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Integration of Smart Technologies for the Elderly in Home-Based Fall Prevention Systems: A Systematic Review

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Abstract

The increasing global aging population has led to a surge in falls among the elderly, which has emerged as an escalating public health concern. Despite active research on fall detection and prevention in older adults, addressing this complex issue requires the integration of multiple advanced technologies and theoretical underpinnings. This study employs a systematic review approach to comprehensively examine the latest technologies and algorithms available for preventing falls in elderly households. Specifically, it provides an overview of various techniques employed for fall monitoring along with their respective advantages and disadvantages. Likewise, it discusses the application, accuracy, and reliability of advanced detection algorithms. The paper also evaluates design principles and methodologies for developing fall prevention systems tailored to older adults, emphasizing the importance of privacy protection and social support as critical factors. The identification of critical challenges and the proposal of prospective research directions are discussed. The conclusions drawn from this review are intended to provide researchers, service providers, and designers with a comprehensive understanding of current advanced technologies and potential future directions in the field of elderly home fall prevention.

Keywords: Elderly fall Prevention, Fall Detection Algorithms; Smart Home System, Internet of Things (IOT)

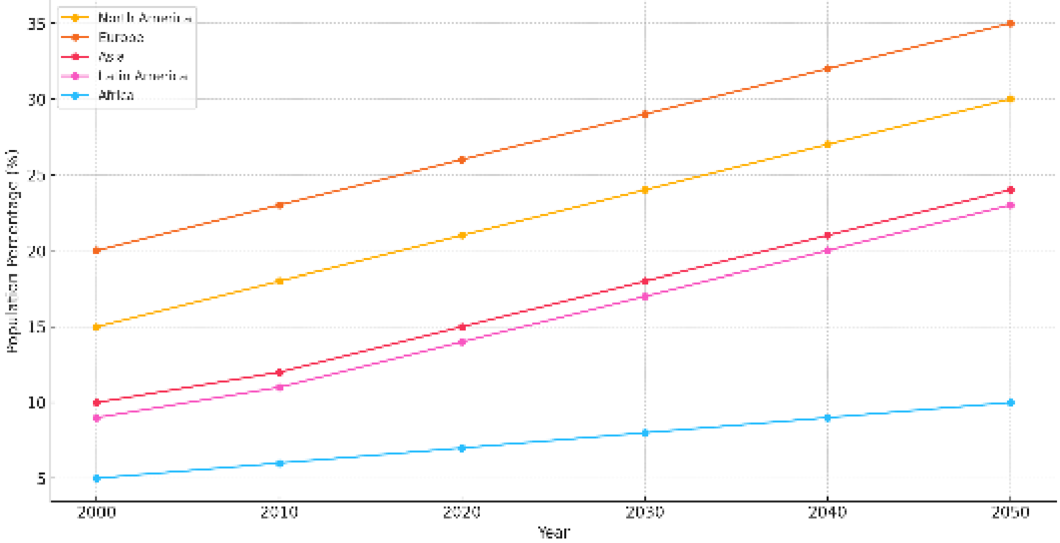
Introduction

In recent years, the academic community has paid more and more attention to the fall of the elderly at home. Over the past decades, researchers have increasingly put their efforts into research on fall detection technologies, fall prevention algorithms, and related devices, resulting in notable advancements.

