi-scale sparse graph convolutional network for the assessment of Parkinsonian gait[3]

The research centers on the Multi-scale Sparse Graph Convolutional Network, tailored for analyzing Parkinsonian gait. This network integrates graph convolutional networks and a multi-scale strategy to understand intricate walking patterns. Using a Graph Convolutional Network (GCN), the approach processes graph-structured data representing interconnected gait aspects. Employing a multi-scale framework, the research captures a holistic perspective of Parkinsonian gait across different levels of detail, including diverse time scales and joint interactions. Sparse representations condense data, enhancing computational efficiency for focused gait analysis.

The network primarily assesses Parkinsonian gait, offering a more refined analysis than conventional methods. In the broader machine learning and neural networks landscape, the research contributes to understanding and managing neurological disorders, especially Parkinson's disease. The MS-STAM incorporates a spatial-temporal attention mechanism, enhancing the model's effectiveness in various applications, particularly accurate video classification. The discussion underscores the role of the combination constraint of deep supervision in improving the network's performance, valuable for accurate video analysis.

Recognition is given to regularization terms in the MS-STAM's cost function for effectively improving network performance. Determining optimal parameter values through grid-search experiments ensures method robustness. In summary, the MS-STAM advances video-based gait analysis with unique features, enhancing accuracy and potential applications in diverse video classification tasks, especially in assessing gait motor disorders. Practical implications include improved accuracy in video classification, potential applications in motor assessments, and the development of a versatile method applicable across diverse video analysis tasks.

2.4 Real-Time Gait Phase Detection on Wearable Devices for Real-World Free-Living Gait[4]

The research focuses on an innovative algorithm for real-time gait phase detection on wearable devices, integrating a reduced support vector machine (RSVM) and a finite state machine (FSM). The algorithm's standout feature is the development of the RSVM using cascaded K-means clustering, resulting in an 88% reduction in model size and a 36-fold decrease in computation time, with only a marginal 4% sacrifice in gait phase prediction accuracy. The FSM plays a pivotal role by validating RSVM predictions and rectifying misclassifications. Implemented on a wearable device's microcontroller and evaluated with twenty healthy subjects in real-world scenarios, the algorithm exhibits impressive real-time performance with 91.51% accuracy, 91.70% sensitivity, and 95.77% specificity. Its robustness across varying walking conditions adds to its practical utility.

The paper underscores the algorithm's clinical relevance, especially in gait rehabilitation and early diagnosis of neurological diseases. It addresses challenges in real-time gait phase detection on microcontrollers, positioning itself as a promising solution with potential for unobtrusive and reliable gait analysis in free-living scenarios. The amalgamation of RSVM and FSM streamlines computational demands and renders the algorithm suitable for resource-constrained microcontrollers. Consistently high accuracy, sensitivity, and specificity, coupled with resilience in diverse conditions, highlight its potential for accurate gait phase detection in real-world settings. Overall, the paper significantly contributes to advancing real-time gait analysis methodologies, particularly in wearable devices and healthcare applications.

2.5 Video-Based Quantification of Gait Impairments in Parkinson's Disease Using Skeleton-Silhouette Fusion Convolution Network[5]

The proposed methodology offers a novel approach to quantifying gait impairments in Parkinson's disease (PD) using a skeleton-silhouette fusion convolution network. It begins by capturing sagittal-view gait videos from smartphones, employing advanced algorithms like Mask R-CNN and OpenPose for extracting human silhouettes and skeleton sequences. This dual-extraction process transforms silhouette sequences into Long-Term Gait Energy Images (GEI) and organizes skeleton sequences into undirected pose graphs. The resulting two-stream network utilizes 2D convolution for silhouette features and graph convolution for spatial and temporal Parkinsonian gait features, predicting Movement Disorder Society Unified Parkinson's Disease Rating Scale (MDS-UPDRS) gait scores. Training involves the cross-entropy loss function and stochastic gradient descent (SGD).

The proposed method undergoes robust evaluation through a 5-fold cross-validation scheme, assessing precision, recall, F1 score, ROC curve area, and accuracy. Validation highlights the method's potential for automated, quantitative gait assessment in PD, particularly in natural environments. The method introduces supplementary features, enhancing its credibility with higher-resolution metrics for assessing gait disorders. These features, including arm swing amplitude, torso velocity, and neck forward bending angle, correlate significantly with gait scores, serving as valuable indicators, especially in nuanced presentations.

Beyond diagnosis and quantification, the method holds promise for personalized rehabilitation strategies. By accurately assessing intricate gait features through smartphone data collection, it surpasses the limitations of traditional clinical assessments. However, the study acknowledges limitations, including challenges in real-world clinical implementation, lack of detailed dataset descriptions, and missing information on reliability. Future directions include expanding the participant pool, ablation experiments, and exploring real-world implementations, reflecting a commitment to refinement and broader applicability in gait assessment for Parkinson's Disease.

2.6 Existing Systems

Gait analysis is crucial for identifying health issues like Parkinson's disease and arthritis, with various systems and technologies developed for this purpose. Wearable sensors, including Inertial Measurement Units (IMUs) and pressure-sensing insoles, provide data on movements and foot pressure distribution, aiding in assessing gait changes.[6, 7] Motion capture systems, like optical motion capture using cameras, offer detailed movement recording for precise gait analysis in research settings.[8, 9] Advances in computer vision and AI bring machine learning and deep learning models that process gait data to recognize patterns associated with these health conditions, analyzing features like step length and cadence.[10, 11] Clinical tools such as the Unified Parkinson's Disease Rating Scale (UPDRS) assess symptoms, including gait abnormalities, in Parkinson's disease. Similarly, clinical tests for arthritis focus on gait abnormalities and joint movements.[10, 11] Mobile applications use smartphone sensors for gait analysis, offering remote monitoring and feedback based on detected irregularities.[12] Ongoing research initiatives employ specialized systems for gait analysis, contributing to more accurate early detection methods for Parkinson's disease and arthritis. These efforts collectively enhance diagnosis and management strategies, aiding both clinical assessments and research studies.

Gait analysis research has made significant progress using technologies ranging from wearable sensors to advanced artificial intelligence algorithms. Despite these advances, research gaps remain, particularly in the integration of many different methods for comprehensive gait assessment, the development of standardized protocols for data collection and analysis across platforms, and the validation of new technologies in diverse patient populations. Addressing these gaps will not only improve current diagnostic and monitoring methods, but also pave the way for more personalized and effective interventions for people with Parkinson's disease and arthritis. In addition, future research should focus on longitudinal studies to understand the progression of gait disorders over time and their relationship to disease severity and functional decline. Ultimately, addressing these gaps will lead to more robust and more readily available tools for early detection, accurate diagnosis, and targeted management of gait disorders, improving patient outcomes and quality of life.

Chapter 3

Hardware and Software Requirements

3.1 Hardware Requirements

1. Data Processing Units:

   -Intel Core processors such as i3, i5, or i7 series.

   - Minimum of 100GB on the hard disk for storage

   - 8GB RAM or higher in terms of memory

2. Motion Capture Hardware Units:

   High-quality cameras or motion sensors for capturing gait data. Systems like Kinect, OptiTrack, or specialized cameras designed for motion capture may be used.

3. Wearable Sensors:

   Inertial Measurement Units (IMUs) or accelerometers attached to specific body parts (e.g., legs) for measuring movements and accelerations.

4. Pressure-Sensing Insoles:

   Insoles with pressure sensors for measuring foot pressure distribution during walking.

5. Computer System:

   A powerful computer or server capable of handling large datasets and running complex algorithms for data processing and analysis.

These specifications ensure a decent computing capability for various tasks related to data processing, analysis, and software execution.

3.2 Software Requirements

- Motion Capture Software:

  Software for capturing and processing motion data from cameras or sensors, such as OptiTrack Motive or OpenPose.

- Data Processing Tools:

  MATLAB, Python (with libraries like NumPy, SciPy), or R for preprocessing, cleaning, and transforming raw gait data into usable formats.

- Machine Learning or Statistical Software:

  Tools like TensorFlow, PyTorch, scikit-learn, or MATLAB's Machine Learning Toolbox for building and training classification models to identify gait patterns associated with Parkinson's disease or arthritis.

- Statistical Analysis Tools:

  Software for statistical analysis to derive insights from the collected data, such as Jupyter Notebooks.

- Visualization Tools:

  Tools like Matplotlib, Seaborn (Python), or MATLAB for visualizing gait patterns, classification results, and statistical findings

Chapter 4

System Architecture

4.1 System Overview

The architecture depicts a pipeline for automatically extracting movement features from videos, focusing on gait and rhythm, to potentially identify early signs of Arthritis or Parkinson's disease. The journey begins with feeding a video file into the system. Then, the system meticulously analyzes the video to uncover features about movement. It detects specific body motions, patterns, and subtle changes in posture over time. These detected features are then sorted into two categories: gait, the way we walk and move, and rhythm, the flow and timing of our movements.

Next comes the identification of relevant features from the movements that tell us about health. A sophisticated classifier, examines the features, comparing them to established norms and patterns associated with Arthritis and Parkinson's disease. It might set thresholds for specific movement characteristics or employ powerful machine learning algorithms to decipher complex patterns.

Based on the classifier's verdict, the system outputs a diagnosis, as a nuanced probability score. This score reflects the system's confidence level in its assessment of Arthritis or Parkinson's likelihood.

