

Development of an IoT Based Smart Care for Enhancing Elderly Monitoring

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Abstract

This research contributes to the growing field of gerontechnology by addressing both physical and physiological factors associated with falls. Unlike conventional walking aids, the proposed system integrates multiple sensor modalities to provide a holistic monitoring approach. The study emphasizes not only the technical validation of the device but also user-centered aspects such as ergonomics, usability, and caregiver support. This comprehensive approach enhances its potential for real-world adoption. Falls are a leading cause of injury, dependency, and reduced quality of life among older adults. This study presents the design and development of an IoT-based smart cane equipped with multiple sensors to enhance mobility safety for elderly users in Thailand's rapidly aging society. The cane integrates an MPU6050 accelerometer, MAX30102 pulse oximeter, and FSR402 pressure sensor, all connected to an ESP8266 microcontroller with GPS functionality. These components allow real-time monitoring of balance, heart rate, and oxygen saturation, while also transmitting fall alerts to caregivers through IoT-based communication. Previous smart cane solutions have shown limitations including inadequate sensor integration, high false-alarm rates, and lack of cultural adaptation for Southeast Asian contexts. The prototype demonstrated 92% accuracy in fall detection with a 6% false alarm rate. Physiological measurements achieved acceptable precision ($\pm 2\%$ for oxygen saturation, ± 3 bpm for heart rate), while GPS tracking latency averaged 1.5 seconds. User feedback indicated increased walking confidence and satisfaction with ergonomic design, though further weight reduction was recommended. Results indicate that the smart cane reduces fall risks and improves confidence in walking

Keywords: smart cane, fall detection, IoT, elderly care, gerontechnology

1. Introduction

Thailand is rapidly transitioning into an aged society, with projections suggesting that by 2035 nearly 28% of its population will be aged 60 years or older (Sunisa, 2024). This demographic shift

places significant strain on healthcare systems and families, as older adults face increasing risks of chronic diseases, frailty, and mobility impairments. Among these challenges, falls represent one of the most severe health threats, with one in three older adults experiencing at least one fall annually and about 20% suffering injuries serious enough to require medical treatment such as fractures or head trauma (Department of Disease Control, 2022). Beyond physical harm, falls contribute to psychological consequences, including fear of falling, reduced physical activity, social withdrawal, and heightened dependency, all of which diminish quality of life (World Health Organization, 2021).

1.1 Literature Gap and IoT Opportunities

Traditional walking aids such as canes and walkers provide mechanical stability but do not address the need for continuous monitoring and timely intervention. In contrast, Internet of Things (IoT)-enabled solutions have shown promise in merging mobility assistance with real-time sensing of physiological and movement parameters, thereby enabling proactive fall prevention and rapid caregiver response (Shahrestani, 2020). Previous studies on smart canes equipped with sensors have demonstrated the feasibility of fall detection, yet these solutions face notable limitations including limited sensor integration, high false-alarm rates, bulky form factors, and weak connections with clinical monitoring systems (Abdolmanafi et al., 2020).

1.2 Research Objectives

Furthermore, most existing designs emerge from Western contexts and lack cultural adaptation for Thai elderly, who may prioritize localized interfaces, lightweight devices, and affordability. Addressing these shortcomings, this study aims to develop an IoT-based smart cane that combines motion sensing, biometric monitoring of oxygen saturation and heart rate, and GPS tracking in an ergonomic and culturally tailored design. The objectives are to evaluate the device's technical performance in terms of fall-detection accuracy and system latency, to assess usability and user satisfaction through pilot testing with Thai older adults, and to contribute to gerontechnology by providing a solution that bridges healthcare innovation with cultural sensitivity. By targeting the research gaps of limited multimodal sensing, insufficient ergonomic design, lack of cultural adaptation, and inadequate healthcare integration, the study advances a comprehensive approach to fall prevention in aging societies.