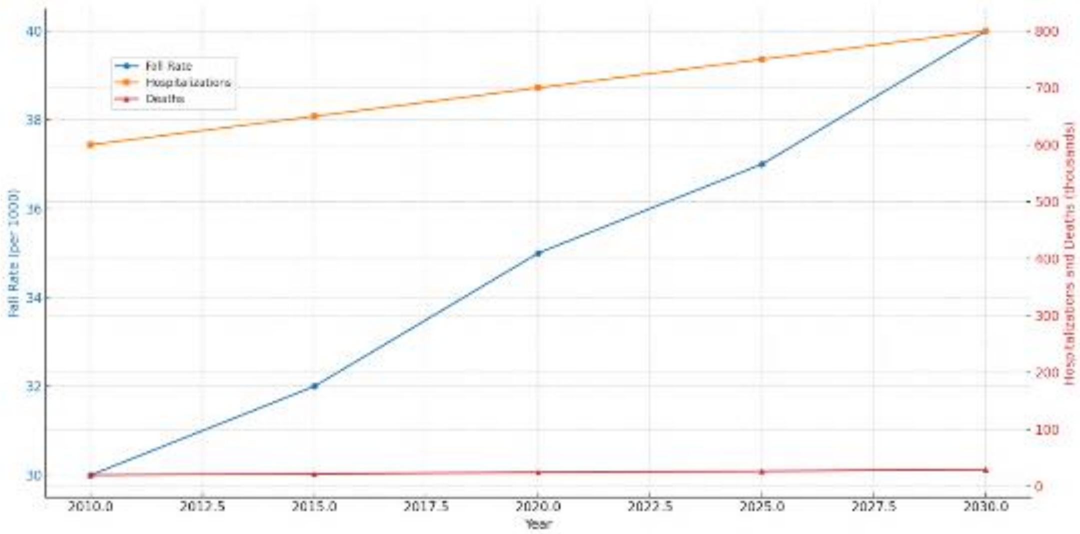
Background

The increasing global aging population has brought the safety of elderly individuals at home, particularly fall prevention, to the forefront of social concern. According to data from the Centers for Disease Control and Prevention (CDC), falls are the leading cause of injury-related deaths among people aged 65 and above. Each year, there are approximately 32 million fall incidents, resulting in 800,000 hospitalizations and about 30,000 deaths (CDC & WHO, 2023). Additionally, falls have significant negative impacts on individuals' physical health, family harmony, and the entire healthcare system (NCOA, 2024).

Figure 1's (a) chart shows the demographic shift in the population aged 60 and above across major global regions from 2000 to 2050. (b) The chart shows the trends in falls incidence (number of falls per thousand people), falls-related hospitalizations (thousands of people), and falls-related deaths (thousands of people) among older adults from 2010 to 2030. The two-axis format effectively illustrates the temporal correlation between these variables. Together, Figure 1 offers a comprehensive outlook on the demographic and health-related obstacles confronting an aging population, underscoring the pressing necessity for integrated and innovative approaches to mitigate falls and provide care for elderly individuals.



(a)



(b)

Fig. 1. Global Aging Trends Compared with Elderly Fall Incident (a) Global Aging Trends (b) Elderly Fall Incident Statistics.
Source: (United Nations, 2019; CDC, 2023; WHO, 2021; NCOA, 2024)

Research Gap & Aim

Currently, there are numerous research projects and product developments focused on fall prevention for the elderly. Scholars are dedicated to developing systems and devices that can accurately detect falls and respond immediately. These research areas include household fall warning devices, motion-sensing anti-fall products, fall prevention safety airbags, and smart mobile applications (Abbasi, Alam, & Malik, 2021; Mubashir, Shao, & Seed, 2013). Moreover, intelligent home devices, such as environmental monitoring systems and remote alarms, further enhance the multi-layered defenses for elderly home safety (Wang, Yang, & Zhang, 2020).

Despite numerous related research findings and product designs, there are still many gaps and challenges in the field of intelligent aging research (Mitzner *et al*., 2010; Chen & Chan, 2014). The primary issue is how to construct a smart home fall prevention system environment based on the Internet of Things (IoT) technology, making it compatible with more application products and devices (Liu, Huang, & Yang, 2019). Additionally, there is an insufficient understanding of the complex factors and dynamic evolution processes involved in the fall risks of the elderly, which directly affects the effectiveness of preventive measures (Bergen *et al*., 2021; CDC, 2021). Furthermore, the design of products suitable for the elderly needs further refinement to ensure these products better meet the special needs and personal preferences of the elderly (Lee, Azam, & Ahmed, 2022). Considering the low integration level of the elderly with new technologies, improving user experience and convenience is also a key concern (Peek *et al.*, 2014; Lee & Coughlin, 2015).

This study aims to organically integrate various advanced technologies mentioned above into the construction of a home fall prevention environment, thereby increasing the safety of the elderly in their living environments, reducing their fall risks, and improving their overall quality of life.

Methodology

This systematic review aims to explore the integration of smart technologies in home-based fall prevention systems for the elderly. To address this, the research methodology was designed to systematically collect, analyze, and synthesize relevant literature from various academic databases, including PubMed, IEEE Xplore, Google Scholar, and Scopus. A structured search was conducted using specific keywords such as "elderly fall prevention," "home fall detection," and "smart home technology." These keywords were chosen to ensure comprehensive coverage of existing fall prevention technologies and their implementation in elderly care.The inclusion criteria for the selected studies include peer-reviewed articles published between 2010 and 2024 that provide empirical data or comprehensive reviews of in-home fall prevention techniques. Studies without adequate empirical evidence or unrelated to home-based prevention systems were excluded.