It leverages its insights to offer suggestions or advice for the next step. This could be a gentle nudge towards consulting a doctor for further evaluation or providing helpful tips for managing the conditions. While it holds immense promise for early detection, it's crucial to view its pronouncements with a healthy dose of skepticism. These predictions, should never replace the wisdom and expertise of qualified medical professionals.

4.2 Architectural Design

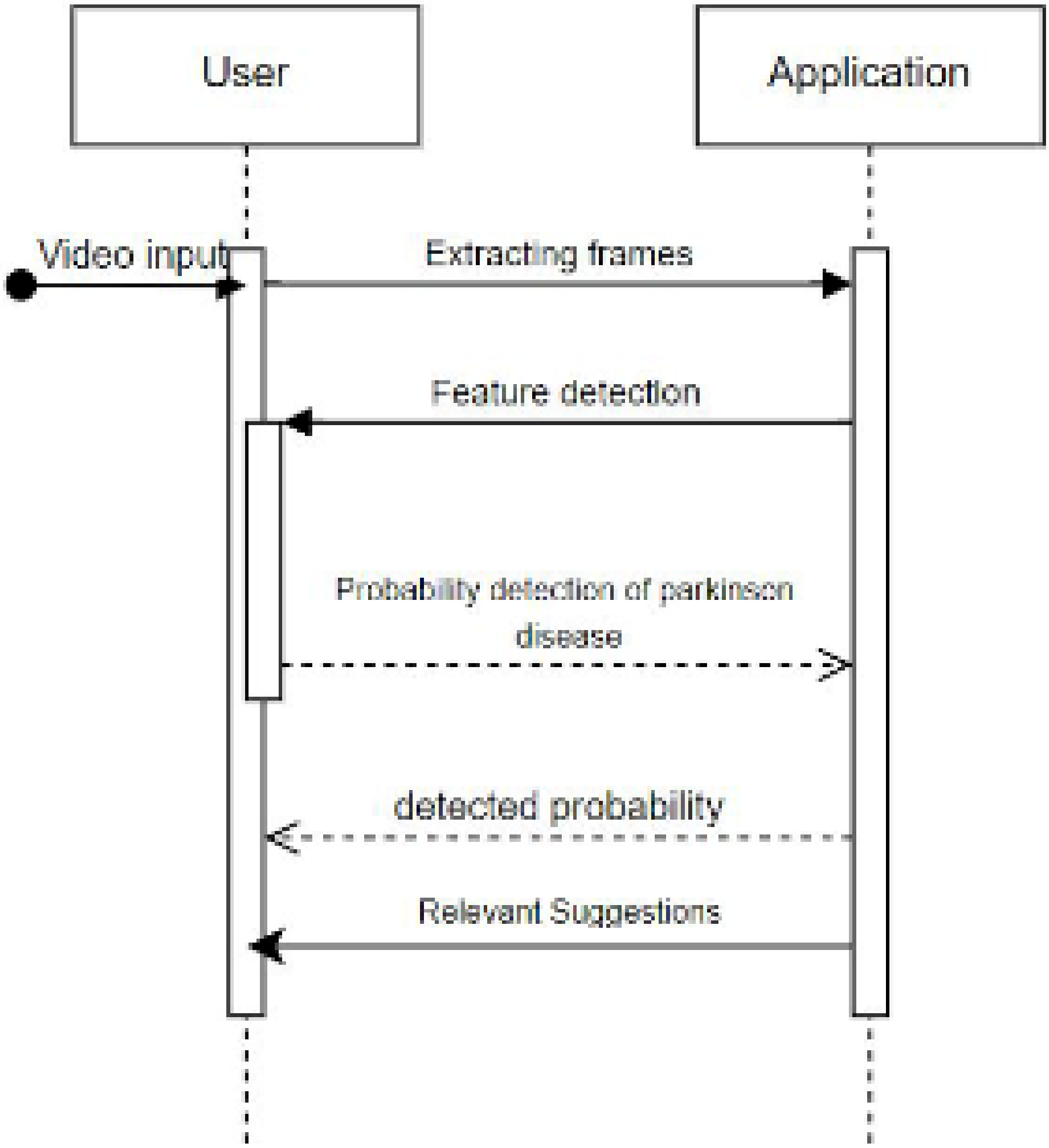


Figure 4.1: Sequence Diagram

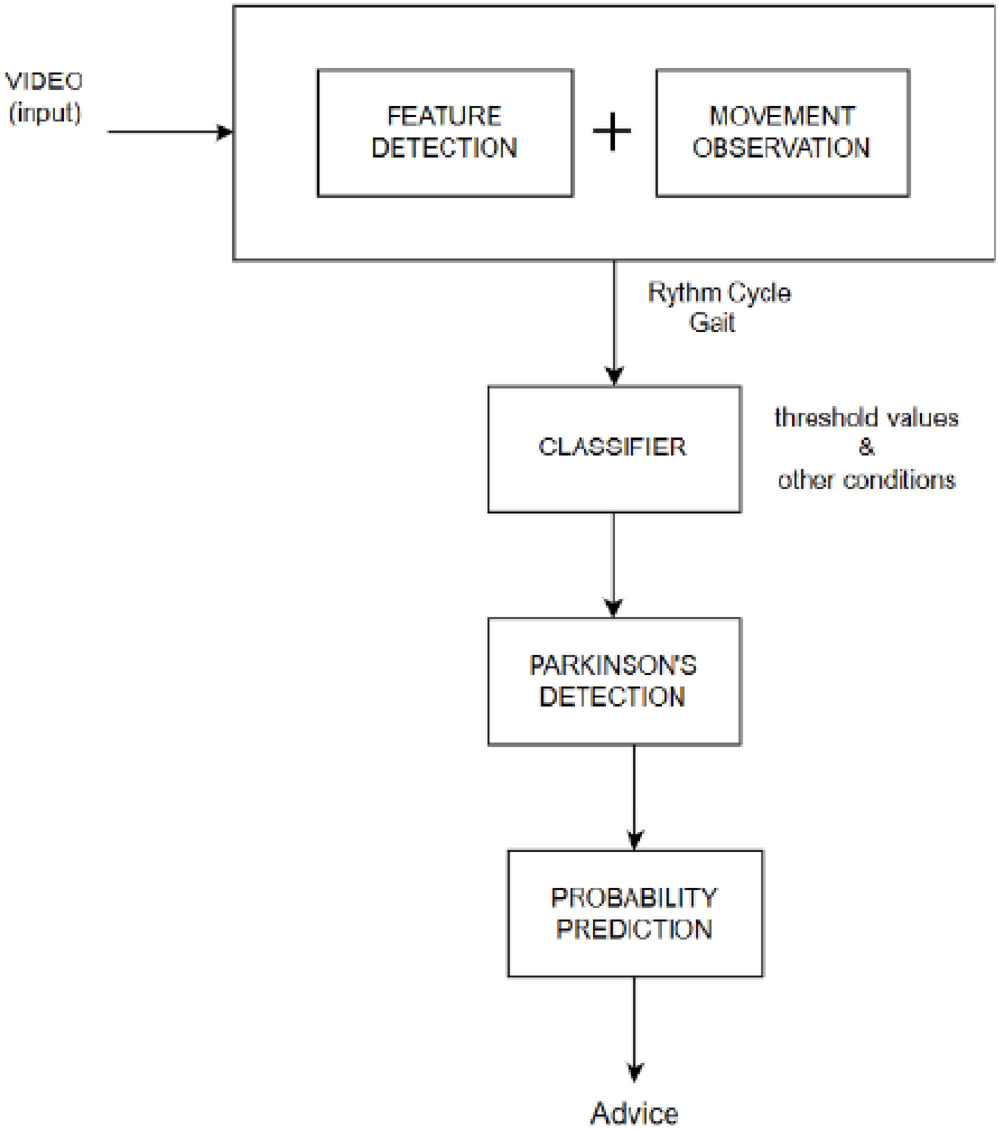


Figure 4.2: Architecture Diagram

4.3 Module Division

Module 1 - Preprocessing: This initial module focuses on data preprocessing tasks. It encompasses activities such as data collection, cleaning, and formatting to prepare the gait-related data for analysis. Preprocessing techniques like noise reduction, normalization, and feature extraction might be employed in this stage to ensure the data is ready for further analysis.

Module 2 - Classification: The second module is dedicated to classification methodologies. It involves the application of machine learning or statistical techniques to classify and categorize gait patterns. Various algorithms and models are likely explored and evaluated to distinguish different gait characteristics or conditions.

Module 3 - Parkinson's Disease Probability Prediction and Advice: This module concentrates on predicting the probability of Parkinson's disease through gait analysis. It extends beyond prediction to offer advice or guidance based on the analysis results. Recommendations or insights related to Parkinson's disease management or further medical evaluations might be included.

These modules collectively constitute a comprehensive approach to gait analysis, covering preprocessing, classification, and the prediction of specific health conditions. They aim to derive actionable insights and guidance from gait-related data to assist in identifying potential health issues and offering informed recommendations for further medical consideration or intervention.

Each module plays a crucial role in the analysis pipeline, contributing to a thorough understanding of gait patterns and their implications for health conditions like arthritis and Parkinson's disease.