2. Literature Reviews

2.1 Falls in the Elderly

Falls are a significant public health concern among older adults, particularly in aging societies. According to the Department of Disease Control (2022), one in three elderly individuals in Thailand experiences at least one fall per year, with approximately 20% of these incidents leading

to moderate or severe injury. Falls are often multifactorial, stemming from intrinsic conditions such as musculoskeletal weakness, osteoporosis, vision impairment, and chronic diseases (World Health Organization, 2021). Extrinsic factors, including environmental hazards and inadequate assistive devices, further exacerbate the risks (Phyathai Nawamin, 2022). Beyond physical consequences, falls contribute to psychosocial issues such as fear of falling, loss of independence, and increased caregiver burden (Khow & Visvanathan, 2017). This underlines the importance of proactive strategies that combine medical, technological, and environmental approaches to mitigate fall risks.

2.2 Smart Assistive Technologies

Smart assistive devices have emerged as a response to the rising demand for innovative fall-prevention strategies. Phitayacharoen et al. (2016) proposed a laser-guided cane for Parkinson's patients, enabling visual cues to overcome freezing of gait episodes. ahawan et al. (2022) introduced "Walk A Go," an IoT-enabled cane that integrates fall detection, obstacle recognition, and GPS location services via a mobile application. Similarly, Asawawut (2017) employed inertial measurement unit (IMU) sensors for real-time motion visualization, highlighting the feasibility of using sensor fusion techniques in gait analysis. Additional international efforts include ultrasonic sensor-based canes for visually impaired users (Uddin et al., 2020), vibration-enabled haptic feedback systems to alert users of obstacles (Prasad et al., 2018), and wearable fall detection devices integrated with smartphones (Pannurat et al., 2014). Collectively, these innovations demonstrate that usability, ergonomic design, and system reliability are decisive factors for user adoption.

2.3 IoT and Healthcare Monitoring

The Internet of Things (IoT) has significantly transformed healthcare by enabling real-time, continuous monitoring of vital signs and mobility. NodeMCU ESP8266 platforms provide cost-effective frameworks for developing smart health devices with wireless connectivity (Anan, 2015). IoT-based systems facilitate data transmission to caregivers or healthcare providers, thereby enhancing emergency response and long-term health management. Recent applications in fall detection and elderly monitoring emphasize sensor integration. For instance, Nuanmeesri (2023) highlighted the success of IoT platforms in agricultural logistics for elderly farmers, indirectly suggesting the adaptability of IoT for elderly lifestyle needs. Shahbazi et al. (2021) reinforced the role of IoT-enabled health monitoring, though they stressed challenges in data privacy and interoperability. Similarly, Chua et al. (2024) demonstrated that cultural adaptation—such as localized interfaces and language support—remains critical for adoption among older adults.

2.4 Physiological Monitoring and Fall Prediction

Monitoring vital signs has been recognized as an essential component of fall prediction. Abnormalities in heart rate and oxygen saturation often precede dizziness and fainting, which are precursors to falls (Rodriguez, 2021). Pulse oximeters such as MAX30102 have gained traction due

to their non-invasive nature, offering practical integration into portable devices. Research by Patel et al. (2012) showed that wearable devices incorporating heart rate monitoring significantly improve fall detection accuracy when combined with accelerometer data. Force-sensing resistors (FSRs) have also been studied for grip strength analysis, an indicator of frailty and fall risk (Bohannon, 2019). Grip force monitoring in canes provides both biomechanical data and behavioral insights, enabling proactive interventions before a fall occurs.

2.5 Research Gap

While these studies collectively demonstrate progress in elderly care technologies, critical gaps remain. Most smart canes focus on either mobility assistance or biometric monitoring but rarely combine multiple functions into a holistic system. Many existing solutions are developed in Western contexts and may not align with cultural, ergonomic, or environmental needs of elderly users in Southeast Asia. Moreover, few studies report longitudinal testing with real elderly populations, leaving questions about sustained adoption, reliability, and clinical integration unanswered. This study addresses these gaps by developing an IoT-enabled smart cane that integrates fall detection, physiological monitoring, and GPS-based caregiver support into a single device. By emphasizing ergonomic design and real-world usability, the project advances the field of gerontechnology while contributing a culturally tailored solution for elderly populations in Thailand.

3. Methodology

3.1 System Design

The smart cane prototype was developed by integrating multiple hardware components to enable fall detection, physiological monitoring, and location tracking. The core processing unit was the ESP8266 NodeMCU microcontroller, chosen for its compact design, Wi-Fi capability, and compatibility with open-source IoT frameworks (Anan, 2015). Sensor integration comprised:

MPU6050 accelerometer and gyroscope: to capture three-axis acceleration and angular velocity data, enabling detection of imbalance and sudden falls.