The selection process involved multiple stages: initially, titles and abstracts were screened for relevance. After this, a full-text review of the selected studies was conducted to ensure

that they met the inclusion criteria. Data extraction focused on key components such as technical specifications, effectiveness indicators, and algorithm performance metrics. The synthesized data were then qualitatively analyzed to highlight trends, challenges, and recommendations for future research.
Throughout the literature review process, EndNote was used for reference management.

Research Significance

From an academic point of view, this study broadens the theoretical research scope of current fall prevention technologies while offering specific application scenarios for future inquiries. Regarding practical implementation, these findings can serve as a guideline for designing and deploying home anti-fall systems. Overall, this study will provide valuable guidance to older adults in reducing fall incidents, enhancing their quality of life, and contributing to economic advancements in the aging society.

Advances in Fall Monitoring and Detection Technologies

Fall monitoring and detection technologies have seen significant advancements in recent years, driven by the urgent need to address the high incidence of falls among the elderly (Pannurat *et al*., 2017). Fall monitoring technologies can be broadly categorized into three main types: wearable devices, environmental sensors, and camera-based systems (Zhou *et al*., 2021). These technologies utilize a variety of sensors and algorithms to accurately detect falls and send alerts in time for timely intervention, or to predict falls before they occur so that preventive measures can be taken (El-Bendary *et al.*, 2013). Each of these technologies has unique advantages and limitations, making them suitable for different applications and environments (Khan & Byun, 2020).

Wearable Devices

Wearable devices have made significant contributions to fall monitoring due to their portability and ability to provide real-time alerts. These devices are particularly valuable for elderly individuals who live alone or are at high risk of falling. Wearable devices also often include additional health-monitoring features, such as heart rate and activity tracking, making them a comprehensive tool for managing health. The integration of machine learning algorithms has further enhanced the accuracy of fall detection in wearable devices (Gao *et al*., 2020).

The integration of accelerometers and gyroscopes has become crucial in the latest wearable technology for fall detection. These sensors are typically embedded in wearable items like wristbands or pendants, utilizing sensor fusion technology to generate a comprehensive description of the wearer's movements and orientation (Yu *et al*., 2022). By fusing data from these sensors, it becomes possible to construct detailed action models that not only identify sudden movements such as falls but also differentiate them from non-hazardous activities like abruptly sitting down (Luo *et al.*, 2020). Moreover, an immediate response is ensured once a fall is detected through real-time analytics capabilities of these devices. This includes alerting users or caregivers and activating emergency plans if necessary.

Based on the aforementioned analysis, Figure 2 was created to presents a visually intuitive representation of how wearable fall detection devices, specifically those utilizing accelerometers and gyroscopes, collect and analyze data during a fall event. This diagram, based on research conducted by Burke *et al*. (2010), Yavuz *et al*. (2019), and Wang *et al*. (2022), illustrates the temporal variations in acceleration and angular velocity throughout simulated falls. The blue line depicts the recorded acceleration data while the red line represents angular velocity measurements. This graphical depiction effectively demonstrates the dynamic changes in accelerometer and gyroscope readings during a fall episode, thereby highlighting the complementary attributes of these two sensors for accurate detection and analysis purposes.

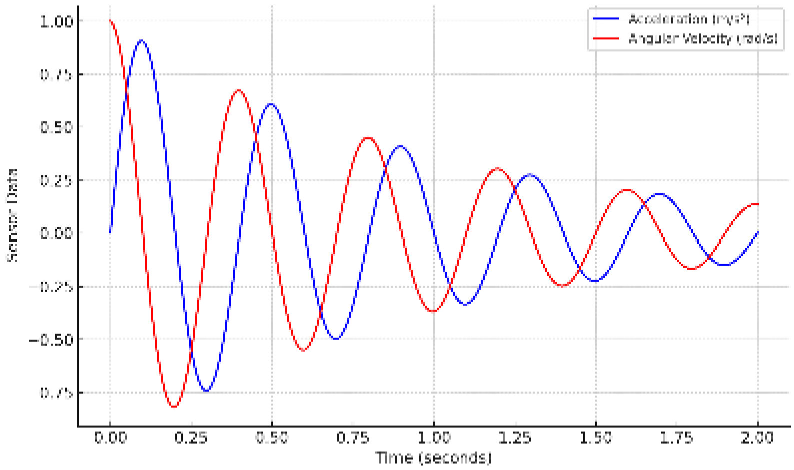


Fig. 2. Acceleration and Angular Velocity Over Time During a Fall Event

It is worth mentioning that many modern wearables also incorporate context-aware features. Through analyzing daily movement patterns and environmental data, these devices can further refine the sensitivity of fall detection, reducing unnecessary alarms while enhancing the accuracy of detecting actual falls (Tarnwar *et al*., 2022).