4.4 Module Division

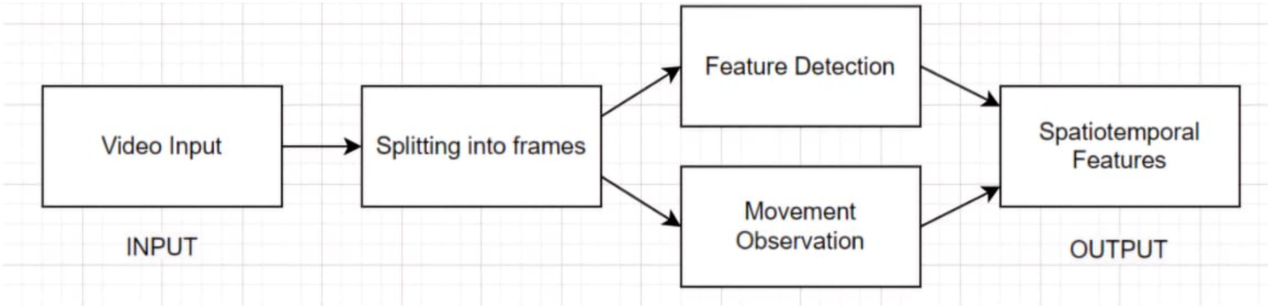


Figure 4.3: Module 1

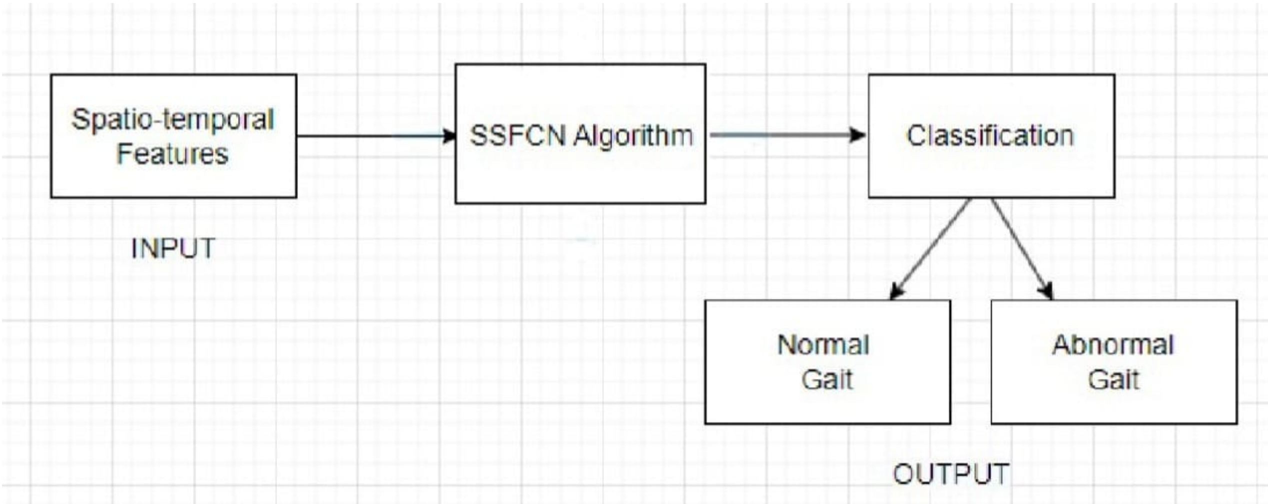


Figure 4.4: Module 2

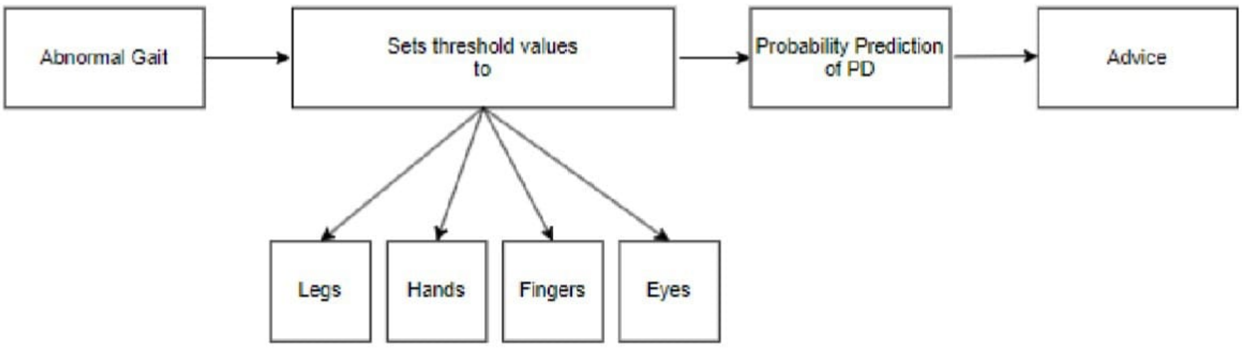


Figure 4.5: Module 3

4.5 Work Schedule - Gantt Chart

	6/11/2023	6/12/2023	6/1/2024	6/2/2024	6/3/2024	6/4/2024
Task 1	Splitting video into frames					
Task 2		Feature detection and movement observation				
Task 3			Classification			
Task 4				PD probability prediction		
Task 5					Arthritis probability prediction	
Task 6						Relevant Suggestions

Figure 4.6: Gantt Chart

Chapter 5

Results and Discussions

Introducing an innovative system aimed at enhancing health monitoring and safety through sophisticated gait analysis methods. By utilizing skeleton and silhouette techniques, this approach transforms the way we identify possible health concerns and safeguard individuals' well-being. From accurate gait identification to instant health evaluations, every aspect contributes significantly to promoting proactive health management and establishing safer surroundings for everyone.

5.1 Overview

Gait analysis in Parkinson's disease (PD) represents a specialty that aims to understand the variable sea changes caused by this neurodegenerative disorder. Parkinson's disease mainly affects the central nervous system, especially the motor system, which causes various movement disorders. Gait disturbances are the most common and impactful symptoms of people with Parkinson's disease, significantly affecting their mobility and quality of life. Gait analysis for Parkinson's disease involves a multifaceted approach that includes clinical assessment, objective measurements, characterization of specific gait abnormalities, therapeutic interventions, and longitudinal monitoring of disease progression and response to therapy. The process usually begins with a thorough clinical evaluation by a health professional, suppliers specialists who specialize in movement disorders, such as neurologists or physiotherapists. This evaluation includes a detailed medical history, including the onset and progression of symptoms, and a thorough assessment of the patient's current symptoms and functional limitations. Observational gait analysis during various activities such as walking, turning, and movement initiation provides valuable information about the nature and severity of gait disturbance in Parkinson's disease. Objective measurements play a key role in gait analysis in Parkinson's disease, allowing clinicians to accurately determine and characterize certain gait parameters. Instrumented gait analysis systems, such as wearable sensors or motion capture systems, are used to collect quantitative data on parameters such as stride length, stride time, gait speed, stride length, cadence, and variation in gait parameters. These objective measurements provide valuable information about the nature and severity of gait disturbances, including shortened stride length, increased gait variability, altered gait rhythm, stooped posture, and decreased arm swing. Assessment of freezing episodes using gait analysis techniques allows physicians to quantify the frequency, duration, and triggers of freezing episodes, facilitating the development of targeted interventions to alleviate this debilitating symptom. Treatment interventions are tailored to the normal gait associated with Parkinson's disease, specific gait characteristics detected by gait analysis. Physical therapy programs may include a combination of gait training, balance exercises, signaling strategies, and multidisciplinary approaches such as auditory or visual cues to improve gait and reduce episodes of freezing. Additionally, assistive devices such as canes, walkers, or advanced mobility aids may be recommended based on individual walking patterns and functional limitations identified through gait analysis. Longitudinal monitoring of gait is required to assess disease progression and efficacy for treatment over time. Regular follow-up assessments using gait analysis techniques allow clinicians to monitor changes in gait parameters, assess response to therapeutic interventions and make informed changes in treatment strategies when necessary. By providing objective and quantitative information about the gait characteristics characteristic of Parkinson's disease, gait analysis facilitates individualized treatment planning and optimization of functional outcomes for people with this complex neurodegenerative disease.

