A Comparative Study of Fall Detection Device for Elderly People Using Machine Learning

Dr. Dileep J[1], Janavi V G[2], Kampalli Pallavi[2], Talapaneni Mohan Krishna[2], R. Ranjith Kumar[2]

[1]Assistant Professor / Dept. of ECE / K S School of Engineering and Management /

Visvesvaraya Technological University, Bengaluru, India
[2]Student / Dept. of ECE / K S School of Engineering and Management /

Visvesvaraya Technological University, Bengaluru, India
Corresponding Author Email: mohankrishns11@gmail.com | ORCID: https://orcid.org/my-orcid?orcid=0000-0001-8998-7136

How to Cite this Article:

J, D., G, J. V., Pallavi, K., Krishna, T. M. & Kumar, R. R. (2026). A Comparative Study of Fall Detection Device for Elderly People Using Machine Learning. International Journal of Creative and Open Research in Engineering and Management, <i>02</i>(9), 1-9. https://doi.org/10.55041/ijcope.v2i9.099

https://doi.org/10.55041/ijcope.v2i9.099

ABSTRACT —

Falls are a major cause of injury, disability, and hospitalization among elderly individuals, particularly those living independently without continuous supervision. The absence of timely assistance following a fall can lead to severe medical complications and increased mortality risk. To address this challenge, extensive research has been carried out in the domain of fall detection, employing a variety of approaches ranging from simple threshold-based methods to advanced Machine Learning and Deep Learning techniques. This paper presents a comparative study of existing fall detection methodologies, evaluating their accuracy, computational complexity, power consumption, and suitability for real-time wearable applications. Threshold-based systems, while computationally simple, often suffer from high false-positive rates and lack adaptability to varied movement patterns. Deep Learning-based approaches offer improved accuracy but demand significant computational resources, making them less suitable for low-power embedded devices. Based on insights drawn from this comparative analysis, the paper proposes a smart fall detection system that combines wearable sensor technology, a lightweight Machine Learning model, and IoT-based communication to achieve a practical balance between accuracy, efficiency, and cost-effectiveness. The system acquires motion data through a tri-axial accelerometer and gyroscope, applies preprocessing and feature extraction techniques, and utilizes a lightweight ML model deployed on a low-power microcontroller for real-time fall classification. Upon detecting a fall, the system triggers immediate local alerts and transmits emergency notifications along with location data to caregivers through an IoT platform, along with a reset mechanism to minimize false alarms. The comparative evaluation demonstrates that the proposed approach effectively overcomes the limitations of traditional threshold-based and resource-intensive deep learning methods, offering a scalable and reliable solution for elderly safety and remote health monitoring.

Keywords— Fall Detection, Machine Learning, ESP32, MPU6050, IoT, Elderly Care, Wearable Sensors, GPS Module

I. INTRODUCTION

Falls represent a significant health risk for elderly individuals, as aging is often associated with decreased muscle strength, impaired balance, and slower reflex responses. These factors increase the likelihood of accidental falls, which can lead to severe injuries such as fractures, head trauma, and long-term disabilities. In many cases, elderly individuals live independently without constant supervision, and a delay in receiving medical assistance after a fall can result in critical health complications or even fatal outcomes. Therefore, timely detection and rapid response are essential to minimize the impact of such incidents.

Traditional monitoring by caregivers is not always practical, as it requires continuous human supervision, which may not be feasible in real-life scenarios. Conventional fall detection systems based on threshold values of acceleration or orientation are simple but often unreliable. These systems struggle to accurately differentiate between normal daily activities, such as sitting, bending, or lying down, and actual fall events, leading to high false alarm rates and reduced trust in the system.

With advancements in wearable sensor technology and embedded systems, there has been a growing interest in developing intelligent fall detection systems. Sensors such as accelerometers and gyroscopes are capable of capturing real-time motion data, which can be analyzed to identify patterns associated with falls. Machine Learning techniques play a crucial role in improving detection accuracy by learning complex patterns from sensor data rather than relying on fixed threshold values. This enables the system to adapt to different user behaviors and environments.

In this project, a smart fall detection system based on Machine Learning is proposed to address the limitations of traditional methods. The system utilizes an MPU6050 sensor to capture tri-axial acceleration and angular velocity data, which is processed using an ESP32 microcontroller. Data preprocessing techniques such as noise filtering and feature extraction are applied to improve data quality and highlight important motion characteristics. The extracted features are then used by a Machine Learning model to classify activities into fall and non-fall categories.

Furthermore, the system integrates Internet of Things (IoT) technology to provide real-time alert mechanisms. When a fall is detected, an immediate local alert is generated using a buzzer, and remote notifications along with GPS-based location tracking are sent to caregivers through platforms such as Blynk. This ensures timely assistance even if the user is unable to respond. A reset mechanism is also incorporated to minimize false alarms and improve system usability. The proposed system aims to provide a cost-effective, portable, and reliable solution for continuous monitoring of elderly individuals. By combining Machine Learning, wearable sensors, and IoT communication, the system enhances safety, reduces emergency response time, and contributes to the development of smart healthcare solutions.