Environmental Sensors

Environmental sensors are a critical component in modern fall monitoring systems, designed to detect and prevent falls in specific environments without requiring the individual to wear any device (Delahoz & Labrador, 2014; Sixsmith & Johnson, 2004). These sensors are typically installed in high-risk areas within a living space, such as bathrooms, bedrooms, and stairways, where falls are more likely to occur (Igual *et al*., 2013). Environmental sensors work by monitoring the physical environment and detecting anomalies that could indicate a fall, such as sudden changes in pressure, vibrations, or motion (Alwan *et al*., 2006). Their non-intrusive nature and ability to cover large areas make them particularly effective for monitoring elderly individuals who may not be comfortable wearing personal devices or for situations where continuous, passive monitoring is required (Liu *et al*., 2016).

There are several types of environmental sensors used in fall detection. Pressure-sensitive flooring is one of the most common; sensors embedded in the floor detect changes in pressure when a person falls. Products such as the "Smart Floor" system, which analyzes pressure patterns to distinguish between normal walking and a fall, have implemented this technology (Lu *et al*., 2018; Hussain *et al*., 2019). Vibration sensors, another widely used type, detect falls by sensing the vibrations caused when a person hits the ground. Often integrated into the floor or furniture, these sensors are particularly effective in detecting hard falls (Yu *et al.*, 2019; Elnour *et al.*, 2020). Fall detection systems also employ infrared motion sensors, which detect changes in infrared radiation. Typically, fall detection systems use these sensors in conjunction with other sensors to enhance accuracy, as they can detect the movement and heat signature of a person in the monitored area (Chaudhuri *et al*., 2021). Market products like the Vayyar Home, designed to detect falls and monitor movement without invading privacy, utilize a combination of sensors, including infrared (Wang *et al*., 2020).

Table 1, presents a comprehensive comparison of environmental sensors utilized in fall detection systems. This systematic analysis highlights the distinct sensor types, emphasizing their functionalities, advantages, disadvantages, and typical applications. Notably, the table incorporates specific examples and products employing these sensors to offer a well-structured overview of their practical implementation in real-world settings.

Table 1
Detailed Sensor Comparison Table

Sensor Type	Researchers & Year	Function	Working Principle	Advantages	Drawbacks
Accelerometers	Liu *et al*., 2020; Shany *et al*., 2012	Measures acceleration forces	Measure acceleration forces along multiple axes(X,Y,Z).Detect sudden changes in movement,characteristic of a fall.	High sensitivity, real-time monitoring, portable	False positives due to non-fall activities
Gyroscopes	Liu *et al*., 2020; Shany *et al*., 2012	Measures orientation and angular velocity	Measure the rate of rotation around an axis. Provide information about orientation and angular velocity.	Precise body orientation, reduces false positives	Requires calibration, magnetic interference
Pressure Sensors	Yang *et al*., 2019; Noury *et al*., 2007	Detects pressure changes on surfaces	Detect changes in pressure when a force is applied to a surface, indicating a fall.	Effective in specific locations, non-intrusive	Limited to specific areas, no continuous monitoring
Floor Vibration Sensors	Yang *et al*., 2019; Noury *et al*., 2007	Detects vibrations caused by falls	Detect vibrations that occur when a person falls to the ground, differentiating from normal foot traffic.	Non-intrusive, covers larger areas	Ineffective on soft surfaces
Infrared Motion Sensors	Chen *et al*., 2021; Stone & Skubic, 2011	Detects movement and infrared radiation changes	Use infrared light to detect movement and changes in infrared radiation patterns.	Effective in low-light, non-intrusive	Limited range, false positives from pets
Cameras	Chen *et al*., 2021; Stone & Skubic, 2011	Uses video and computer vision algorithms	Analyze video feeds using computer vision algorithms to identify unusual movements indicative of a fall.	Monitors large areas, detailed fall event information	Privacy concerns, high computational requirements

The table serves as an effective resource for researchers, developers, and decision-makers in relevant industries, offering a comprehensive and succinct overview of sensor options. This facilitates the advancement of safer and more efficient monitoring solutions tailored to older adults.

