

LITERATURE REVIEW: DESIGN OF INTERNET OF HEALTH THINGS (IOHT) MODEL FOR FALL RISK DETECTION IN ELDERLY AT HOME

Dhika Dharmansyah¹

¹Doctoral Study Program, Faculty of Medicine, Universitas Padjadjaran, Bandung 45363, Indonesia

²Lecturer in the nursing study program, Faculty of Sports and Health Education, Universitas Pendidikan Indonesia, Bandung 45363, Indonesia

Email: dhika.dharmansyah@upi.edu

ABSTRACT

Background: Fall is a serious health issue among the elderly population with various contributing internal, environmental, and balancing activity-related risk factors. Internet of Health Things (IOHT) has a great potential to improve real-time elderly health monitoring and enable early detection of falls through risk-based intervention. Purpose: To know design an IOHT-based fall risk detection model for the elderly at home utilizing appropriate sensors and machine learning algorithms. Methods: A literature review was conducted to explore recent fall detection studies using motion, physiological, and environmental sensors in an IoT/IOHT-based system. Key findings were extracted and categorized based on sensor types and fall detection approaches. Results: Several motion sensors (accelerometer, gyroscope), physiological sensors (plantar pressure, inertial sensors), and environmental sensors (ultrasonic, sound) have been applied individually or in combination for falls risk prediction and detection among the elderly. Deep learning-based models have shown promising performance in identifying fall risks using multi-parameter sensor data. Conclusions: An IOHT model integrating various sensors shows potential for comprehensive fall risk monitoring and early intervention for the elderly at home. However, further developments in hardware, algorithms, clinical validation, and privacy/security are still needed to maximize the benefits of IOHT-enabled elderly healthcare.

Keywords: elderly, internet of health things (IoHT), falls injury

Introduction

The prevalence of falls among the elderly at home is a significant issue in geriatric health. Various studies highlight factors contributing to the risk of falls in the elderly population. One significant factor is the relationship between fall risk and activities of daily living (ADL) (Soleha, 2022). Additionally, home environmental factors also play a crucial role in falls among the elderly

(Widowati et al., 2022). Research also indicates a connection between forward head posture and fall risk in the elderly (Salatong, 2023).

In addition to internal and environmental factors, balance exercises such as Tai Chi and yoga have been proven effective in reducing fall risk among the elderly (Sumarsih et al., 2020; Swandari, 2021). Exercise programs like the Otago Home Exercise can also help reduce fall risk in the elderly (Mutnawasitoh, 2021). Furthermore, fall risk assessment using scales such as the Hendrich Fall Scale and Morse Fall Scale is crucial for identifying individuals vulnerable to falls (Sarah & Sembiring, 2021). Epidemiological studies from various countries such as China, Iran, India, and Saudi Arabia also highlight the prevalence of falls among the elderly (Xu & Han, 2020; Gheshlaghi, 2023; Marmamula et al., 2020; Alabdullgader & Rabbani, 2021).

These data provide a comprehensive overview of the fall problem in the elderly population across different cultural and geographic contexts. Thus, to reduce fall risk among the elderly at home, it is essential to consider the mentioned risk factors, engage in appropriate balance exercises, and regularly assess fall risk using valid and reliable scales. The Internet of Health Things (IOHT) is a concept that combines the Internet of Things (IoT) with healthcare applications, aiming to improve healthcare services and patient monitoring. The IOHT definition encompasses the use of sensor technology, connected devices, and information systems to collect real-time health data, allowing better monitoring of individual health conditions, including the elderly (Tang & Wang, 2020; Rajasekaran et al., 2022; Shahid et al., 2022).

The primary benefit of IOHT in addressing elderly health issues at home is its ability to provide continuous and proactive health monitoring. With IOHT adoption, the elderly can be monitored in real-time for early detection of fall risks, changes in health conditions, and urgent medical intervention needs (Aroosa et al., 2021; Khan et al., 2020). Additionally, IOHT enables remote healthcare services (telemedicine), facilitating elderly access to healthcare services without leaving their homes (Coelho et al., 2022; Junaid et al., 2022). Data security and privacy are also important focuses in implementing IOHT for the elderly. Various studies have highlighted the importance of protecting elderly health data within the IOHT environment, including the use of secure encryption technology, authentication, and data privacy measures (Wang et al., 2020; Fan et al., 2022; Suleski & Ahmed, 2023). Thus, IOHT not only provides significant health benefits for the elderly but also ensures the necessary data security and privacy in a healthcare context.

Overall, IOHT has great potential in improving the quality of life for the elderly by providing better health monitoring, easier access to healthcare services, and strong data protection to keep their health information safe and secure. The Internet of Health Things (IOHT) design model holds great potential in detecting fall risks among the elderly at home. IoT-based fall detection systems have been developed to minimize the impact of falls on the elderly (Pandelaki et al., 2023). By using monitoring tools connected via IoT, vital information such as physical signs related to fall risks can be monitored in real-time, enabling early detection and swift intervention. Physiological factors in the elderly can also be measured and integrated into the IOHT system to evaluate fall risks.

A study using instruments to measure physiological factors such as balance checks, muscle strength, vision, hearing, and fall risk questionnaires showed a relationship between these factors and fall risks in the elderly (Sholekah, 2022). In addition to fall risk detection, socialization about fall risk prevention and balance exercise training for the elderly can also be facilitated through the IOHT model. Through socialization and training activities, the elderly can enhance their knowledge of fall risks and acquire balance skills to help reduce the risk of falls (Lilyana, 2023). Thus, integrating the IOHT model design into fall risk detection among the elderly at home can

provide significant benefits in improving their quality of life, preventing serious fall-related injuries, and providing timely interventions.