5.2 Discussion

Gait analysis in Parkinson's disease (PD) represents a specialty that aims to understand the variable sea changes caused by this neurodegenerative disorder. Parkinson's disease mainly affects the central nervous system, especially the motor system, which causes various movement disorders. Gait disturbances are the most common and impactful symptoms of people with Parkinson's disease, significantly affecting their mobility and quality of life. Gait analysis for Parkinson's disease involves a multifaceted approach that includes clinical assessment, objective measurements, characterization of specific gait abnormalities, therapeutic interventions, and longitudinal monitoring of disease progression and response to therapy. The process usually begins with a thorough clinical evaluation by a health professional who specializes in movement disorders, such as neurologists or physiotherapists. This evaluation includes a detailed medical history, including the onset and progression of symptoms, and a thorough assessment of the patient's current symptoms and functional limitations. Observational gait analysis during various activities such as walking, turning, and movement initiation provides valuable information about the nature and severity of gait disturbance in Parkinson's disease. Objective measurements play a key role in gait analysis in Parkinson's disease, allowing clinicians to accurately determine and characterize certain gait parameters. Instrumented gait analysis systems, such as wearable sensors or motion capture systems, are used to collect quantitative data on parameters such as stride length, stride time, gait speed, stride length, cadence, and variation in gait parameters. These objective measurements provide valuable information about the nature and severity of gait disturbances, including shortened stride length, increased gait variability, altered gait rhythm, stooped posture, and decreased arm swing.One of the hallmarks of Parkinson's disease is freezing of gait (FOG), a sudden, transient inability to start or continue walking, often described as feeling stuck to the ground. Assessment of freezing episodes using gait analysis techniques allows physicians to quantify the frequency, duration, and triggers of freezing episodes, facilitating the development of targeted interventions to alleviate this debilitating symptom. Treatment interventions are tailored to the normal gait associated with Parkinson's disease i.e., specific gait characteristics are detected by gait analysis. Physical therapy programs may include a combination of gait training, balance exercises, signaling strategies, and multidisciplinary approaches such as auditory or visual cues to improve gait and reduce episodes of freezing. Additionally, assistive devices such as canes, walkers, or advanced mobility aids may be recommended based on individual walking patterns and functional limitations identified through gait analysis. Longitudinal monitoring of gait is required to assess disease progression and efficacy. treatment over time. Regular follow-up assessments using gait analysis techniques allow clinicians to monitor changes in gait parameters, assess response to therapeutic interventions, and make informed changes in treatment strategies when necessary. By providing objective and quantitative information about the gait characteristics characteristic of Parkinson's disease, gait analysis facilitates individualized treatment planning and optimization of functional outcomes for people with this neurodegenerative disease.

5.3 Testing

Figure 5.1: UI

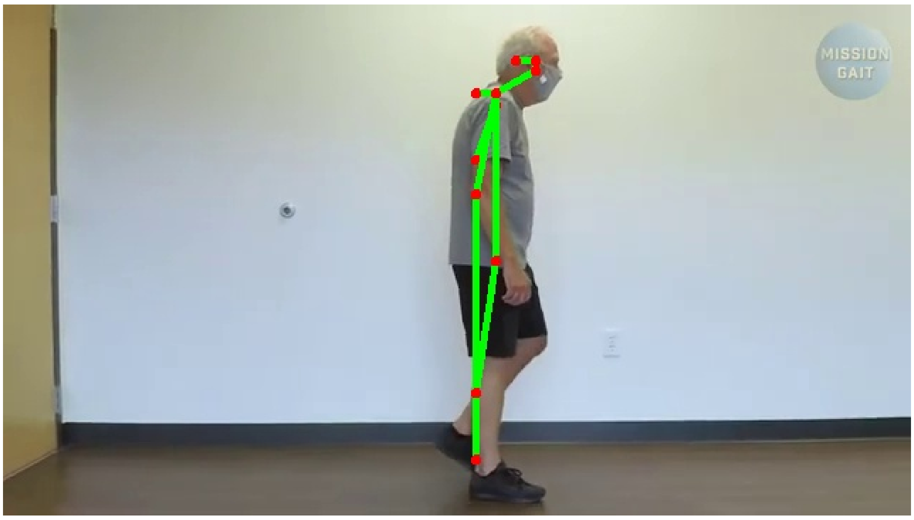


Figure 5.2: Pose Graph

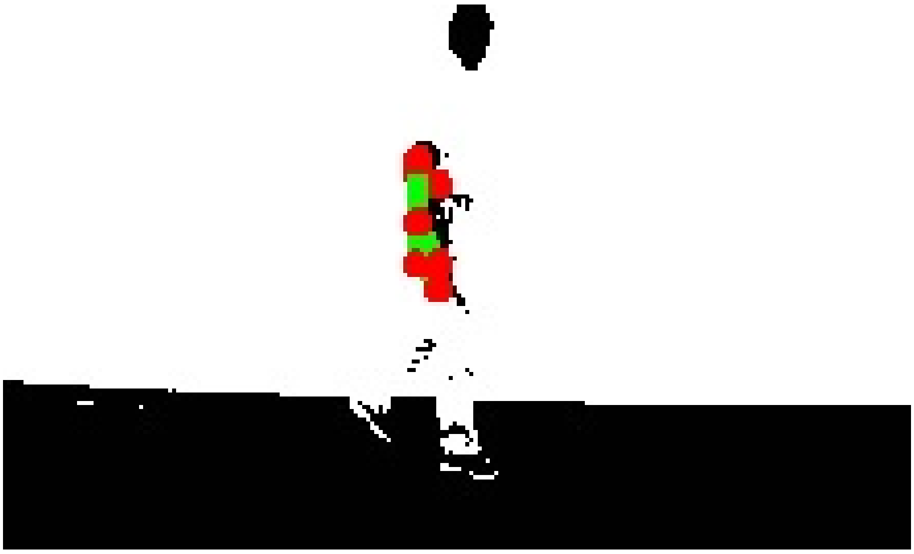
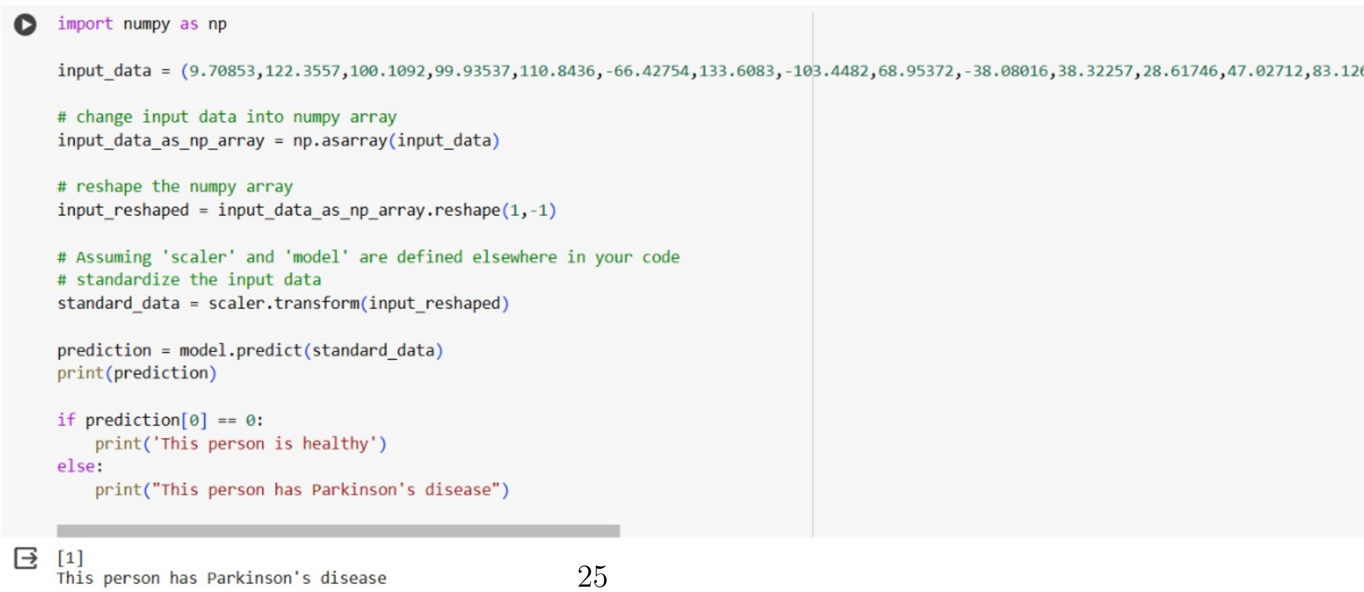


Figure 5.3: Skeleton-Silhouette

Figure 5.4: Silhouette



```
import numpy as np

input_data = (9.70853,122.3557,100.1092,99.93537,110.8436,-66.42754,133.6083,-103.4482,68.95372,-38.08016,38.32257,28.61746,47.02712,83.12

# change input data into numpy array
input_data_as_np_array = np.asarray(input_data)

# reshape the numpy array
input_reshaped = input_data_as_np_array.reshape(1,-1)

# Assuming 'scaler' and 'model' are defined elsewhere in your code
# standardize the input data
standard_data = scaler.transform(input_reshaped)

prediction = model.predict(standard_data)
print(prediction)

if prediction[0] == 0:
    print('This person is healthy')
else:
    print("This person has Parkinson's disease")
```

```
[1]
This person has Parkinson's disease
```


Figure 5.5: Prediction

5.4 Conclusion

In conclusion, the integration of clinical assessment, objective measurements and customized treatment Interventions marks a significant advancement in the management of Parkinson's disease. These elements collaborate effectively to enhance patient well-being and enhance their quality of life. Our evaluation has identified both successes and potential challenges. Moving forward, continuous research and innovation in this field are crucial to refining these approaches and ensuring their continued effectiveness in assisting individuals coping with Parkinson's disease.

Chapter 6

Conclusion

The web application for gait analysis is a groundbreaking advancement in healthcare technology, providing a non-invasive means to assess walking patterns and posture. Through the integration of computer vision, machine learning, and web development, the application identifies irregularities and predicts the likelihood of gait-related disorders, particularly focusing on conditions like Parkinson's Disease and arthritis. This innovative tool offers benefits such as early detection, remote assessment convenience, and personalized insights based on individual gait patterns. The inclusion of a user dashboard empowers individuals to actively manage their gait health, fostering a proactive approach to healthcare. However, challenges like data privacy, model interpretability, and clinical validation need addressing, presenting opportunities for refinement, expansion, and collaboration with healthcare professionals. Overcoming these challenges can revolutionize gait analysis, making the web application an indispensable tool in preventive healthcare and early disorder detection.