The "Environmental Sensors and Their Applications in Fall Detection" figure3, is designed to facilitate users' comprehension of the diverse environmental sensors employed in fall detection systems and their practical applications. The X-axis represents the significance and universality of each sensor type along with its application method. The Y-axis enumerates the distinct types of sensors (blue) and their corresponding application methods (green). The length of each colour block indicates the popularity and importance of this particular sensor type as well as its application method within the fall detection environment.

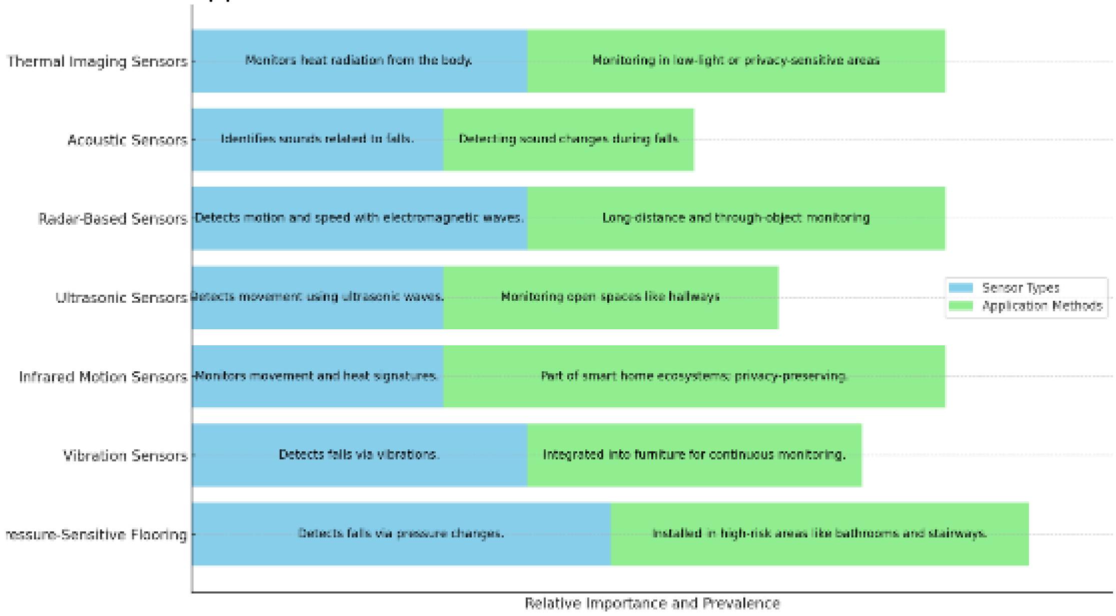


Fig.3. Environmental Sensors and Their Applications in Fall Detection

By analyzing this chart, users can efficiently identify the predominant types of sensors and comprehend their typical applications in settings such as smart homes or healthcare facilities, thereby facilitating the selection of the most suitable technology for specific needs.

Summary

This chapter provides an in-depth look at advancements in fall monitoring and detection technology, with a focus on wearable devices, environmental sensors, and camera-based systems. For each technology category, its unique advantages, limitations, and specific applications are analyzed, highlighting how they can enhance the safety of older adults in a variety of settings.

As a comprehensive overview of the findings in this chapter, Table 2 presents a side-by-side comparison of key fall monitoring techniques, encompassing specific examples and products utilized by each technology type, along with the corresponding sensors employed, as well as their respective advantages and disadvantages. The table serves as a succinct and precise point of reference for comprehending the trade-offs inherent in different fall monitoring techniques.