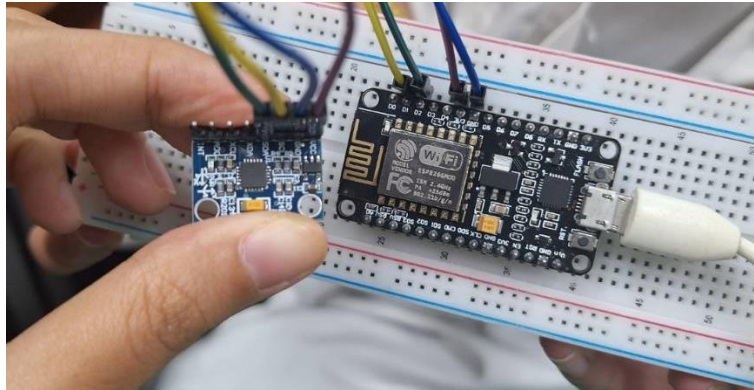


Fig 1 MPU6050 Accelerometer and Gyroscope Sensor

MAX30102 pulse oximeter: for continuous monitoring of heart rate and blood oxygen saturation, parameters that may indicate dizziness or hypoxia preceding a fall (Rodriguez, 2021).

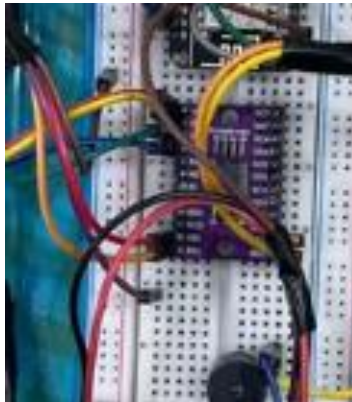


Fig. 2 MAX30102 Pulse Oximeter

FSR402 force-sensing resistor: embedded in the cane's grip to assess grip strength, serving as an indirect measure of frailty and hand stability (Bohannon, 2019).

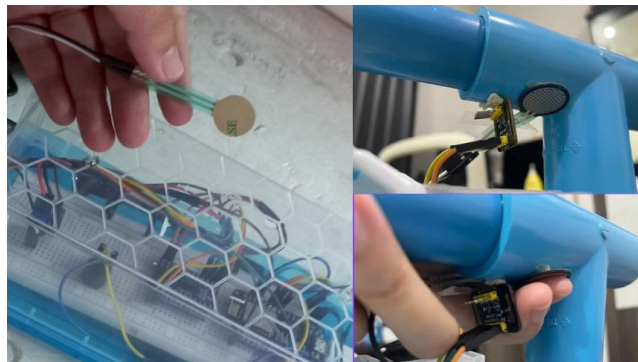


Fig. 3 FSR402 Force-Sensing Resistor

GPS module: to provide geolocation in real time, ensuring caregivers can track the user's location during emergencies.

All components were enclosed in a lightweight PVC frame to maintain durability and ergonomic usability. The system was powered by a rechargeable battery with a 5V output regulated through a step-down converter.

3.2 Software and IoT Platform

The software architecture was implemented on NodeMCU firmware, allowing direct integration of C/C++ code through the Arduino IDE. Libraries specific to each sensor (e.g., `Wire.h` for I²C communication, `Adafruit_Sensor.h` for accelerometer calibration) were employed. Real-time data transmission was established using the MQTT protocol over Wi-Fi, enabling low-latency communication between the cane and a cloud-based dashboard accessible to caregivers. The IoT platform stored and processed sensor readings, generating alerts when thresholds were exceeded. For instance, acceleration exceeding 1.5 g combined with loss of grip pressure was classified as a fall event, triggering both local alarms (buzzer and LED) and remote notifications (GPS-linked alert to caregiver).

3.3 Participants

The field test was conducted with a pilot group of elderly participants aged 60 years and above residing in On Nut District, Bangkok. Participants were recruited through community centers and selected based on their ability to walk with or without assistive devices. Exclusion criteria included severe cognitive impairment or conditions that prevented safe participation. A total of 10 participants were involved in initial usability testing, aligning with recommendations for prototype evaluation in assistive device research (Pannurat et al., 2014).

