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Research Article

Development of a Wearable IoT and Artificial Neural Network-Based Gait Screening System for Parkinson's Disease

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Abstract: *Parkinson's Disease affects gait, balance, and mobility, while conventional assessment methods rely on brief clinical observation and specialist interpretation. This study develops a wearable IoT and Artificial Neural Network-based gait screening system for early Parkinson-like movement detection. The proposed innovation, GaitAI, integrates bilateral knee-mounted MPU6050 IMU sensors, ESP32 wireless communication, Blynk monitoring, Google Sheets cloud logging, ANN-based classification, and a web-based reporting platform. The system collects lower-limb acceleration data during walking, extracts gait features, and classifies gait patterns as either Normal or Parkinson-like. The prototype demonstrates wearable data acquisition, IoT transmission, cloud-based storage, machine learning integration, analytics visualization, and report generation. This innovation provides a practical, low-cost screening platform that may assist early awareness, user monitoring, and healthcare research. Although not intended to replace clinical diagnosis, the system shows potential as a digital healthcare support tool for Parkinson's gait screening.*

1. INTRODUCTION

Parkinson's Disease (PD) is a progressive neurodegenerative disorder that affects motor control, postural stability, balance, and walking performance. It is commonly associated with degeneration of dopaminergic neurons in the substantia nigra, which leads to dopamine deficiency and the development of motor and non-motor symptoms (Mi et al., 2020). The major motor symptoms of PD include resting tremor, bradykinesia, rigidity, postural instability, and gait disturbance (Atrsaei et al., 2021). Among these symptoms, gait abnormality is an important movement-related indicator because it affects mobility, safety, and daily independence. PD patients may experience slower walking speed, shorter step or stride length, increased double support time, irregular walking rhythm, and Freezing of Gait (FOG), which can increase fall risk and reduce quality of life (Warmerdam et al., 2021). Recent wearable-sensor studies have shown that subtle gait differences can be detected in early-stage

PD and between different motor subtypes, while IMU-based deep learning has also been used to assess FOG objectively (Zhang et al., 2024; Yang et al., 2024).

Current clinical assessment methods for PD motor symptoms commonly rely on clinical observation and standardized scoring tools such as the Unified Parkinson's Disease Rating Scale (UPDRS) and Hoehn and Yahr (H&Y) staging. Although these tools are widely accepted, they are limited by subjectivity, short observation duration, and dependence on trained specialists (Oftedal et al., 2023). Clinical walking tests may also fail to fully represent real-life gait performance because assessments are usually conducted in controlled environments for a limited period (Pedersen et al., 2024). Recent wearable-sensor and machine-learning studies have shown that gait and posture symptoms can be estimated more objectively from standardized walking data, supporting the need for complementary sensor-based assessment methods (Ma et al., 2025). Therefore, an objective, portable, and low-cost gait monitoring system is needed to support early identification of Parkinson-like movement abnormalities. Wearable sensor-based screening has also shown strong potential for early-stage PD assessment in both clinic and home settings (Johnson et al., 2024).

Advanced gait analysis systems such as three-dimensional motion capture, pressure walkways, force platforms, and multi-camera laboratories can provide detailed gait parameters. However, these systems are expensive, require specialized facilities, and are not practical for routine screening, community-based assessment, or home-care monitoring (Trabassi et al., 2022). Wearable sensing technology has become a promising alternative because it allows movement to be measured using small, lightweight, and non-invasive devices. Inertial Measurement Unit (IMU) sensors are especially suitable for gait analysis because they can capture acceleration and angular motion signals during walking (Yang et al., 2022; Chan et al., 2024; Zhang et al., 2022). Previous and recent wearable studies have shown that IMU-based systems are useful for detecting abnormal gait, monitoring movement performance, supporting PD-related mobility analysis, and enabling remote screening (Yang et al., 2022; Bikias et al., 2021; Poleur et al., 2025; Johnson et al., 2024; Zhang et al., 2024).

However, several limitations remain in existing wearable systems. Some systems use multiple sensor placements on the wrist, trunk, shoes, lower back, thighs, or ankles, which can increase complexity and reduce user comfort (Chan et al., 2024; Zhang et al., 2022; Bikias et al., 2021). Some designs focus mainly on specific symptoms such as tremor or FOG instead of providing a complete gait screening workflow (Bikias et al., 2021; Saez et al., 2025; Sáez et al., 2025; Yang et al., 2024). Other systems demonstrate strong sensing capability but do not fully integrate wearable data acquisition, IoT communication, cloud-based data storage, machine learning classification, user management, analytics visualization, and report generation into one practical platform (Faisal et al., 2021; Saez et al., 2025; Khalil et al., 2025). The MPU6050 sensor is a low-cost and widely available IMU module suitable for motion measurement and wearable applications (Sáez et al., 2025). Knee-mounted sensing is also relevant for lower-limb movement analysis because the knee region directly reflects walking motion and joint movement during gait activity (Faisal et al., 2021; Franco et al., 2022; Aich et al., 2020).