Looking ahead, the Gait Analysis web application holds potential for enhancements, including integration with wearable devices for real-time gait monitoring, expansion of disorder predictions, and collaboration with healthcare institutions for clinical adoption. Implementing user feedback mechanisms, enhancing security measures, ensuring global accessibility, and incorporating educational initiatives would further extend the application's impact in remote healthcare services. User profiles and partnerships with rehabilitation centers underscore the application's potential for comprehensive early detection, proactive gait health management, and personalized health insights.

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Appendix A: Final Presentation

Health Anomaly Detection using Human Gait Analysis

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Firoz Yoosef 6 (U2003080)
Hitha Mathew P 23 (U2003096)
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Rajagiri School of Engineering and Technology, Kakkanad
Department of CSE

May 3, 2024

Guided by: Dr.Tripti C

Contents

Problem Definition

To develop a method that effectively identify anomalies in human walking patterns that may indicate underlying health conditions.

Project Objective

To detect Parkinson's disease by analysing the motion of a human body through walking patterns.

Novelty of Idea and Scope of implementation

- Novelty of Idea
  - Using SSFCN (Skeleton-Silhouette Fusion Convolution Network Algorithm) to predict the probability of health anomaliesoki like Parkinson's Disease
- Scope of implementation
  - Early Detection of Health Problems
  - Tracking progress/ decline
  - Feedback and Recommendation

Literature Survey

- An automatic system for detecting gait-related health problems using Deep Neural Networks (DNNs). [1]
- Takes a video of patients as input, estimates their 3D body pose using a DNN-based method, and analyzes the resulting time series in a classifier to classify gait videos into different groups, including Healthy, Parkinson's disease, Post Stroke patient, and orthopedic problems. [1]
- Experimental results showed classification accuracies ranging from 56 percent to 96 percent for different groups, with the highest accuracy achieved for classifying healthy subjects. [1]

Literature Survey - II

- Video-based assessment of gait impairments in Parkinson's disease using a skeleton-silhouette fusion convolution network. Mask R-CNN and OpenPose used for extraction.
  - Overall classification accuracy is 71.25 percent with sensitivity of the model to screen patients with PD as 92.3 percent. [2]
- Algorithm for real-time gait phase detection on wearable devices, which combines a reduced support vector machine (RSVM) and a finite state machine (FSM).
  - It shows a promising real-time performance with an accuracy of 91.51 percent, a sensitivity of 91.70 percent and a specificity of 95.77 percent. [3]

Literature Survey - III

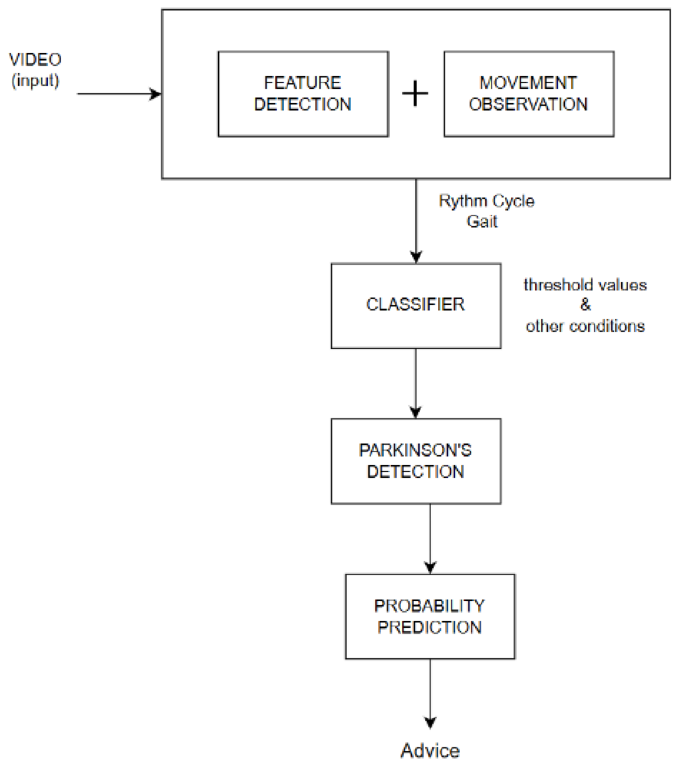
- CycleGait - A strong and robust skelton based gait recognition method which introduces gait periodicity priors into gait feature extraction.
  - Experiment results shows that CycleGait achieves the highest recognition accuracy with other algorithms.[4]
- Algorithm that combines components of ankle bio-mechanics and subject-specificity to classify human walking modes in real-time achieving an accuracy of 89.57 percent and 87.55 percent in left and right sensors, respectively.
  - It utilizes a single-DoF IMU axis and achieves high accuracy in classifying different walking modes, such as upstairs, downstairs, treadmill, overground, and stationary .[5]

Methodology

To analyze and quantify human gait patterns and build a web application to assess an individual's walking pattern and posture to identify irregularities or abnormalities that may be indicative of underlying health issues like Parkinson's Disease, Hemiplegia. The highlighted methods are:

1. Data Pre-processing
2. Classification
3. Parkinson's Disease Probability Prediction and Advice

Architecture Diagram



Results

- Preprocessing of video to obtain frames and extract gait features
- Classification of gait into normal and abnormal gait from silhouette features extracted
- Predicting probability of Parkinson's Disease using SSFCN algorithm and provide relevant suggestions

Task Distribution

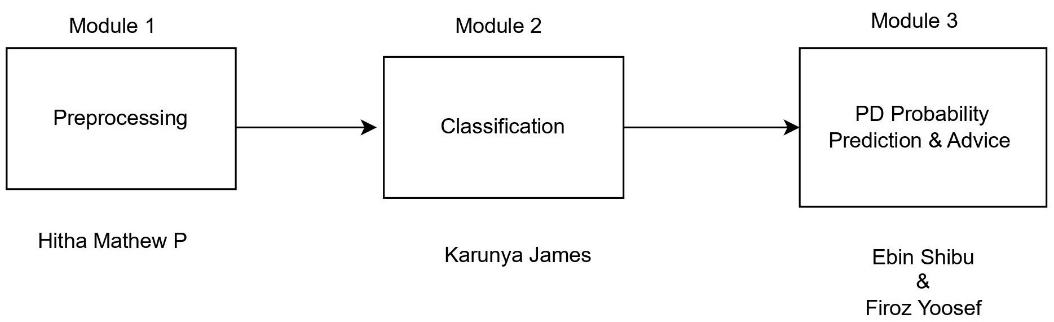
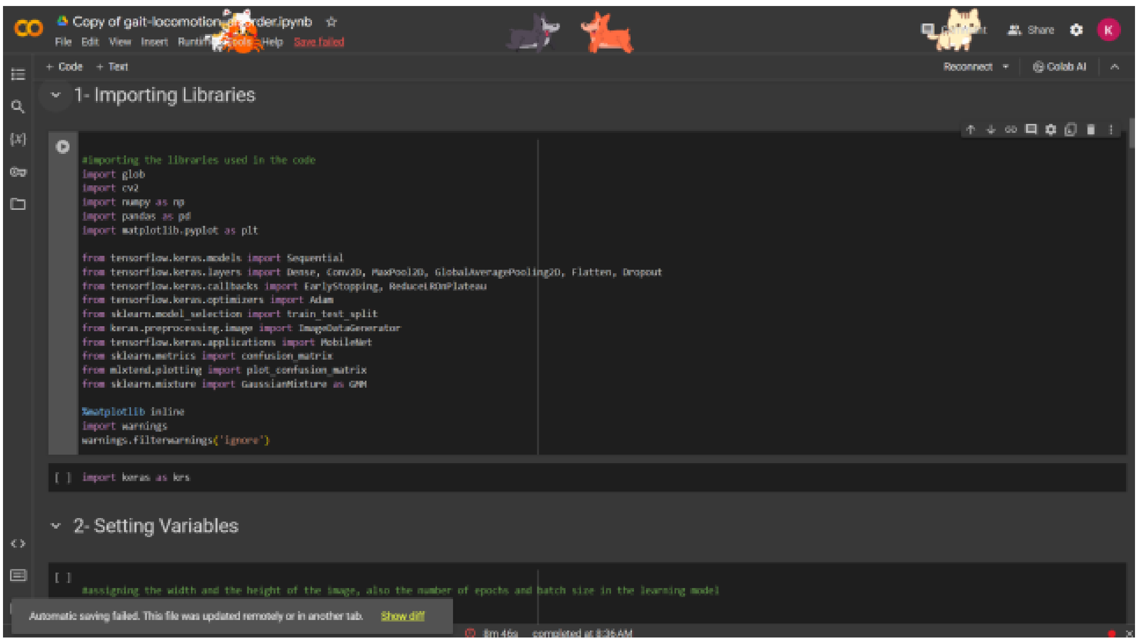