Table 2
Comparison of Fall Monitoring and Detection Technologies

Items	Examples&Products	Sensors Used	Advantages	Drawbacks
Wearable Devices	Apple Watch, Fitbit (Apple Inc., 2023; Fitbit Inc., 2022)	Accelerometers, Gyroscopes	Portable, real-time monitoring, integrated health features (Pannurat *et al*., 2017; Khan & Byun, 2020)	False positives, requires continuous use, limited battery life (Yavuz *et al*., 2018)
	Philips Lifeline, MyNotifi (Philips Lifeline, 2023)	Accelerometers, Gyroscopes	Reliable, specific design for elderly, immediate alerts (Pannurat *et al*., 2017; Abbate *et al.*, 2020)	False positives, requires continuous use, potential cost barriers (Weinschrott *et al.*, 2020)
	ActiveProtective Smart Belt, Fall Detection Vest (Stone *et al*., 2018; Gietzelt *et al*., 2013)	Accelerometers, Gyroscopes, Airbag Systems	Continuous monitoring, less intrusive, provides protection (e.g., airbags) (Gietzelt *et al*., 2013; Kozina *et al*., 2019)	Higher cost, maintenance required, potential discomfort for some users (Stone *et al*., 2018)
Sensors	Pressure-sensitive flooring (Yang *et al*., 2019)	Pressure Sensors, Vibration Sensors, Infrared Motion Detectors	Non-intrusive, large area coverage, effective in high-risk areas (Yang *et al*., 2019; De Miguel *et al*., 2020)	Limited to specific locations, may not detect falls on soft surfaces, costly (Yang *et al*., 2019)
Systems	AI-powered camera systems, privacy-preserving techniques (Zhang *et al*., 2021; Chen *et al*., 2021)	Cameras, Computer Vision Algorithms	Detailed fall information, large area monitoring, useful in clinical settings (Zhang *et al*., 2021; Synnott *et al*., 2019)	Privacy concerns, high computational needs, expensive installation and maintenance (Chen *et al*., 2021)

Algorithms in Home anti-Fall Systems Design

To establish an efficient family anti-fall system, it is imperative to rely on a well-designed framework. In the initial stages of constructing this framework, apart from considering the integration of cutting-edge technologies, the Internet of Things (IoT) technology also played a pivotal role. A thorough review of relevant literature in these domains will provide indispensable guidance for developing a comprehensive home fall protection system (Salah *et al.*, 2022; Modak *et al.*, 2024).

Design Principles and IoT

To design a family anti-fall system should prioritize the unique characteristics of the family environment, particularly for elderly individuals. Existing fall detection systems often emphasize user-centric design principles to ensure accessibility, non-intrusiveness, and ease of use (Mannhardt, Petersen, & Oliveira, 2018). This involves strategic sensor placement in high-risk areas such as bathrooms and staircases, as well as integration of wearable devices that seamlessly blend into daily life. Moreover, reliability and accuracy are crucial factors; the system must effectively differentiate between genuine falls and non-hazardous activities to minimize false positives (Newaz & Hanada, 2023). It is important to note that privacy concerns are also paramount due to the sensitive nature of personal space monitoring. To address these issues, privacy-preserving technologies like anonymous data processing and edge computing are increasingly being incorporated into system designs (Hiller, Schuldes, & Eckstein, 2019). These technologies guarantee local data processing with removal of identifying information before transmission or storage, thus preventing potential privacy breaches. Striking a balance between privacy protection, availability, and effectiveness is recommended by current standards through a multi-sensor approach that amalgamates data from various sensors to provide a comprehensive understanding of users' environments and behaviors (Morel, Cunche, & Métayer, 2019). Adhering to these principles is essential for developing fall prevention systems that are both effective in their purpose while being acceptable to users (Williamson & Prybutok, 2024).

The role of the Internet of Things (IoT) in the development of home protection systems is invaluable. It serves as the foundational infrastructure for constructing intelligent home systems, which can seamlessly connect and integrate various devices and sensors within a household, enabling them to communicate with each other and collaborate harmoniously. This connectivity plays a crucial role in facilitating real-time monitoring and response capabilities by allowing data collected from diverse sensors to be aggregated, analyzed, and acted upon instantaneously (Alharbi & Hassan, 2023). For instance, if a wearable device detects a fall incident, it can trigger an alert through a connected home assistant, send notifications to caregivers, or even activate emergency protocols. Moreover, IoT enables seamless integration with external data sources such as health records or environmental conditions that further enhance the system's ability to predict and prevent falls (Yacchirema *et al.*, 2018). The scalability and flexibility inherent in IoT systems also allow for personalized customization based on individual users' specific needs, providing tailored monitoring and intervention strategies (Gia *et al.*, 2018). In this way, the Internet of Things not only supports the technical realization of anti-fall systems but also enhances their functionality and responsiveness significantly—making them more effective in ensuring safety and well-being for elderly individuals at home (Manikandan *et al.*, 2020).