Machine learning has improved the potential of wearable gait analysis by enabling automated classification of movement patterns. Several machine learning algorithms, including Support Vector Machine (SVM), Random Forest, Decision Tree, K-Nearest Neighbour (KNN), and Artificial Neural Network (ANN), have been applied to IMU-based PD gait assessment (Khalil et al., 2025; Trabassi et al., 2022; Aich et al., 2020; Zhang et al., 2025; Gutowski et al., 2025). Previous studies reported promising classification performance using wearable sensor data and extracted gait features, showing that machine learning can support objective and data-driven PD screening (Khalil et al., 2025; Trabassi et al., 2022; Aich et al., 2020). However, model performance can still be affected by task selection, dataset size, class imbalance, diagnostic heterogeneity, and real-world variability (Khalil et al., 2025; Gutowski et al., 2025; Ma et al., 2025). These findings highlight the need for a practical development approach

that combines wearable sensing, meaningful gait feature extraction, and a deployable machine learning platform.

The scope of this study focuses on the development, integration, and initial functional evaluation of a wearable IMU-based gait screening system. The target application is early Parkinson-like gait screening for users who are still able to walk independently. Therefore, the system is most relevant to users within Hoehn and Yahr stages I to III, where mobility is still preserved but subtle gait and balance changes may be present (Trabassi et al., 2022). The system is intended as a screening support tool and not as a replacement for clinical diagnosis. The relevant stages are summarized in Table 1. The system is intended as a screening support tool and not as a replacement for clinical diagnosis.

Table 1. Hoehn and Yahr stages relevant to this study (Trabassi et al., 2022)

Stage	Description
Stage I	Unilateral involvement only, with minimal or no functional disability
Stage II	Bilateral involvement without impairment of balance
Stage III	Mild to moderate bilateral disease with postural instability; physically independent

In this study, a wearable IoT and Artificial Neural Network-based gait screening system for Parkinson's Disease was developed. The system, named GaitAI in the implementation stage, uses bilateral knee-mounted MPU6050 IMU sensors attached to knee guards using Velcro straps. Each wearable unit integrates an MPU6050 sensor, ESP32 microcontroller, and portable battery pack inside a compact casing. The ESP32 is used for real-time data acquisition and Wi-Fi communication due to its built-in wireless capability and suitability for IoT-based wearable systems (Faisal et al., 2021; Saez et al., 2025). The system collects tri-axial acceleration data from both legs and transmits the data through the Blynk application for live monitoring and control. The recorded data are also stored in Google Sheets through session-based logging, allowing each walking session to be saved and downloaded as a CSV file for web-based analysis. The overall end-to-end system architecture is shown in Figure 1.

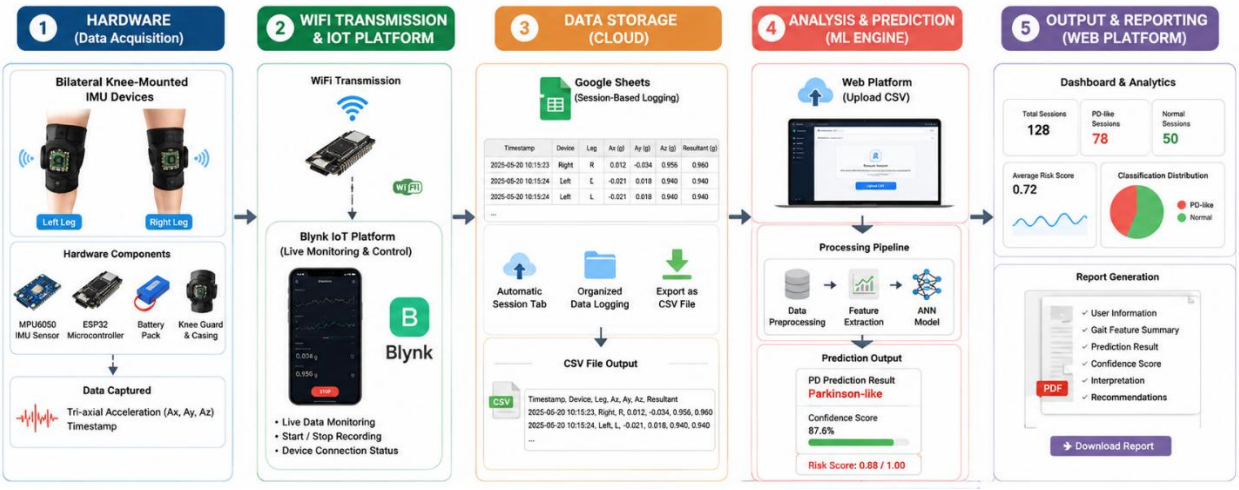


Figure 1. Proposed end-to-end system architecture

The developed web platform extends the system beyond hardware data collection by providing CSV upload, user registration, result history, dashboard overview, analytics visualization, ANN-based classification, and printable report generation. The uploaded gait data undergo

preprocessing, signal filtering, resultant acceleration calculation, window-based feature extraction, and machine learning classification. The extracted features include time-domain, frequency-domain, and gait-related parameters such as acceleration magnitude, root mean square, standard deviation, jerk, cadence, step frequency, dominant frequency, tremor power, gait power, and freeze ratio. The PD-BIOSTAMPRC21 accelerometry dataset was used as the reference dataset for initial machine learning development and model preparation (Tanim, 2021). Several machine learning models were considered during development, including SVM, Random Forest, Decision Tree, KNN, and ANN. Based on the current implementation, ANN was selected as the final model for integration into the GaitAI web platform because of its suitability for learning nonlinear relationships from multidimensional gait features.

