Credit Task 4.2: Outcomes – Propose a conceptual solution.

I. Identifying Challenges

Challenge 1. Lack of Coverage, Accuracy, and Privacy Issues with Traditional Camera-Based Gait Detection

Context and Background

While widely used, traditional camera-based gait detection systems present challenges related to coverage, accuracy, and privacy. These systems often capture the entire image of an individual, raising concerns about privacy infringement.

Rationale for Proposed Solution

Unlike traditional cameras, 3D LIDAR sensors focus on capturing spatial information rather than detailed visual images, mitigating privacy concerns. The technology allows for precise gait analysis, even in challenging environmental conditions, and offers comprehensive coverage by capturing multidimensional data.

Challenge 2. Integration Issue of machine learning within different aspects of Gait Analysis

Context and Background

The fragmented integration of these algorithms across different aspects, such as Gait Analysis, Anomaly Detection, Health Assessment, and User Feedback, hampers the realization of the full potential of machine learning in gait analysis. This fragmented approach limits the synergy and holistic understanding of gait patterns.

Rationale for Proposed Solution

The proposed solution involves systematic optimization of machine learning algorithms, customizing them for Gait Analysis, Anomaly Detection, Health Assessment, and User Feedback. This approach maximizes their efficiency within the realm of gait analysis, and through experimentation with multiple algorithms, it seeks to offer a more holistic comprehension of gait-related data, fostering real-time adaptability and an overall improvement in the gait analysis system.

Challenge 3: Operationalizing Correlations from Gait Pattern Analysis to Clinical Disorders

Context and Background

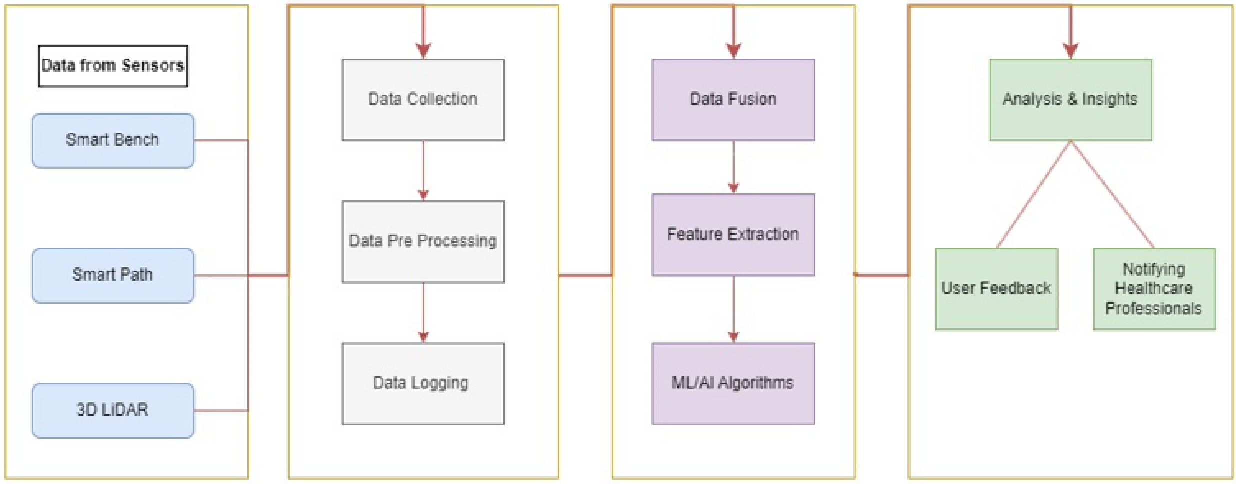
While gait pattern analysis holds promise for early clinical disorder detection, the challenge lies in operationalizing the observed correlations. The context involves translating research insights into actionable applications for healthcare providers and clinicians. Bridging the gap between theoretical correlations and practical implementation is essential to enhance patient care and outcomes.

Rationale for Proposed Solution

The proposed solution is designed to transition from theoretical insights to practical applications in the realm of gait pattern analysis and clinical disorders. By establishing standardized protocols, encouraging collaboration across disciplines, and fostering continuous education, the solution aims to seamlessly integrate correlations into clinical workflows. This approach ensures healthcare practitioners can use gait pattern analysis effectively for diagnosis, treatment planning, and patient monitoring, with a focus on real-time feedback.

II. Proposed Conceptual Solution

A. System Architecture



The Proposed Smart Gait Monitoring System employs a comprehensive architecture and methodology for acquiring, processing, and analyzing gait-related data. The system comprises Smart Bench and Smart Path components, each equipped with diverse sensors for collecting user interaction data.

I. Data from Sensors

A. SMART BENCH

The Smart Bench utilizes NFC technology for user identification, capturing numeric data on sit-to-stand exercises, landing coordinates, forces during landing, and foot pressure. Capacitive touch sensors on handles gauge user support during transitions, providing numeric data on touch duration, pressure exerted, and categorical labels for varying support levels.