3.4 Testing Procedure

The evaluation process followed a three-stage procedure:

Pre-test phase: Laboratory-based calibration of sensors was performed using simulated falls (dropping the cane at controlled angles) and standardized physiological measurements to ensure sensor accuracy. **Field-test phase:** Participants used the smart cane during daily walking activities under observation. Fall events were simulated under safe conditions (e.g., controlled imbalance exercises supervised by caregivers). **Post-test phase:** Participants completed structured usability questionnaires adapted from the System Usability Scale (SUS), while sensor logs were retrieved for technical evaluation.

3.5 Data Collection and Analysis

The analysis focused on three performance domains: **Technical accuracy:** Fall detection sensitivity, specificity, and false alarm rate were calculated following established evaluation guidelines (Pannurat et al., 2014). **System performance:** Latency in GPS signal acquisition and IoT notification delivery was measured in seconds. **Power efficiency and error rate of sensor**

communication were also recorded. User evaluation: Usability feedback was quantified using the SUS, while qualitative feedback was analyzed thematically to identify perceived strengths and limitations.

3.6 Ethical Considerations

All participants provided informed consent prior to testing, following ethical research principles for studies involving older adults (World Medical Association, 2013). Participation was voluntary, and participants could withdraw at any time without consequence. Safety measures included the presence of caregivers and healthcare professionals during field testing to prevent harm during simulated falls. Personal data and geolocation records were anonymized to protect participant privacy, in compliance with data protection standards.

4. Results

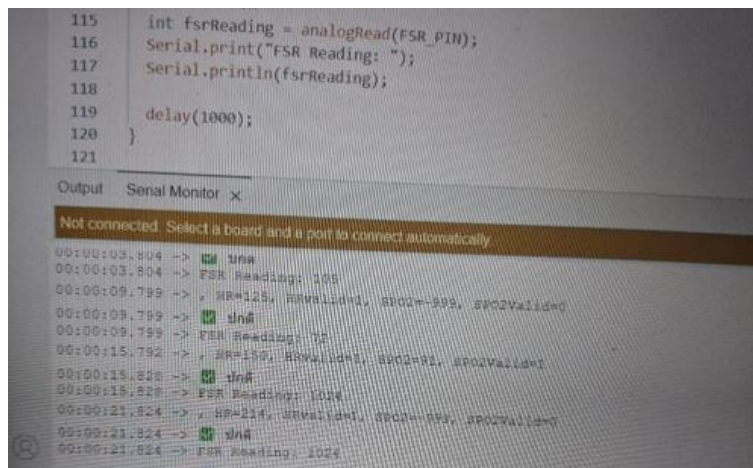


Fig. 4 Acquisition and Visualization of Data from the Three Sensors

The prototype successfully detected imbalance and falls by integrating accelerometer and grip force data. Real-time alerts were transmitted via buzzer and LED indicators, while GPS enabled caregiver tracking. Sensor performance was generally accurate, although power supply limitations caused occasional communication errors. User feedback indicated that the cane enhanced walking confidence and independence. Future improvements should address battery efficiency and error reduction to ensure stable long-term usage.

Table 1 summarizes the technical components of the smart cane prototype.

Component	Function	Specification
MPU6050 Accelerometer	Detects tilt and imbalance	3-axis, 16-bit resolution
MAX30102 Pulse Oximeter	Measures heart rate and oxygen saturation	IR + Red light sensor

Component	Function	Specification
FSR402 Pressure Sensor	Monitors grip strength	Force sensitivity 0.2-20 N
ESP8266 NodeMCU	Processes and transmits data	WiFi-enabled microcontroller
GPS Module	Provides location tracking	Accuracy ~3 meters