The aim of this paper is to present the development methodology of the proposed wearable IoT and ANN-based gait screening system for Parkinson's Disease. The focus is placed on system architecture, hardware development, IoT transmission workflow, web platform implementation, feature extraction pipeline, ANN model integration, and functional system output. This paper does not aim to provide a complete clinical validation or detailed statistical comparison between Parkinson and non-Parkinson gait datasets. Instead, it focuses on the design and implementation process of an end-to-end wearable healthcare platform that can support early Parkinson-like gait screening and future clinical research. The main objectives are to design a wearable bilateral knee-mounted IMU system using MPU6050 and ESP32 for real-time gait data collection and IoT transmission, to develop and integrate a machine learning model into a web-based platform, and to evaluate the developed system in terms of functional accuracy, reliability, and effectiveness for early gait screening support.

2. LITERATURE REVIEW

The development of a wearable IoT and Artificial Neural Network-based gait screening system for Parkinson's Disease requires understanding of three related research areas: Parkinson's Disease movement impairment, wearable IMU-based sensing, and machine learning-based gait classification. Previous studies have shown that Parkinson's Disease affects gait, balance, tremor, posture, and movement coordination, while wearable sensors and machine learning provide a promising method for objective movement assessment. However, the literature also shows that many existing systems remain limited by complex sensor placement, laboratory-based operation, lack of IoT integration, and limited user-friendly reporting functions. Therefore, this section reviews related works and identifies the research gap addressed by this study.

2.1 Parkinson's Disease and Movement-Based Assessment

Parkinson's Disease is a progressive neurodegenerative disorder that affects motor function and presents complex clinical symptoms. From a movement perspective, gait abnormality is one of the most important functional impairments because it affects walking stability, mobility, and fall risk. Mi et al. (2020) showed that freezing of gait is related to abnormal brain connectivity and can be improved through repetitive transcranial magnetic stimulation. This confirms that freezing of gait is an important movement-related symptom in PD and supports the need for gait-based assessment. Atrsaei et al. (2021) compared gait speed measured in clinical and daily living settings and found that clinical assessment may overestimate real-world walking performance. This highlights the limitation of clinic-based observation and supports wearable monitoring systems that can capture movement data more objectively.

Warmerdam et al. (2021) showed that movement response in PD depends on task complexity and symptom severity, demonstrating that movement data can provide useful information about motor

function and disease-related changes. Oftedal et al. (2023) showed that seed amplification assay can provide high diagnostic accuracy for newly diagnosed PD, while Pedersen et al. (2024) reported that serum neurofilament light may predict disease progression. However, these biological and laboratory-based approaches are not designed for practical real-time gait monitoring. Therefore, although clinical and biological assessments are useful, they do not fully address the need for a simple, wearable, and movement-based screening tool.

Wearable IMU sensors have become important in gait analysis because they are small, lightweight, low-cost, and capable of measuring movement outside laboratory environments. Yang et al. (2022) developed an intelligent wearable system using IMU and pressure sensors for abnormal gait detection and cueing in people with Parkinson's Disease. Their work demonstrated that wearable systems could support real-time gait monitoring and intervention. However, the system involved multiple sensors and focused mainly on cueing rather than an integrated AI-based screening platform. Chan et al. (2024) introduced laser-light cueing shoes with integrated foot pressure and inertial sensing to study visual cueing effects on gait characteristics in PD. Although the system demonstrated the value of multimodal sensing, shoe-based systems may be less practical for general screening because they depend on specific footwear design.

Zhang et al. (2022) presented a multimodal dataset for freezing of gait detection using accelerometry, surface electromyography, and electrodermal activity. While this dataset supports advanced algorithm development, multiple sensing modalities increase system complexity and may reduce practicality for low-cost wearable implementation. Bikias et al. (2021) developed DeepFoG using wrist-worn IMU data and deep learning for freezing of gait detection. Their study showed that IMU-based deep learning can achieve strong detection performance. However, wrist-mounted sensing may provide limited direct information about lower-limb gait mechanics. Similarly, Saez et al. (2025) developed an IoT-based wearable system for quantitative hand tremor assessment, showing the potential of cloud-connected wearable monitoring, but the focus was tremor rather than gait screening.

Several studies support the relevance of knee-mounted sensing for lower-limb movement analysis. Faisal et al. (2021) developed a low-cost wearable knee monitoring system using multiple sensors and demonstrated reliable joint angle estimation. Franco et al. (2022) also validated motion sensors for knee angle recognition in rehabilitation applications. These findings support knee-level sensing because the knee is directly involved in gait movement and lower-limb coordination. Sáez et al. (2025) further showed that the MPU6050 sensor can be calibrated for motion measurement, supporting its suitability for low-cost wearable applications.