Figure: Work Breakdown and Responsibilities

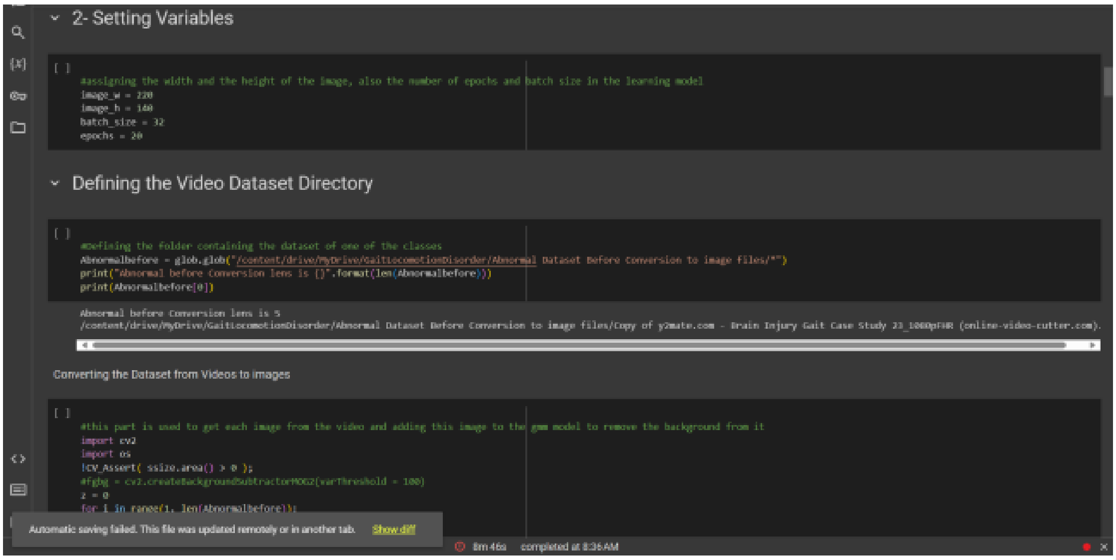
Task Distribution

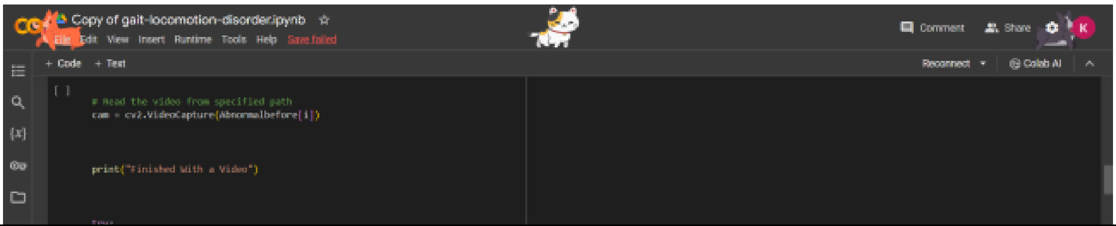
- Module 1 - Preprocessing: This encompasses activities such as data collection, cleaning, and formatting to prepare the gait-related data for analysis. Preprocessing techniques like noise reduction, normalization, and feature extraction might be employed in this stage to ensure the data is ready for further analysis.
- Module 2 - Classification: This involves the application of machine learning or statistical techniques to classify and categorize gait patterns. Various algorithms and models are likely explored and evaluated to distinguish different gait characteristics or conditions.
- Module 3 - Parkinson's Disease Probability Prediction and it concentrates on predicting the probability of PD through gait analysis. Recommendations or insights related to PD management or further medical evaluations might be included.