Algorithms integration in the Anti-Fall System

The algorithm's integration into the architecture of the fall protection system is essential to guaranteeing the technology's effectiveness and dependability. A range of algorithms frequently analyze sensor data in the fall detection domain to precisely detect instances of falls. Support vector machines (SVMs), decision trees, and threshold-based algorithms are commonly used to handle continuous data streams from wearables, environmental sensors, and camera-based systems (Khan, Liu, & Bailey, 2021). These algorithms are favored for their distinct advantages in handling such data. For instance, Support Vector Machines (SVMs) excel in classification, frequently identifying the optimal boundary between falls and non-fall activities for effective differentiation (Liu, Zhao, & Liu, 2022). However, decision trees provide a clearer and more understandable model that can handle both categorized and continuous data sources. This makes them ideal for complex scenarios that require careful consideration of various factors. Threshold-based algorithms, which are simpler yet efficient, utilize predetermined criteria to detect falls. These algorithms are commonly integrated into wearable devices due to their lower processing demands. Also, more advanced methods like adaptive threshold algorithms, sensor fusion techniques, convolutional neural networks (CNNs), and recurrent neural networks (RNNs) are being used more and more to make fall detection systems more accurate and durable (Tao, Zhou, & Zhu, 2018; Islam *et al.*, 2019; Fung *et al.*, 2019). These advanced algorithms are highly effective in minimizing the occurrence of incorrect positive results, and they can easily adjust to changing conditions in real-life settings (Newaz & Hanada, 2023). As a result, they have become essential elements of contemporary fall detection systems.

Table 3 presents a comparison of the aforementioned algorithms, focusing on three primary performance indicators: accuracy, response time (inversely proportional), and computing economy. Each method is evaluated based on its accuracy in detecting falls (a higher % indicates better performance), response time (inversely proportional, meaning a lower number is preferable), and efficiency in utilizing computing resources (a higher percentage indicates greater efficiency). To enhance the clarity of this information, we have also generated Figure 4. Those conclusions can serve as a point of reference for other researchers in the same field.

Table 3
Algorithms Performance Comparison Table

Algorithm	Accuracy (%)	Response Time (Inverse)	Computational Efficiency (%)
SVM	85	70	75
Decision Trees	75	80	85
Threshold-based	60	90	90
Adaptive Threshold	80	85	80
Sensor Fusion	85	75	70
CNN	90	60	60
RNN	85	65	65
RF-based	70	75	80

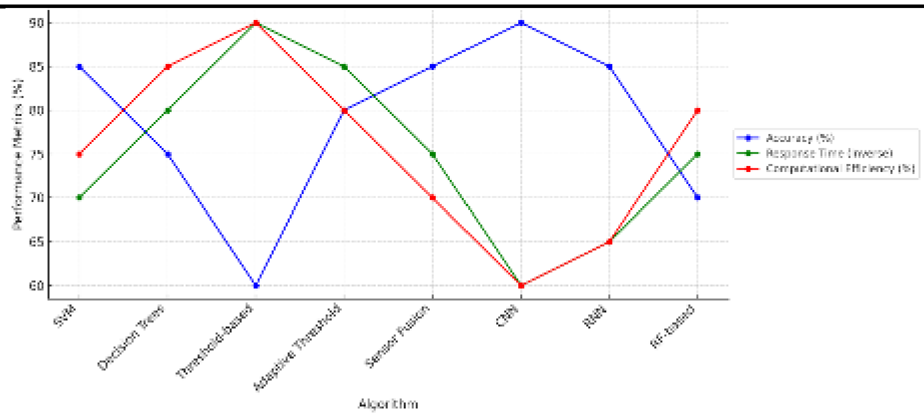


Fig.4. Environmental Sensors and Their Applications in Fall Detection

The incorporation of various algorithms into a home fall protection system has notable benefits, particularly in enhancing the overall precision and dependability of the system (Tao, Xu, Yun, & Zhu, 2018; Islam *et al.*, 2019; Newaz & Hanada, 2023). Table 4 has been created to provide a clear presentation of the pros and cons of different algorithms. Its purpose is to assist designers and decision makers in selecting the most suitable technique for their research.

This table enumerates a range of algorithms, such as support vector machines (SVMs), decision trees, threshold methods, adaptive threshold algorithms, sensor fusion techniques, convolutional neural networks (CNNs), and recurrent neural networks (RNNs), all of which are crucial in precisely analyzing sensor data to identify instances of falls. These algorithms are intended to analyze data from various sensors in wearables, smart home systems, or medical monitoring settings. Their purpose is to detect and differentiate fall occurrences from safe activities. The table demonstrates that each algorithm possesses its own set of benefits and drawbacks. However, combining various techniques, particularly in systems that necessitate exceptional accuracy and instantaneous processing, can result in a more efficient solution for detecting falls. This comparison emphasizes the significance of choosing the appropriate algorithm or combination of algorithms for the particular application and environment in order to enhance the performance of a fall detection system.