Machine learning has been widely applied in wearable sensor-based Parkinson's Disease assessment because it can identify patterns from complex gait and movement data. Khalil et al. (2025) applied machine learning models to wearable sensor data collected during clinical mobility tasks and reported that Random Forest achieved 78.2% balanced accuracy using the Timed Up and Go task. Their findings show that task selection and feature selection are important for reliable classification. Trabassi et al. (2022) compared supervised machine learning algorithms, including Support Vector Machine, Random Forest, Decision Tree, K-Nearest Neighbour, and Artificial Neural Network, using IMU-based gait data. Their study reported that SVM achieved strong generalization performance when combined with structured feature selection.

Aich et al. (2020) developed a machine learning-assisted wearable accelerometer system using bilateral knee-mounted sensors and achieved 88.46% classification accuracy using a Decision Tree model. This study is relevant because it supports bilateral knee accelerometers for Parkinsonian gait analysis and shows that meaningful gait information can be extracted from lower-limb sensor placement. However, their system did not include an IoT-connected web platform or automated report

generation. More advanced studies have explored multimodal and deep learning methods. Zhang et al. (2025) reported high classification performance using wearable inertial measurement units and surface electromyography sensors with advanced feature extraction. Gutowski et al. (2025) also showed that machine learning can assess PD symptoms using wearable and smartphone sensors, although performance may be affected by data imbalance and dataset variability.

Overall, previous studies confirm that wearable sensors and machine learning can support Parkinson's gait analysis. However, many systems remain focused on specific symptoms, complex sensor placements, or algorithm performance only. A more practical system should integrate wearable sensing, IoT communication, cloud data storage, machine learning classification, user management, analytics, and report generation into one complete platform.

2.2 Research Gap and Contribution

Based on the reviewed literature, previous studies have provided strong evidence that wearable sensors and machine learning can support Parkinson's gait analysis. However, several gaps remain. First, many wearable systems are still symptom-specific, focusing mainly on tremor or freezing of gait rather than complete gait screening. Second, many systems require multiple sensors or complex placements, which may reduce comfort and usability. Third, several studies focus mainly on algorithm development and do not provide a complete end-to-end platform for user management, data upload, analytics visualization, and report generation. Fourth, IoT integration is often limited, even though wireless data transmission and cloud logging are important for practical use. A summary of the reviewed literature identified gaps, and the contribution of this study is presented in Table 2.

Table 2. Summary of reviewed literature and identified research gap

Research Area	Supporting Literature	Main Contribution	Limitation / Gap	Contribution of This Study
PD movement assessment	Mi et al. (2020); Atrsaei et al. (2021); Warmerdam et al. (2021); Oftedal et al. (2023); Pedersen et al. (2024)	PD affects gait, balance, posture, tremor, and freezing of gait	Clinical observation is subjective and limited to short assessment	Develops an objective gait screening support system
Wearable IMU systems	Yang et al. (2022); Chan et al. (2024); Zhang et al. (2022); Bikias et al. (2021); Faisal et al. (2021); Franco et al. (2022); Sáez et al. (2025)	IMU sensors can capture movement data for gait and mobility analysis	Many systems use complex sensor placement or focus on specific symptoms	Uses a practical bilateral knee-mounted IMU configuration
IoT-based monitoring	Saez et al. (2025); Yang et al. (2022); Faisal et al. (2021)	IoT systems support remote data transfer and monitoring	Limited integration with full gait analysis and reporting workflow	Integrates Blynk monitoring and Google Sheets session logging
Machine learning classification	Khalil et al. (2025); Trabassi et al. (2022); Aich et al. (2020); Zhang et al. (2025); Gutowski et al. (2025)	ML models can classify PD-related movement patterns	Many studies focus mainly on algorithm performance, not deployment	Integrates ANN into a functional web platform
Digital healthcare platform	Khalil et al. (2025); Saez et al. (2025); Gutowski et al. (2025)	Digital platforms can improve accessibility and data-driven screening	Limited complete end-to-end systems for gait screening	Provides dashboard, upload, analytics, user registry, and report generation

This study addresses these gaps by developing a wearable bilateral knee-mounted IMU system integrated with ESP32-based IoT communication, Blynk live monitoring, Google Sheets session logging, ANN-based classification, and a custom web platform. The system is designed not only to collect gait data, but also to support data upload, feature extraction, classification, analytics, user record management, and printable report generation. Therefore, the main contribution of this study is the development of a practical end-to-end wearable IoT and ANN-based gait screening system for Parkinson's Disease.

3. METHODOLOGY

The methodology of this study focuses on the development of a wearable IoT and Artificial Neural Network-based gait screening system for Parkinson's Disease. The system was developed as an end-to-end prototype that integrates wearable data acquisition, wireless communication, cloud-based data storage, machine learning processing, and web-based reporting. The development process was organized into five main parts: system architecture, wearable hardware and data collection, IoT communication, machine learning pipeline, and web platform implementation.

3.1 System Architecture and Workflow

The proposed system was designed using a modular architecture consisting of three main layers: wearable data acquisition, IoT communication and storage, and web-based machine learning analysis. The wearable layer collects lower-limb gait movement data using bilateral knee-mounted IMU devices. The IoT layer supports wireless monitoring and session-based data storage through Blynk and Google Sheets. The web-based layer allows gait data to be uploaded, processed, classified, visualized, and converted into a printable report.