Screenshots



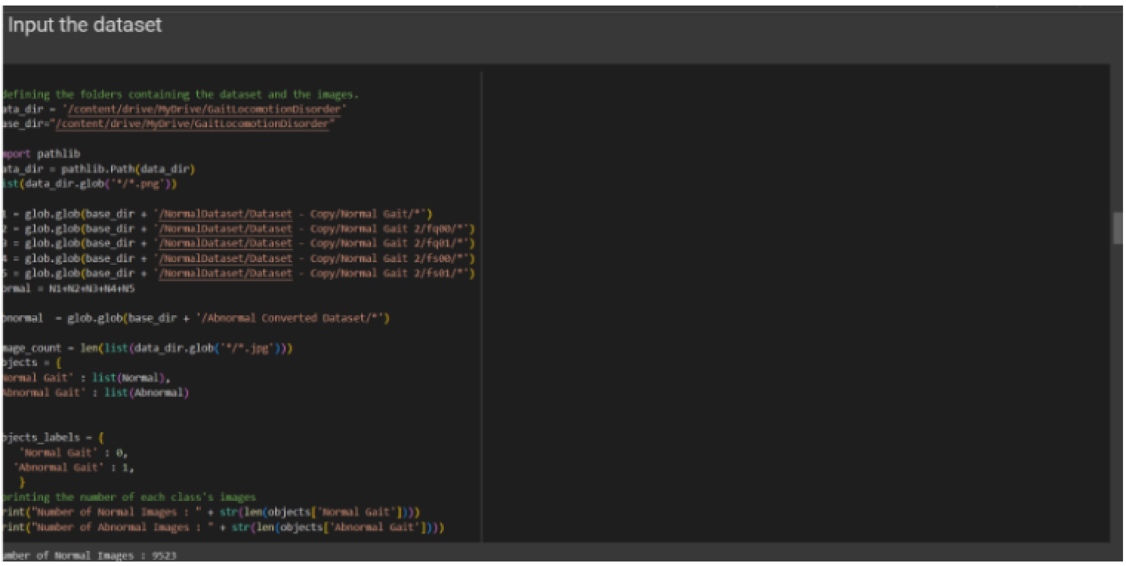
Screenshots



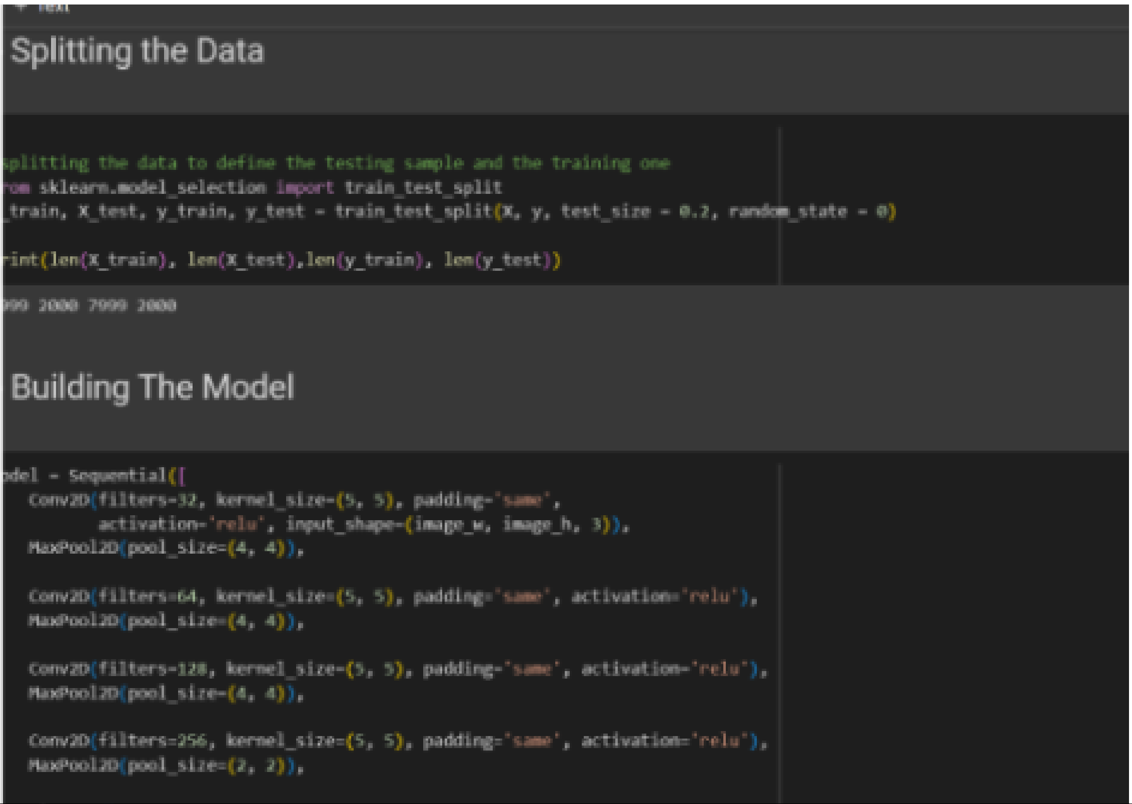


Health Anomaly Detection using Human Gait Analysis

Screenshots

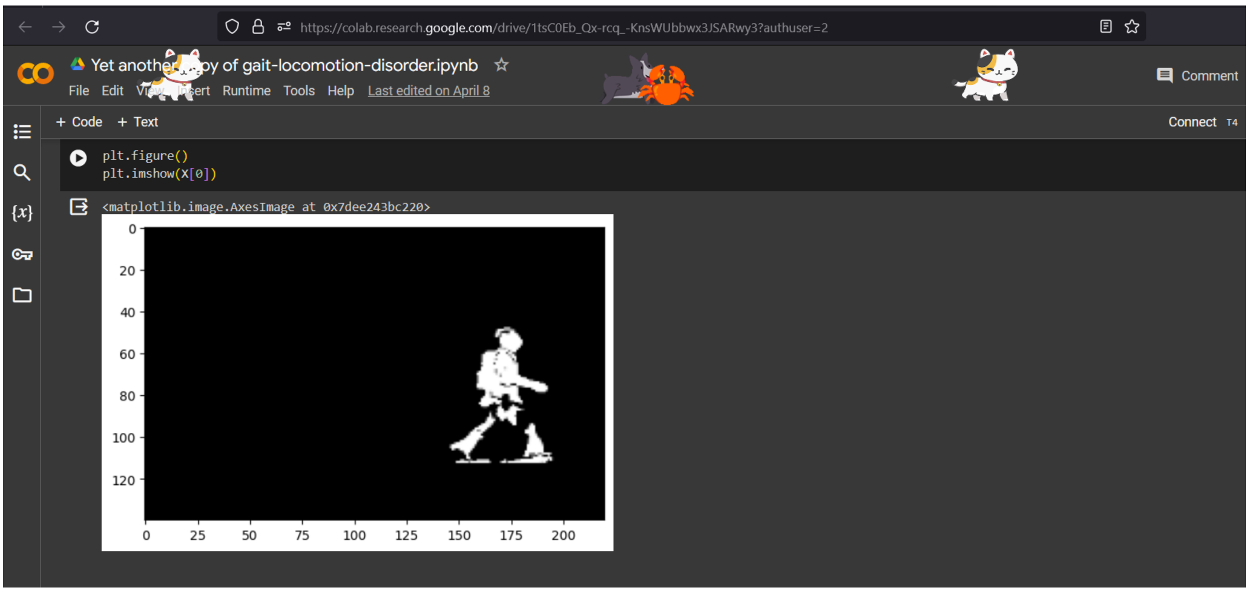


Screenshots

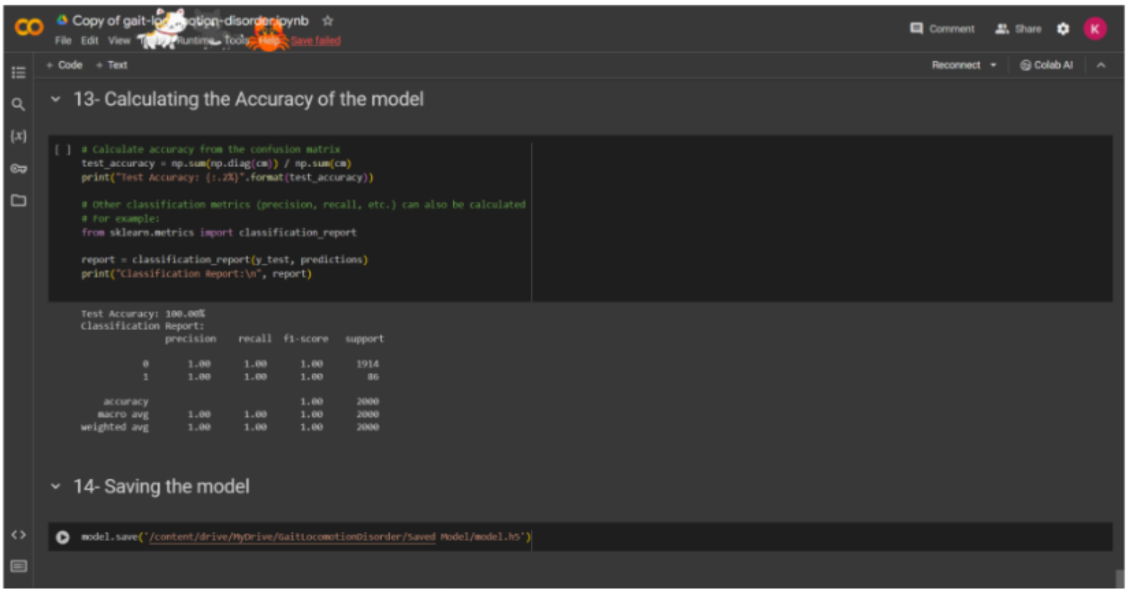


Health Anomaly Detection using Human Gait Analysis

Screenshots



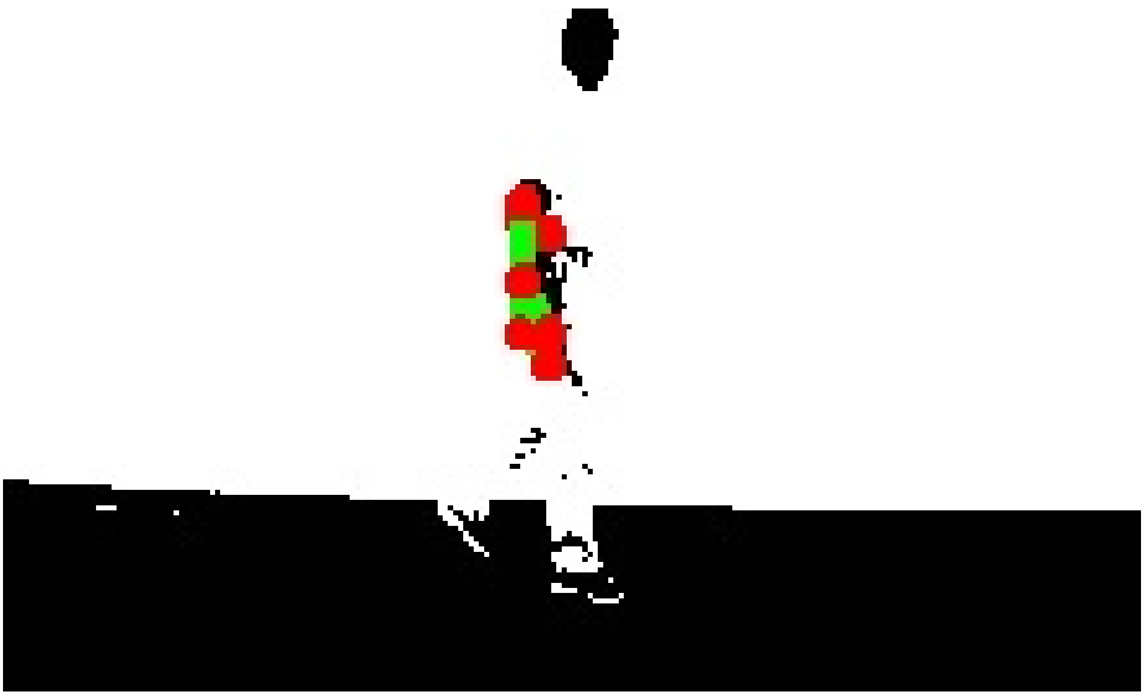
Screenshots



Screenshots

Screenshots

Screenshots



Screenshots

```
[ ] # split into training and test data
    X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size=0.3

[ ] print(X.shape, X_train.shape, X_test.shape)

    (278, 58) (194, 58) (84, 58)

[ ] scaler = StandardScaler()

    scaler.fit(X_train)
    print(scaler.get_params())

    {'copy': True, 'with_mean': True, 'with_std': True}
```


Health Anomaly Detection using Human Gait Analysis

Screenshots

```
import numpy as np

input_data = (100.1092,99.93537,110.8436,19.70853,122.3557,-66.42754,133.6083,-103.4482,68.95372,-38.08016,

# change input data into numpy array
input_data_as_np_array = np.asarray(input_data)

# reshape the numpy array
input_reshaped = input_data_as_np_array.reshape(1,-1)

# Assuming 'scaler' and 'model' are defined elsewhere in your code
# standardize the input data
standard_data = scaler.transform(input_reshaped)

prediction = model.predict(standard_data)
print(prediction)

if prediction[0] == 0:
    print('This person is healthy')
else:
    print("This person has Parkinson's disease")

[0]
This person is healthy
```

Screenshots

```
import numpy as np

input_data = (9.70853,122.3557,100.1092,99.93537,110.8436,-66.42754,133.6083,-103.4482,68.95372,-38.08016,3

# change input data into numpy array
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print(prediction)

if prediction[0] == 0:
    print('This person is healthy')
else:
    print("This person has Parkinson's disease")
```

```
[1]
This person has Parkinson's disease
```


Conclusion

- Gait analysis represents a powerful and multifaceted tool with significant implications for healthcare, rehabilitation, sports, and research.
- Through the systematic evaluation of human walking patterns, it offers valuable insights into the detection, diagnosis, and management of various health problems, including musculoskeletal, neurological, and biomechanical conditions.

Future Scope

- Classification of pathological gaits that can be attributed to neurological conditions: hemiplegic, spastic diplegic, neuropathic, myopathic, Parkinsonian, choreiform, ataxic (cerebellar) and sensory.
- Web application can be used for real-time patient data.

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- 3. J. Wu et al., "Real-Time Gait Phase Detection on Wearable Devices for Real-World Free-Living Gait," in IEEE Journal of Biomedical and Health Informatics, vol. 27, no. 3, pp. 1295-1306, March 2023, doi: 10.1109/JBHI.2022.3228329.

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Status of Paper Publication

The paper is based on our research on Health Anomaly Detection using Human Gait Analysis.The study demonstrates the feasibility and effectiveness of using machine learning-based gait analysis for health anomaly detection. By analyzing subtle variations in gait patterns, our approach offers a promising avenue for early diagnosis and intervention in a variety of health conditions.
The paper has been communicated with our guide.

Appendix B: Vision, Mission, Programme Outcomes and Course Outcomes

Vision, Mission, Programme Outcomes and Course Outcomes

Institute Vision

To evolve into a premier technological institution, moulding eminent professionals with creative minds, innovative ideas and sound practical skill, and to shape a future where technology works for the enrichment of mankind.