II. LITERATURE REVIEW

Fall detection systems (FDS) have gained significant importance in recent years due to the increasing elderly population and the growing demand for continuous healthcare monitoring. Recent research focuses on integrating wearable sensors, Internet of Things (IoT), and Machine Learning (ML) techniques to improve detection accuracy, reduce false alarms, and provide real-time emergency response [1], [2]. Desai et al. [3] proposed a wearable belt-based fall detection system called “Hip-grip” using a 32-bit microcontroller and Logistic Regression algorithm. The system achieved 100% accuracy on a custom dataset and detected falls within 0.25 seconds. However, the system relied on manually collected data from a fixed body position, limiting its adaptability to different real-world conditions. To improve temporal learning and reduce noise in sensor signals, Kim et al. [4] introduced a lightweight Bidirectional Gated Recurrent Unit (BGRU) architecture. The model used a Butterworth low-pass filter to separate body acceleration from gravity and unwanted noise before classification. This filtering process improved the quality of motion signals and helped the model achieve over 92% accuracy with a prediction time of only 0.14 ms. The Butterworth filter improves accuracy by smoothing sudden signal fluctuations while preserving important fall-related motion patterns. Deep learning-based methods have also shown significant improvement in fall detection performance.

Bhatti et al. [5] proposed a Hybrid CNN–LSTM–Attention framework capable of detecting falls across pre-impact, transition, and post-impact phases. The CNN layers extract spatial motion features, while the LSTM network captures temporal dependencies in sequential sensor data. The attention mechanism prioritizes important motion features during classification. By using optimized lightweight layers and reduced feature dimensions, the framework achieved sub-20 ms inference time with 98% accuracy. In this framework, the pre-impact phase refers to the stage before the body hits the ground, where sudden imbalance or abnormal acceleration begins. The transition phase represents the actual falling movement where rapid posture change and body tilt occur. Post-impact refers to the condition after the body reaches the ground and remains motionless. Detecting falls during the pre-impact phase is important because it allows preventive safety mechanisms such as airbags or protective gear to activate before impact occurs.To reduce computational complexity for embedded systems,

Wang et al. [6] proposed CMFALL, a three-state cascade algorithm using a lightweight Self-Attention Convolutional Neural Network (SA-CNN).The model effectively filtered non-fall activities while maintaining a high F1-score of 99.13% with a model size of only 8.8 KB, making it suitable for low-power wearable devices.Context-aware fall detection approaches were explored by Besrour et al. [7], where fall signals were inserted into continuous daily activity data to simulate realistic environments. The study showed that CatBoost outperformed other tree-based models for detecting hard falls, although performance decreased when falls were only partially captured. Sensor placement also plays an important role in wearable fall detection systems. Mekruksavanich and Jitpattanakul [8] proposed the FD-ResNeXt deep residual framework and found that neck-mounted sensors achieved the highest accuracy of 99.15%, while pocket-placed sensors showed poor performance of only 33.98%.

Their work highlighted the importance of optimal sensor positioning for reliable detection.

Pratap et al. [9] introduced the “Kinesi” framework using the Uniform Manifold Approximation and Projection (UMAP) algorithm for dimensionality reduction and motion visualization. The framework achieved 92.5% accuracy while reducing computational complexity for wearable edge devices. IoT-based systems have also been widely investigated. Hossain et al. [10] proposed the FallDS-IoT system using an MPU6050 sensor and Arduino Uno platform. Among several machine learning algorithms tested, the K-Nearest Neighbors (K-NN) classifier achieved 97.85% accuracy in classifying fall and daily living activities. Similarly, Santhanamari et al. [11] developed a smart wearable healthcare monitoring system integrating MPU6050, MAX30100, GPS, and GSM modules. Their Random Forest model achieved 97% accuracy while simultaneously monitoring heart rate and SpO2 levels. Beyond detection, proactive protection mechanisms have also been explored. Devipriya et al. [12] integrated a K-NN-based fall detection model with an automatic airbag system capable of reducing peak impact force by 65–75%, thereby minimizing injury during falls. Vision-based approaches provide an alternative to wearable systems.