The workflow begins when the user wears the bilateral knee-mounted IMU devices to capture lower-limb movement during walking. These wearable sensors continuously measure acceleration and angular velocity data from both knees, enabling the system to monitor gait patterns in real time. Gait data are collected using the MPU6050 sensors and transmitted wirelessly by the ESP32 microcontroller to the Blynk application for live monitoring and recording control. The Blynk platform allows the user or clinician to start and stop recordings conveniently while simultaneously observing the incoming sensor signals. After data collection, the recorded data are stored in Google Sheets, exported as a CSV file, and uploaded into the GaitAI web platform for further processing and analysis. The ANN model then analyzes the extracted gait features and generates the classification result, confidence score, and screening report, as illustrated in Figure 2.

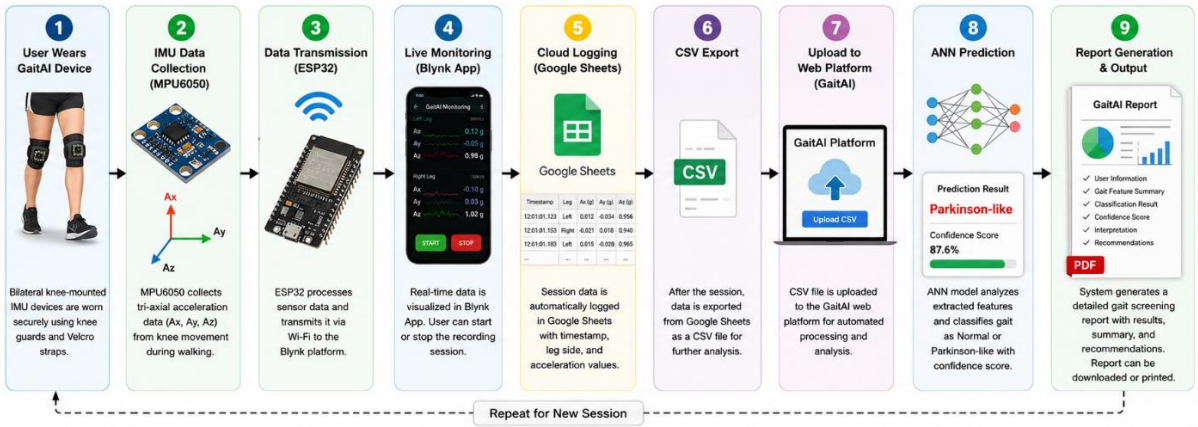


Figure 2. Overall workflow of the proposed GaitAI system

3.2 Wearable Hardware and Data Collection

The hardware system was developed using two wearable knee-mounted devices, one for each leg. The main hardware components include the MPU6050 IMU sensor, ESP32 microcontroller, portable battery pack, casing, knee guard, and Velcro strap. The MPU6050 was selected because it is compact and suitable for collecting tri-axial acceleration data, while the ESP32 was selected due to its Wi-Fi capability and suitability for IoT-based wearable applications.

In the final prototype, the electronic components are housed inside a compact casing and attached to the knee guard using a Velcro strap. This design allows the device to be worn and removed easily while maintaining a stable position during walking. The bilateral knee-mounted configuration allows gait movement data to be collected from both legs and supports left-right comparison for future gait symmetry analysis.

A controlled start-up and recording procedure was used to ensure both ESP32 devices were connected to the same Blynk application before data collection. Once both devices were connected, the user performed a walking session for approximately one minute. During the session, acceleration data from both devices were transmitted and stored for further analysis.

Figure 3 shows the developed bilateral knee-mounted wearable hardware prototype used for gait data collection. The system consists of two wearable knee guard devices equipped with electronics casings containing the MPU6050 IMU sensor, ESP32 microcontroller, and portable battery pack. The casing is attached securely to the knee guard using a Velcro strap positioned behind the casing to improve stability during walking. This bilateral wearable configuration allows simultaneous gait data collection from both the left and right legs for lower-limb movement analysis.



Figure 3. Bilateral knee-mounted wearable hardware prototype

3.3 IoT Communication and Data Management

The IoT communication system was developed using Blynk and Google Sheets. Blynk functions as the live monitoring and control interface, allowing the operator to observe sensor readings and control the start or stop of the recording session. This provides a simple method to confirm device connection and sensor activity during movement.

Google Sheets was used as a cloud-based storage platform for session logging. Each walking session was stored separately to simplify data management and later analysis. The recorded data were downloaded as CSV files and used as input for the web-based gait screening platform. This approach provides a low-cost and accessible IoT workflow without requiring a complex cloud database during the prototype stage.

Figure 4 shows the IoT communication and cloud-based data management workflow used in the proposed system. The Blynk application provides real-time monitoring and recording control for the bilateral wearable devices, while Google Sheets functions as the session-based cloud logging platform for storing gait acceleration data collected during walking activities.