Table 4
Detailed Algorithm Comparison Table

Algorithm Type	Function	Application Area	Advantages	Drawbacks
Support Vector Machines (SVM)	Classification of fall vs. non-fall activities	Wearable devices	High accuracy in distinguishing classes	Computationally intensive
Decision Trees	Interpretable model for complex decision-making	Smart homes	Easily interpretable, handles both categorical and continuous data	Can be prone to overfitting with small datasets
Threshold-based	Simple detection based on predefined thresholds	Basic wearable falls detectors	Low computational requirements, fast processing	May generate false positives due to simple criteria
Adaptive Threshold	Dynamic adjustment of thresholds based on real-time data	Advanced wearable fall detectors	Adapts to changes in the environment or user behavior	Complex to implement and tune
Sensor Fusion	Combining data from multiple sensors for more accurate detection	Smart homes and healthcare	Reduces uncertainty by leveraging multiple data sources	High computational cost
Convolutional Neural Networks (CNN)	Pattern recognition in image or sequential data	Camera-based systems	High accuracy in recognizing complex patterns	Requires large datasets for training
Recurrent Neural Networks (RNN)	Sequential pattern recognition for time-series data	Integrated systems	Effective in capturing temporal dependencies	Can be computationally expensive and slow to train

Summary

This chapter provides an overview of the essential components required to create a successful home fall protection system, with a focus on integrated design concepts, Internet of Things (IoT) technologies, and advanced algorithms. Emphasizing the importance of user-centered design principles and privacy protection technologies is crucial for the development of fall detection systems that are accessible, dependable, and secure. The integration of the Internet of Things (IoT) enables smooth communication and enables real-time data processing, resulting in improved system responsiveness and customization. Furthermore, it is crucial to include a range of algorithms, such as support vector machines, decision trees, and advanced machine learning approaches, into the system to guarantee precision and dependability. By offering comprehensive comparison tables and charts, it offers researchers and designers a great resource for selecting the most suitable method for their specific application. This chapter highlights the importance of taking a comprehensive approach that integrates strong design, technical advancements, and precise algorithms to create efficient fall detection systems for senior individuals.

Conclusions

In this presented paper, we conduct a comprehensive review among the latest studies about the home fall prevention technology for the elderly. We compare various fall detection techniques and algorithms and find that integrating advanced algorithms such as machine learning, artificial intelligence, and adaptive threshold systems can significantly improve fall detection systems' accuracy and reliability. The Internet of Things (IoT) has proven to be a key component in creating connected systems with real-time monitoring and responsiveness. So future technology research should consider interfacing with IoT. Our research also revealed that despite the increasing integration of privacy-protecting technologies into system designs, concerns about data security and user privacy persist, particularly in systems that require continuous monitoring. Therefore, future research in fall prevention for the elderly should concentrate on developing scalable and flexible home systems that can effortlessly adapt to the distinct requirements of various users and environments. Addressing ethical and privacy issues in surveillance systems is critical to earning the trust of users.

In conclusion, while technology for preventing falls in the home setting has made significant progress, there is still plenty of room for innovation. By addressing current limitations and exploring new avenues of research, we can continue to advance this field and improve home safety and quality of life for older adults.

Contributions

This study makes meaningful contributions to both theoretical development and contextual understanding in the domain of smart aging and home-based fall prevention. By integrating smart technologies such as IoT infrastructure, multi-sensor environments, and AI-driven algorithms into a unified framework, the research bridges the gap between abstract technological models and their practical application in elderly care. This integration enhances existing theoretical perspectives by positioning fall prevention as a multidimensional challenge involving not only engineering and algorithmic efficiency but also behavioral health, environmental adaptability, and user-centered design. The comparative analysis of system components, algorithmic strategies, and application contexts expands the conceptual landscape for scholars and practitioners, offering a holistic viewpoint that extends beyond fragmented technological solutions. Importantly, this study highlights the ethical considerations of data privacy and user autonomy, providing theoretical grounding for the responsible design of intelligent systems in sensitive living environments. In the context of global demographic aging, especially in regions like East and Southeast Asia, the proposed framework presents a scalable and adaptable model for fall prevention that can inform interdisciplinary research, policy formulation, and the design of inclusive home-based interventions. It thereby contributes to the academic discourse on gerontechnology while addressing the societal imperative of enabling older adults to age safely and independently in an increasingly digitized world.

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