Institute Mission

To impart state-of-the-art knowledge to individuals in various technological disciplines and to inculcate in them a high degree of social consciousness and human values, thereby enabling them to face the challenges of life with courage and conviction.

Department Vision

To become a centre of excellence in Computer Science and Engineering, moulding professionals catering to the research and professional needs of national and international organizations.

Department Mission

To inspire and nurture students, with up-to-date knowledge in Computer Science and Engineering, ethics, team spirit, leadership abilities, innovation and creativity to come out with solutions meeting societal needs.

Programme Outcomes (PO)

1. Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. Conduct investigations of complex problems: Use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. Modern Tool Usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. Individual and Team work: Function effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings.

10. Communication: Communicate effectively with the engineering community and with society at large. Be able to comprehend and write effective reports documentation. Make effective presentations, and give and receive clear instructions.

11. Project management and finance: Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team. Manage projects in multidisciplinary environments.

12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

Programme Specific Outcomes (PSO)

A graduate of the Computer Science and Engineering Program will demonstrate:

PSO1: Computer Science Specific Skills

The ability to identify, analyze and design solutions for complex engineering problems in multidisciplinary areas by understanding the core principles and concepts of computer science and thereby engage in national grand challenges.

PSO2: Programming and Software Development Skills
The ability to acquire programming efficiency by designing algorithms and applying standard practices in software project development to deliver quality software products meeting the demands of the industry.

PSO3: Professional Skills
The ability to apply the fundamentals of computer science in competitive research and to develop innovative products to meet the societal needs thereby evolving as an eminent researcher and entrepreneur.

Course Outcomes (CO)

Course Outcome 1: Model and solve real world problems by applying knowledge across domains (Cognitive knowledge level: Apply).

Course Outcome 2: Develop products, processes or technologies for sustainable and socially relevant applications (Cognitive knowledge level: Apply).

Course Outcome 3: Function effectively as an individual and as a leader in diverse teams and to comprehend and execute designated tasks (Cognitive knowledge level:Apply).

Course Outcome 4: Plan and execute tasks utilizing available resources within timelines, following ethical and professional norms (Cognitive knowledge level: Apply).

Course Outcome 5: Identify technology/research gaps and propose innovative/creative solutions (Cognitive knowledge level: Analyze).

Course Outcome 6: Organize and communicate technical and scientific findings effectively in written and oral forms (Cognitive knowledge level: Apply).

Appendix C: CO-PO-PSO Mapping

CO-PO AND CO-PSO MAPPING

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO1 1	PO1 2	PSO1	PSO2	PSO3
CO 1	2	2	2	1	2	2	2	1	1	1	1	2	3		
CO 2	2	2	2		1	3	3	1	1		1	1		2	
CO 3									3	2	2	1			3
CO 4					2			3	2	2	3	2			3
CO 5	2	3	3	1	2							1	3		
CO 6					2			2	2	3	1	1			3

3/2/1: high/medium/low

JUSTIFICATIONS FOR CO-PO MAPPING & CO-PSO MAPPING

MAPPING	LOW/MEDIUM/HIGH	JUSTIFICATION
100003/ CS722U.1-PO1	M	Knowledge in the area of technology for project development using various tools results in better modeling.
100003/ CS722U.1-PO2	M	Knowledge acquired in the selected area of project development can be used to identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions.
100003/ CS722U.1-PO3	M	Can use the acquired knowledge in designing solutions to complex problems.
100003/ CS722U.1-PO4	M	Can use the acquired knowledge in designing solutions to complex problems.
100003/ CS722U.1-PO5	H	Students are able to interpret, improve and redefine technical aspects for design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
100003/ CS722U.1-PO6	M	Students are able to interpret, improve and redefine technical aspects by applying contextual knowledge to assess societal, health and consequential responsibilities relevant to professional engineering practices.
100003/ CS722U.1-PO7	M	Project development based on societal and environmental context solution identification is the need for sustainable development.

100003/ CS722U.1-PO8	L	Project development should be based on professional ethics and responsibilities.
100003/ CS722U.1-PO9	L	Project development using a systematic approach based on well defined principles will result in teamwork.
100003/ CS722U.1-PO10	M	Project brings technological changes in society.
100003/ CS722U.1-PO11	H	Acquiring knowledge for project development gathers skills in design, analysis, development and implementation of algorithms.
100003/ CS722U.1-PO12	H	Knowledge for project development contributes engineering skills in computing & information gatherings.
100003/ CS722U.2-PO1	H	Knowledge acquired for project development will also include systematic planning, developing, testing and implementation in computer science solutions in various domains.
100003/ CS722U.2-PO2	H	Project design and development using a systematic approach brings knowledge in mathematics and engineering fundamentals.
100003/ CS722U.2-PO3	H	Identifying, formulating and analyzing the project results in a systematic approach.
100003/ CS722U.2-PO5	H	Systematic approach is the tip for solving complex problems in various domains.
100003/ CS722U.2-PO6	H	Systematic approach in the technical and design aspects provide valid conclusions.
100003/ CS722U.2-PO7	H	Systematic approach in the technical and design aspects demonstrate the knowledge of sustainable development.
100003/ CS722U.2-PO8	M	Identification and justification of technical aspects of project development demonstrates the need for sustainable development.

100003/ CS722U.2-PO9	H	Apply professional ethics and responsibilities in engineering practice of development.
100003/ CS722U.2-PO11	H	Systematic approach also includes effective reporting and documentation which gives clear instructions.
100003/ CS722U.2-PO12	M	Project development using a systematic approach based on well defined principles will result in better teamwork.
100003/ CS722U.3-PO9	H	Project development as a team brings the ability to engage in independent and lifelong learning.
100003/ CS722U.3-PO10	H	Identification, formulation and justification in technical aspects will be based on acquiring skills in design and development of algorithms.
100003/ CS722U.3-PO11	H	Identification, formulation and justification in technical aspects provides the betterment of life in various domains.
100003/ CS722U.3-PO12	H	Students are able to interpret, improve and redefine technical aspects with mathematics, science and engineering fundamentals for the solutions of complex problems.
100003/ CS722U.4-PO5	H	Students are able to interpret, improve and redefine technical aspects with identification formulation and analysis of complex problems.
100003/ CS722U.4-PO8	H	Students are able to interpret, improve and redefine technical aspects to meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
100003/ CS722U.4-PO9	H	Students are able to interpret, improve and redefine technical aspects for design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
100003/ CS722U.4-PO10	H	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools for better products.

100003/ CS722U.4-PO11	M	Students are able to interpret, improve and redefine technical aspects by applying contextual knowledge to assess societal, health and consequential responsibilities relevant to professional engineering practices.
100003/ CS722U.4-PO12	H	Students are able to interpret, improve and redefine technical aspects for demonstrating the knowledge of, and need for sustainable development.
100003/ CS722U.5-PO1	H	Students are able to interpret, improve and redefine technical aspects, apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
100003/ CS722U.5-PO2	M	Students are able to interpret, improve and redefine technical aspects, communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
100003/ CS722U.5-PO3	H	Students are able to interpret, improve and redefine technical aspects to demonstrate knowledge and understanding of the engineering and management principle in multidisciplinary environments.
100003/ CS722U.5-PO4	H	Students are able to interpret, improve and redefine technical aspects, recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.
100003/ CS722U.5-PO5	M	Students are able to interpret, improve and redefine technical aspects in acquiring skills to design, analyze and develop algorithms and implement those using high-level programming languages.
100003/ CS722U.5-PO12	M	Students are able to interpret, improve and redefine technical aspects and contribute their engineering skills in computing and information engineering domains like network design and administration, database design and knowledge engineering.
100003/ CS722U.6-PO5	M	Students are able to interpret, improve and redefine technical aspects and develop strong skills in systematic planning, developing, testing, implementing and providing IT solutions for different domains which helps in the betterment of life.
100003/ CS722U.6-PO8	H	Students will be able to associate with a team as an effective team player for the development of technical projects by applying the knowledge of

		mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
100003/ CS722U.6-PO9	H	Students will be able to associate with a team as an effective team player to Identify, formulate, review research literature, and analyze complex engineering problems
100003/ CS722U.6-PO10	M	Students will be able to associate with a team as an effective team player for designing solutions to complex engineering problems and design system components.
100003/ CS722U.6-PO11	M	Students will be able to associate with a team as an effective team player, use research-based knowledge and research methods including design of experiments, analysis and interpretation of data.
100003/ CS722U.6-PO12	H	Students will be able to associate with a team as an effective team player, applying ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
100003/ CS722U.1-PSO1	H	Students are able to develop Computer Science Specific Skills by modeling and solving problems.
100003/ CS722U.2-PSO2	M	Developing products, processes or technologies for sustainable and socially relevant applications can promote Programming and Software Development Skills.
100003/ CS722U.3-PSO3	H	Working in a team can result in the effective development of Professional Skills.
100003/ CS722U.4-PSO3	H	Planning and scheduling can result in the effective development of Professional Skills.
100003/ CS722U.5-PSO1	H	Students are able to develop Computer Science Specific Skills by creating innovative solutions to problems.
100003/ CS722U.6-PSO3	H	Organizing and communicating technical and scientific findings can help in the effective development of Professional Skills.