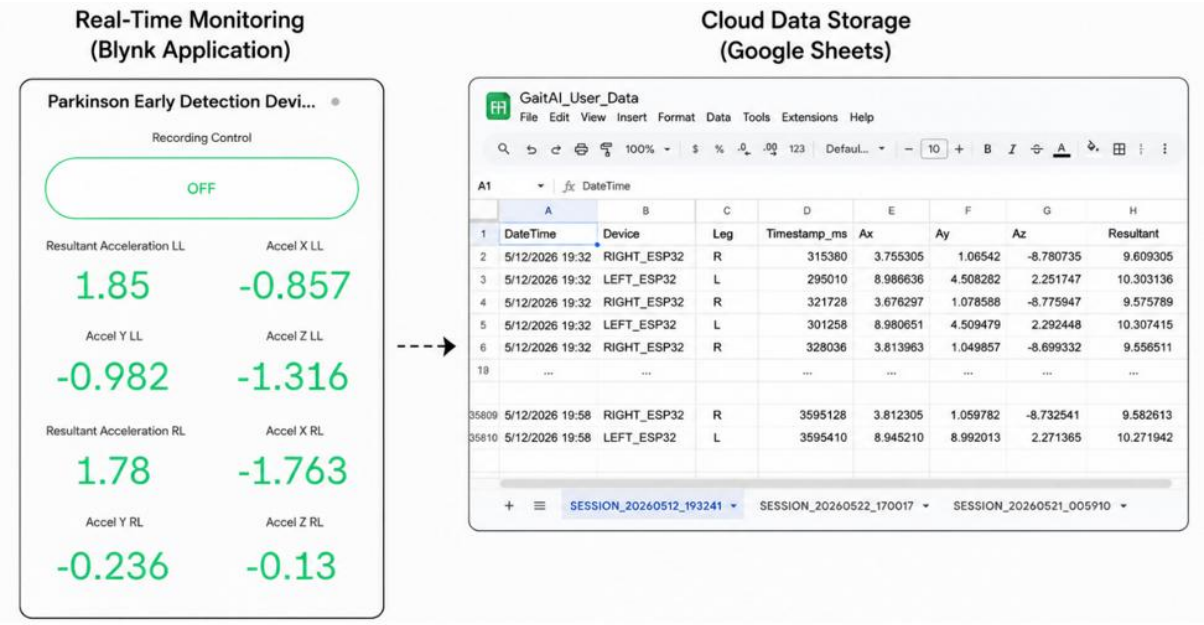


Figure 4. IoT communication and cloud-based gait data management using Blynk and Google Sheets

3.4 Machine Learning Pipeline

The machine learning pipeline consists of data preprocessing, signal processing, feature extraction, and ANN-based classification. The raw accelerometer data were first cleaned, organized, and labelled according to Normal and Parkinson groups. Basic subject information such as subject ID, leg side, gender, and age was also retained to support later analysis. The acceleration signals were arranged in the correct time sequence before further processing.

The processed IMU signals were then transformed into meaningful gait parameters using window-based feature extraction. The extracted features describe movement intensity, gait rhythm, signal variability, frequency characteristics, tremor-related activity, and possible freezing-related behaviour. These features were used as input for the machine learning model.

Several machine learning models were considered during system development, including Support Vector Machine, Random Forest, Decision Tree, K-Nearest Neighbour, and Artificial Neural Network. Based on the current implementation, the ANN model was selected for integration into the web platform because it can learn nonlinear relationships between multiple gait features and classification outputs. The trained ANN model classifies the gait pattern as either Normal or Parkinson-like and provides a confidence score or risk score.

Figure 5 shows the machine learning pipeline used for Parkinson-like gait classification. The pipeline begins with CSV gait data, followed by preprocessing, windowing, feature extraction, ANN-based classification, and prediction output. The final output of the model is presented as either Normal gait or Parkinson-like gait, together with the risk score generated by the system.

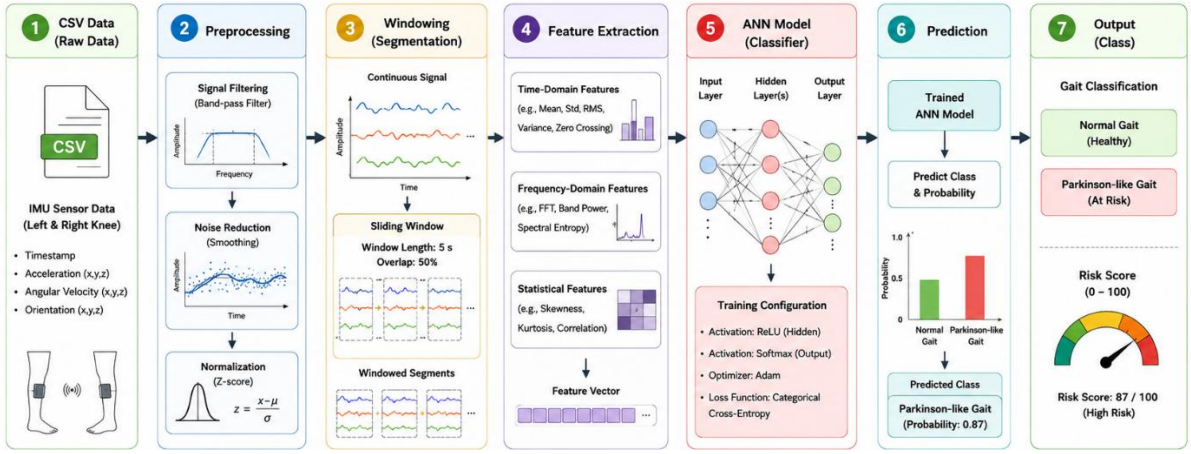


Figure 5. Machine learning pipeline for Parkinson-like gait classification

3.5 Web Platform and System Output

The GaitAI web platform was developed to provide a complete digital workflow from CSV upload to report generation. The platform includes several main modules, including Dashboard, Upload Data, Users, Results, Analytics, and Reports. The dashboard provides an overview of users, gait sessions, classification distribution, and average risk score. The upload module allows recorded CSV files to be analyzed, while the user registry stores user information and screening history. Figure 6 shows the developed GaitAI dashboard interface used for gait screening overview and system monitoring.