B. SMART PATH

Sensor tiles on the Smart Path measure gait dynamics, including speed, step length, stride length, and foot pressures. The surface sensor assesses handrail reliance, recording numeric data on activation duration and categorical data indicating frequently used sides. The implementation of 3D LIDAR enhances gait monitoring by capturing high-resolution point cloud data, offering insights into joint movement, gait dynamics, posture, and balance.

II. Data Collection, Pre-Processing & Logging

Post-acquisition, the system undergoes real-time data collection, followed by pre-processing steps like noise reduction and calibration. Processed data is logged using a microcontroller or computer, adopting tabular or JSON/XML formats. For LiDAR data, a robust computing system processes and logs the 3D point cloud data.

III. Data Fusion

Data fusion techniques integrate various sensor data into a unified stream, enhancing overall data quality and providing a holistic view of user mobility patterns. Real-time communication between components is facilitated through defined communication protocols.

IV. Feature Extraction

Different feature extraction methods are applied for pressure sensor data, Smart Path sensor tiles, capacitive touch sensors, and 3D LIDAR data. Extracted features include COP, gait speed, step length, foot pressures, touch duration, joint angles, posture metrics, and spatial coordinates.

V. ML/AI Algorithms

Integrating Machine Learning (ML) algorithms holds the potential to enhance the analysis of extracted features, offering intelligent insights into gait dynamics and health monitoring. Algorithmic choices, including Hidden Markov Models and Support Vector Machines for gait analysis, and Random Forests, Decision Trees, Neural Networks for health assessment, underscore a flexible approach based on project objectives. Anomaly detection may involve Isolation Forests and Autoencoders, user feedback could employ Reinforcement Learning and K-means clustering, while a Multi-Agent System might leverage Multi-Agent Reinforcement Learning and Ensemble Learning. These choices reflect adaptability, acknowledging uncertainty until further exploration and experimentation occur.

VI. Analytics & Insights

Analytics involve data visualization techniques (line charts, bar graphs, heat maps), user profiling using adaptive algorithms and clustering, predictive analytics using ARIMA or LSTM, and real-time monitoring with streaming analytics. This comprehensive framework ensures the acquisition, processing, and analysis of gait-related data, providing valuable insights into user mobility and health metrics.

B. Novelty and Innovativeness

- **Integration of Advanced Technologies:** The proposed Gait Monitoring System stands out by integrating cutting-edge technologies, such as NFC for user identification. This distinguishes it from traditional gait monitoring solutions and enhances the overall user experience.
- **Comprehensive Gait Analysis with Diverse Sensor Arrays:** The system's utilization of diverse sensor arrays on the Smart Bench and Smart Path contributes to a more nuanced and comprehensive gait analysis. This approach surpasses the limitations of singular-sensor solutions commonly found in existing approaches.
- **3D LIDAR Technology for High-Resolution Gait Monitoring:** The incorporation of 3D LIDAR technology in the Smart Path represents a significant departure from conventional methods. It enables high-resolution gait monitoring, offering detailed insights into joint movement, posture, and balance that surpass the capabilities of traditional monitoring systems.
- **Multi-Agent System with Reinforcement Learning:** The use of a Multi-Agent System, including reinforcement learning and ensemble learning, adds a layer of adaptability and collaborative intelligence. This novel approach fosters continuous improvement, making the system more responsive and accurate over time.

C. Potential Benefits and Advantages

- **Non-Intrusive Continuous Monitoring for Enhanced User Engagement:** The Smart Gait Monitoring System provides a non-intrusive and continuous monitoring solution. This enhances user engagement with the Smart Bench, promoting consistent and meaningful data collection.

- **Advanced Sensors for Accurate and Detailed Gait Analysis:** The diverse sensor arrays and advanced 3D LIDAR technology contribute to improved performance and accuracy in gait analysis. The system's ability to capture intricate details of joint movement, posture, and balance offers a more thorough understanding of user mobility.
- **Personalized User Feedback with ML/AI Algorithms:** ML/AI algorithms ensure adaptability and personalized user feedback, enhancing the overall user experience. This user-centric approach to gait analysis aligns with the evolving expectations of personalized and preventive healthcare.
- **Cost-Efficient Long-Term Monitoring with Collaborative Learning:** The Multi-Agent System with reinforcement learning enables collaborative learning, leading to improved system accuracy and robustness over time. This cost-efficient long-term monitoring ensures sustained benefits and advancements in preventive healthcare without significant additional costs.
- **Potential for Preventive Healthcare Advancements:** The proposed solution's comprehensive gait analysis, adaptability, and continuous monitoring contribute to advancements in preventive healthcare. Early detection of anomalies and personalized insights empower users and healthcare providers to take proactive measures, potentially reducing overall healthcare costs in the long run.