Kalaiarasi et al. [13] proposed a YOLOv10-based patient monitoring system for hospital environments. The model achieved 97.2% accuracy without requiring wearable devices, although such systems are limited by privacy concerns and camera coverage constraints.Despite these advancements, existing fall detection systems still face several challenges such as high false alarm rates, dependency on sensor positioning, computational limitations of embedded devices, and the requirement for continuous internet connectivity [5], [8], [10]. Therefore, there is a need for a lightweight, accurate, and energy-efficient fall detection system capable of operating in real time with minimal computational overhead. [14] L. Oden and T. Witt, “Fall-Detection on a Wearable Microcontroller Using Machine Learning Algorithms,” in 2020 IEEE Internationa Conference on Healthcare Informatics (ICHI), 2020, pp. 1–6.

This paper proposed a wearable fall detection system implemented on an Arduino-based microcontroller using lightweight machine learning algorithms. The system utilized acceleration variance and motion features for real-time fall classification while operating under strict memory and computational limitations. The model achieved approximately 94.2% accuracy and demonstrated the feasibility of deploying ML models on low-power embedded wearable devices.[15] A. H. Mohd Saod, A. A. Mustafa, Z. H. Che Soh, S. A. Ramlan, and N. A. Harron, “Fall Detection System Using Wearable Sensors with Automated Notification,” in 2021 IEEE 11th International Conference on Control System, Computing and Engineering (ICCSCE), 2021, pp. 182–187. This work presented an IoT-based wearable fall detection system using MPU6050 accelerometer and gyroscope sensors integrated with NodeMCU and Blynk cloud services.

The system monitored Activities of Daily Living (ADL) and fall events while sending automated notifications to caregivers. The proposed system achieved 97% accuracy and reduced false alarms using threshold-based detection and reset mechanisms. The proposed system addresses these challenges by integrating an MPU6050 sensor for motion detection, a lightweight Machine Learning model for classification, and ESP32-based IoT communication for real-time alert generation. The system ensures accurate fall detection while maintaining low power consumption and cost, making it suitable for practical deployment in elderly care application .The proposed system addresses these challenges by integrating an MPU6050 sensor for motion detection, a lightweight Machine Learning model for classification, and ESP32-based IoT communication for real-time alert generation. The system ensures accurate fall detection while maintaining low power consumption and making it suitable for practical deployment in elderly care applications.

III. COMPARISON OF THE TECHNIQUES

Table I: Comparison Table

Paper	Methodology	Accuracy (%)	Research Gap
[1]	Threshold-based (Accelerometer)	97%	May produce false alarms due to simple threshold logic
[2]	Deep Learning (Wearable Sensor)	99.15% (neck), 33.98% (pocket)	Performance depends on sensor placement
[3]	UMAP + Machine Learning (Tri-axial Sensor)	92.5%	Limited performance in complex real-world scenarios
[4]	Machine Learning (Accelerometer + Gyroscope)	97%	Requires proper training data for accuracy
[5]	Decision Tree / SVM (Sensor-based)	~94.2%	Limited scalability and detection range
[6]	ML-based (Belt Sensor)	Fast (~0.25 sec)	Accuracy depends on correct positioning

The proposed system is built around the ESP32 microcontroller, which serves as the central processing unit, handling sensor data acquisition, Machine Learning-based decision-making, and communication with IoT platforms through its built-in Wi-Fi capability. Motion data is captured using the MPU6050 sensor, which measures tri-axial acceleration and angular velocity to continuously track body movement and detect sudden impacts or abnormal orientation indicative of a fall. This sensor data is processed by a lightweight Machine Learning model that analyzes extracted features such as acceleration magnitude, impact intensity, and motion variation to accurately classify activities as fall or non-fall, thereby reducing false alarms compared to conventional threshold-based methods. Upon fall detection, a buzzer provides an immediate local audible alert, while a GPS module simultaneously determines the user's real-time location to assist caregivers in providing timely help. The alert, along with GPS coordinates, is transmitted through the Blynk IoT platform to a mobile application, ensuring caregivers or family members are notified instantly. To minimize false positives, a push button is incorporated as a manual reset mechanism, allowing the user to cancel an alert if assistance is not required. The entire system is powered by a battery, ensuring portability and enabling continuous, reliable operation as a wearable device.

V. CONCLUSION

This study presented a comparative analysis of existing fall detection methods, highlighting the trade-offs between simplicity, accuracy, and computational efficiency across threshold-based, machine learning, and deep learning approaches. While threshold-based systems are fast but prone to false alarms, and deep learning models offer higher accuracy at the cost of heavy computational resources, both approaches face limitations in practical, real-time wearable applications. Based on these insights, the proposed smart fall detection system combines wearable sensor technology, a lightweight machine learning model, and IoT-based communication to achieve a balanced trade-off between accuracy, efficiency, and real-time performance. By enabling reliable fall detection and immediate alert transmission to caregivers, the system ensures a quick emergency response, reducing the risk of serious injury or complications. Overall, the developed system offers a cost-effective, reliable, and user-friendly solution for elderly monitoring, contributing to improved safety and greater confidence in independent living. Future work can focus on expanding the dataset with more diverse fall and non-fall scenarios, integrating additional health parameters such as heart rate, and further optimizing the model for even lower power consumption and higher classification accuracy.