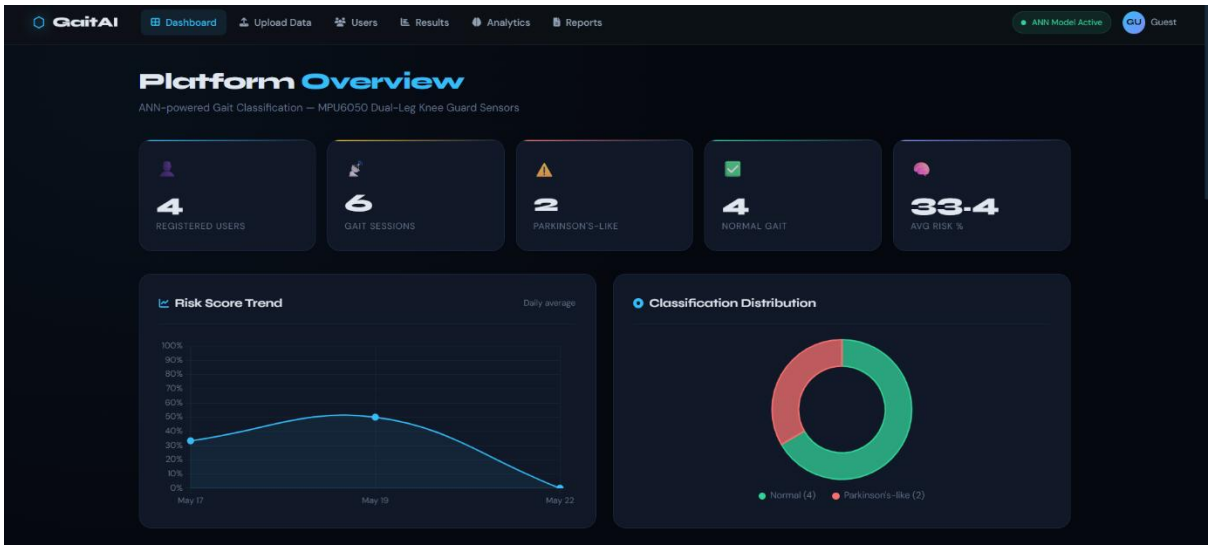


Figure 6. Developed GaitAI web platform dashboard for gait screening overview

The results and analytics modules display ANN classification outputs, extracted gait feature summaries, risk trends, classification distribution, and high-risk user information. The report module

generates a printable gait screening report that includes user information, classification result, confidence score, gait feature summary, interpretation, and recommendation.

The final system output includes a Normal or Parkinson-like gait classification, confidence score, risk score, analytics visualization, and downloadable report. The system is designed as an early screening support tool and not as a confirmed clinical diagnostic device. Therefore, the output should be used to support awareness and further clinical referral, while final diagnosis must be performed by qualified medical professionals.

4. FINDINGS

The findings of this study demonstrate that the proposed GaitAI system was successfully developed as an integrated wearable Internet of Things (IoT) and Artificial Neural Network (ANN)-based gait screening platform for Parkinson's Disease. The system effectively combines wearable data acquisition, wireless communication, cloud-based storage, machine learning processing, and web-based reporting into a unified end-to-end workflow. This confirms the overall feasibility of implementing a complete digital healthcare screening framework using low-cost and accessible technologies.

The bilateral wearable hardware prototype, developed using MPU6050 IMU sensors and ESP32 microcontrollers, was able to reliably capture lower-limb acceleration data during walking activities. The use of knee guards with Velcro fastening ensured stable sensor placement on both knees, enabling continuous monitoring without noticeable displacement during gait sessions. The recorded tri-axial acceleration signals showed consistent responsiveness to walking cycles, indicating that the wearable configuration is suitable for capturing dynamic gait patterns required for further processing. In addition, the bilateral setup supports simultaneous monitoring of both legs, providing a basis for future analysis of gait symmetry and movement imbalance.

The IoT communication architecture, implemented using ESP32, Blynk, and Google Sheets, demonstrated stable and effective performance for real-time data transmission and cloud-based logging. Sensor data from both wearable units were successfully transmitted via Wi-Fi and displayed through the Blynk interface, allowing live monitoring and recording control. The integration with Google Sheets enabled automatic session-based storage of gait data, ensuring that each walking session was systematically recorded and could be retrieved for analysis. The stored data were successfully exported into CSV format and used as valid input for the developed web platform. This workflow validates that a low-cost and simplified IoT architecture can support continuous monitoring and structured data management without the need for complex infrastructure.