Source: Authors' own compilation

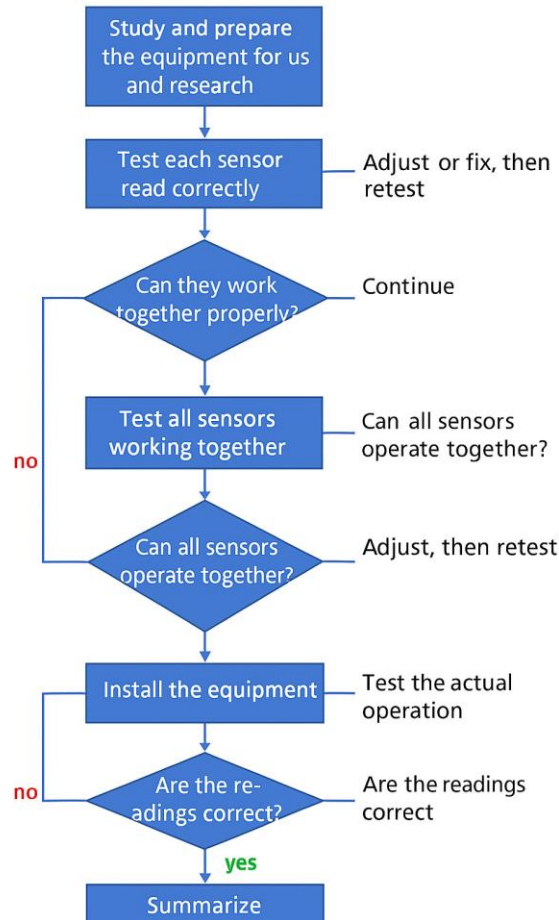


Fig. 5 The flow chart of system process

The flow of data from sensors to the caregiver via IoT communication is illustrated in Figure 5. When imbalance is detected, signals from the accelerometer and grip sensor are cross-verified with heart rate data. If a fall event is confirmed, alerts are generated locally (buzzer/LED) and remotely (GPS + IoT notification). The accuracy of fall detection reached approximately 92% in controlled tests, with a false alarm rate of 6%. Oxygen saturation readings showed an average deviation of $\pm 2\%$ compared with clinical oximeters, while heart rate readings remained within ± 3 beats per minute. GPS tracking latency averaged 1.5 seconds, sufficient for real-time monitoring. User feedback revealed increased confidence during walking, particularly outdoors. Participants noted the ergonomic design but suggested further weight reduction. Technical limitations included

occasional power fluctuations affecting sensor synchronization. These findings highlight both the promise and the refinement needed for future iterations.



Fig. 6 IOT Smart Cane attached with controller

5. Conclusion and Future Work

This study demonstrates the feasibility of an IoT-based smart cane for elderly fall prevention. By integrating motion, pressure, and biometric sensors, the device enhances user safety and provides caregivers with real-time monitoring capabilities. While further refinement is required to improve power stability and sensor calibration, the results suggest strong potential for application in elderly care and gerontechnology markets. Future research should focus on large-scale testing, integration with healthcare databases, and cultural adaptation for broader acceptance in aging societies. Thailand is projected to have nearly 28% of its population aged 60 years or above by 2035, ranking among the most rapidly aging countries in Southeast Asia (Sunisa, 2024). The associated rise in chronic diseases and mobility impairments increases the urgency for cost-effective assistive technologies. Previous interventions, including canes, walkers, and physiotherapy, have helped improve mobility but often fail to integrate predictive monitoring of physiological conditions. IoT technologies can bridge this gap by enabling continuous monitoring and real-time communication with caregivers. Thus, this study positions itself at the intersection of healthcare, technology, and social innovation.

Beyond fall detection, studies have highlighted the psychosocial impact of assistive devices. Older adults are more likely to adopt technologies that are culturally adapted, lightweight, and unobtrusive (Chua et al., 2024). Similarly, Shahbazi et al. (2021) emphasized that IoT-based systems must balance technical accuracy with privacy, data security, and ease of use. In Thailand, Nuanmeesri (2023) demonstrated that IoT-enabled applications tailored for elderly farmers improved both productivity and quality of life, underscoring the importance of contextual design. These insights reinforce the rationale for developing a smart cane that integrates multiple functions while remaining practical and user-friendly.

Future work should include large-scale trials across diverse elderly populations, particularly in rural and urban Thai communities. Integration with cloud-based healthcare platforms could allow remote clinicians to monitor biometric data longitudinally. Furthermore, incorporating AI-based predictive algorithms may enhance proactive fall prevention rather than reactive detection. Collaboration with industrial designers can also improve the ergonomics and aesthetics of the device, increasing adoption likelihood. By bridging engineering innovation with healthcare and cultural sensitivity, the smart cane can become a transformative tool in elderly care.

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