REFERENCES

[1] K. Desai, P. Mane, M. Dsilva, A. Zare, P. Shingala, and D. Ambawade, "A Novel Machine Learning Based Wearable Belt For Fall Detection," Dept. of Electronics and Telecommunication, Sardar Patel Institute of Technology, Mumbai, India, [n.d.].

[2] P. Kalaiarasi, V. Adhitya, K. Naveen, K. Lavanya, and M. V. A. Kumar, "A Real-Time Vision-based Fall Detection System using YOLOv10 and Deep Learning for Ensuring Elderly and Patient Safety," Dept. of Computer Science, Kalasalingam Academy of Research and Education, Krishnankoil, India, 2025.

[3] G. Santhanamari, S. Choudhary, S. M. Mohan PS, Gurusharan, and Vasanth L, "A Smart Wearable-Based Fall Detection and Health Monitoring System for Elderly Care Using IoT and Machine Learning," PSG Institute of Technology and Applied Research, Coimbatore, India, [n.d.].

[4] S. Mekruksavanich and A. Jitpattanakul, "Effect of Sensor Positions on Wearable Sensor-Based Fall Detection Using Deep Residual Network," *2025 IEEE*, pp. 1-6, 2025.

[5] L. Oden and T. Witt, "Fall-detection on a wearable micro controller using machine learning algorithms," *2020 IEEE International Conference on Smart Computing (SMARTCOMP)*, 2020, pp. 296-301.

[6] A. H. M. Saod, A. A. Mustafa, Z. H. C. Soh, S. A. Ramlan, and N. A. Harron, "Fall Detection System Using Wearable Sensors with Automated Notification," School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, Penang, Malaysia, [n.d.].

[7] A. Pratap, D. Sharma, and S. Sharma, "Kinesi: A Fall Detection Framework Converging 3 Axial Representation and UMAP Algorithm," *Proc. 15th ICCCNT IEEE Conference*, 2024,.

[8] I. Basu, S. Ray, S. Sarkar, S. Saha, and S. Panda, "Advancements in Fall Detection Technologies: A Comprehensive Review and Innovative Solutions," *Proc. 2023 7th International Conference on Electronics, Materials Engineering & Nano-Technology (IEMENTech)*, 2023, pp. 1-3.

[9] F. A. Bhatti, Q. Riaz, and B. Krüger, "Beyond Falls: A Hybrid CNN–LSTM–Attention Framework for Pre-, Transition-, and Post-Fall Detection With Wearable Inertial Sensors," *IEEE Access*, vol. 13, pp. 41336–41366, 2025.

[10] S. Besrour, G. S. Mubibya, Z. Liu, and J. Almhana, "Context-Aware Hard and Slow Fall Detection," Dept. of Computer Science, University of Moncton, New Brunswick, Canada, 2023.

[11] S. Kim, G. Lee, and J. Kim, "Lightweight Real-time Fall Detection using Bidirectional Recurrent Neural Network," *Proc. 2020 11th International Conference on Soft Computing and Intelligent Systems (SCIS-ISIS)*, 2020, pp. 1-6.

[12] G. Wang, Q. Li, L. Wang, Y. Zhang, and Z. Liu, "CMFALL: A Cascade and Parallel Multi-State Fall Detection Algorithm Using Waist-Mounted Tri-Axial Accelerometer Signals," *IEEE*

Transactions on Consumer Electronics, vol. 66, no. 3, pp. 261–270, Aug. 2020.

[13] Z. Jiang, M. A. A. Al-Qaness, D. Al-Alimi, A. A. Ewees, M. Abd Elaziz, A. Dahou, and A. M. Helmi, "Fall Detection Systems for Internet of Medical Things Based on Wearable Sensors: A Review," *IEEE Internet of Things Journal*, 2024.

[14] W. Xu, Y. Chen, Q. Zhang, C. Zhang, G. Chen, and Y. Xiao, "A Gait Fall Detection System for the Elderly Based on Wearable Devices and Machine Learning Algorithms," *2025 IEEE*, pp. 1-6, 2025.

[15] M. S. Hossain, A. A. Niloy, M. Akhtaruzzaman, M. W. H. A. Shaan, M. A. A. Noman, and M. M. Hasan, "IoT-Based Fall Detection System for the Elderly Using Machine Learning Algorithms," Canadian University of Bangladesh (CUB), Dhaka, Bangladesh, 2024,.

[16] Dr. R. Lavanya, M. Abinaya, Basaveshwara S.R, and Akshayaa MA, "Fall Detection and Prevention using IoT in Senior Care Facilities," Dr. SNS Rajalakshmi College of Arts and Science, Coimbatore, India, 2023