The machine learning pipeline was successfully integrated within the GaitAI web platform, enabling automated processing of uploaded gait data. The system performed preprocessing, signal organization, window-based segmentation, and feature extraction in a streamlined manner. The extracted features included relevant descriptors of gait behaviour, such as signal magnitude, variability, temporal patterns, and frequency characteristics, which are commonly associated with Parkinson-like movement abnormalities. These features were effectively utilized as inputs to the ANN model, allowing classification to be performed automatically after data upload. The ANN model consistently generated interpretable outputs in the form of Normal or Parkinson-like gait classifications, accompanied by confidence or risk scores. This confirms that the integration between feature extraction and machine learning components is functionally operational and capable of producing meaningful screening outputs.

The developed web platform further demonstrated successful implementation of a complete user-oriented workflow. The system provided dashboard visualization, user registration, gait session management, analytics display, and report generation within a unified interface. The classification results and extracted feature summaries were presented clearly through the analytics modules, while the reporting function produced structured and printable screening reports that included user information, classification outcomes, and interpretation. These outputs indicate that the system is not only capable of processing technical data but also translating the results into a form that is accessible and useful for users or healthcare support purposes.

From an overall evaluation perspective, the GaitAI system exhibited reliable functional performance across all major components, including wearable sensing, IoT communication, cloud data handling, machine learning processing, and web-based reporting. The successful interaction between these components confirms the viability of the proposed architecture as an end-to-end gait screening platform. It is important to note that the evaluation conducted in this study focuses on functional validation and system feasibility rather than detailed clinical or statistical performance analysis. Therefore, while the system demonstrates stable operation and consistent output generation, further large-scale testing and clinical validation are required to assess classification accuracy and diagnostic applicability.

Overall, the developed prototype provides strong evidence that wearable sensing, IoT technology, and machine learning can be effectively integrated into a practical and scalable digital healthcare solution for early Parkinson-like gait screening support.

5. DISCUSSION

The development of the proposed GaitAI system demonstrates the potential of wearable IoT technology and machine learning for practical gait screening applications. Compared to conventional laboratory-based gait analysis systems, the proposed system offers a more portable, low-cost, and accessible approach for movement monitoring. The use of bilateral knee-mounted MPU6050 sensors allows lower-limb movement data to be collected directly from the knee region, which is closely related to walking motion and gait behaviour.

The integration of ESP32 microcontrollers with Blynk and Google Sheets also demonstrates a practical IoT workflow for wearable healthcare applications. Instead of relying on complex cloud infrastructure, the developed system uses a simpler and more accessible approach that still supports real-time monitoring and cloud-based session logging. This makes the system more suitable for prototype development, educational research, and future portable healthcare applications.

The ANN-based machine learning integration further improves the functionality of the system by enabling automated gait classification. Previous studies have shown that machine learning can support Parkinson-related movement analysis, and the findings of this study support the feasibility of integrating such models into a wearable digital healthcare platform. Although several machine learning models were considered during development, ANN was selected because it is capable of learning nonlinear relationships between multiple gait features and classification outcomes.

However, several limitations remain in the current study. The system was developed mainly as an implementation and functional development project rather than a full clinical validation study. Therefore, extensive clinical testing involving large Parkinson's Disease populations was not performed in this work. In addition, the current system focuses mainly on acceleration-based gait analysis and does not include additional sensing modalities such as electromyography, plantar

pressure sensors, or gyroscope-based joint angle analysis. The present implementation also focuses on early-stage Parkinson-like gait screening and is not intended to replace professional clinical diagnosis.

Despite these limitations, the study demonstrates a complete end-to-end workflow that combines wearable sensing, IoT communication, machine learning classification, cloud-based logging, analytics visualization, and report generation into one integrated platform. The developed system provides a strong foundation for future improvement and clinical expansion.

6. CONCLUSION

In conclusion, this study presented the successful development of a wearable IoT and Artificial Neural Network-based gait screening system for Parkinson's Disease, termed GaitAI, which integrates bilateral knee-mounted MPU6050 wearable sensors, ESP32-based wireless communication, Blynk-enabled live monitoring, Google Sheets cloud data logging, ANN-based gait classification, and a web-based reporting platform into a cohesive end-to-end healthcare workflow. The developed prototype demonstrated reliable functionality across all stages, including wearable gait data acquisition, real-time IoT communication, structured cloud storage, automated machine learning processing, analytics visualization, and report generation, with system outputs consisting of gait classification results categorised as Normal or Parkinson-like, accompanied by confidence scores, risk indicators, and feature summaries. This study contributes to the advancement of practical and accessible gait screening solutions by combining wearable sensing and machine learning into a portable digital healthcare application, while its focus on system development and functional integration provides a strong foundation for future work. Although clinical validation and large-scale statistical evaluation were beyond the scope of this study, the proposed platform offers significant potential for further enhancement through expanded datasets, optimized machine learning models, and real-world deployment scenarios. Overall, the GaitAI system demonstrates that wearable IoT and artificial intelligence technologies can be effectively integrated into a scalable and user-oriented platform for early Parkinson-like gait screening support.

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