Methods

This literature review was conducted by searching relevant previous studies on the topic of IOHT model design for detecting fall risks among the elderly at home. Several keywords used in the search through scholarly databases included "fall detection," "elderly fall risk," "internet of health things," and "sensor technology." Sources searched included indexed scientific articles from Google Scholar, ScienceDirect, Web of Science, and IEEE Xplore. The criteria for selecting articles were studies conducted within the last 5 years and relevance to the main research topic. A total of 30 documents were collected.

Key information extracted from the articles included the types of sensors used to detect fall risks, the health parameters measured, and the form of fall detection systems applied. Summary findings were grouped based on sensor types (motion, physiological, environmental) and presented in a systematic narrative format.

Results

The development and implementation of sensors for fall prediction and detection have been a focal point in recent research, aiming to enhance safety and quality of life for the elderly. These sensors can be broadly categorized as motion sensors, physiological sensors, and environmental sensors, each playing a crucial role in comprehensive fall detection and prediction.

Motion Sensors

To detect fall risks among the elderly at home, there are several types of motion sensors that can be utilized. These sensors include:

- (1) Accelerometer: This sensor can detect body acceleration, thus monitoring movements and physical activities of the elderly. Information from the accelerometer can aid in identifying movement patterns that may lead to falls (Zhu et al., 2021).
- (2) Gyroscope: Gyroscope sensors can measure angular velocity or body rotation speed. With information from the gyroscope, changes in the elderly's body orientation can be monitored, enabling detection of potential position changes that may lead to falls (Lee et al., 2021).
- (3) Barometric Pressure Sensor: Barometric pressure sensors can be used to monitor changes in altitude or air pressure. This sensor can help detect changes in the level of activity and body position of the elderly (Geetha, 2020).
- (4) Infrared Sensor: Infrared sensors can detect movement and the presence of objects in their surroundings. This sensor can assist in monitoring the activities of the elderly and detecting fall incidents (Geetha, 2020).
- (5) Kinetic RGBD Camera: Kinetic RGBD cameras can provide information about body movements and object depth. By using this camera, the detection of abnormal movements or falls among the elderly can be visually assessed (Geetha, 2020).

By utilizing a combination of these sensors, the design of motion sensors to detect fall risks among the elderly at home can provide comprehensive information about their movements and physical activities. Integrating data from various sensors can aid in early detection of fall risks and prevention of undesirable incidents.

Physiological Sensors

To detect fall risks among the elderly at home, various types or categories of physiological sensors can be employed. One researched approach involves using plantar pressure sensors worn on the feet to evaluate fall risk in older adults (Song et al., 2022). Additionally, inertial sensors

utilizing inertial signal-based sensors have been used to automatically assess fall risks in individuals who have had strokes (Fan et al., 2022). The use of non-invasive infrared sensors with low resolution has also been studied to classify activities and fall events in older adults (Márquez et al., 2022).

In addition to these sensors, home monitoring technology can also involve passive infrared motion sensors and contact sensors to monitor human behaviors such as body presence and time spent on specific activities (Kim et al., 2022). Furthermore, the use of RGB camera sensors has been proposed to detect falls in complex home environments (Tian et al., 2022). Thus, a combination of various types of physiological sensors such as plantar pressure sensors, inertial sensors, infrared sensors, passive infrared motion sensors, contact sensors, and RGB camera sensors can be used together to detect fall risks among the elderly at home. This approach allows for comprehensive data collection and accurate analysis to identify fall risks and take appropriate preventive measures.

Environmental Sensors

To detect fall risks among the elderly at home, the use of environmental sensors can be an effective approach. Several studies have highlighted the use of environmental sensors in fall detection systems. For example, ultrasonic sensors mounted on room walls and rotated to measure the distance to moving objects have been proposed to monitor the movements of the elderly and detect falls (Nadee & Chamnongthai, 2022). Additionally, other environmental sensors such as sound sensors have been used to analyze fall sounds and other risky activities (Hassan et al., 2022). In addition to environmental sensors, inertia sensors can also be used in fall detection systems. A study proposed the use of deep learning networks based on residual models for fall detection using sensors, showing promising performance in the elderly population (Jitpattanakul, 2022).

Furthermore, plantar pressure sensors used to measure foot movement can also be part of fall risk detection systems in the elderly (Tanwar et al., 2022). Therefore, a combination of environmental sensors such as ultrasonic and sound sensors with inertia sensors such as accelerometers can form a comprehensive fall detection system for the elderly at home. Integrating various types of sensors allows for better monitoring of the surrounding environment and individual movements, aiding in the detection and prevention of fall risks in the elderly population.

Discussion

Based on the review of current literature, the IOHT model design has the potential to enhance fall risk detection among the elderly at home. However, there are still several challenges to maximize its implementation:

- (1) The limitations of device battery power need to be addressed to ensure continuous system operation.
- (2) Processing large data from various sensors requires powerful and efficient computing.
- (3) The accuracy of fall risk prediction depends on the quantity and quality of training data for the model.
- (4) Data security is crucial to gain user trust in health data.
- (5) Telemedicine infrastructure support is needed for swift interventions.
- (6) Clinical evaluations are necessary to ascertain the real benefits of the system in reducing fall risks.

Therefore, further development is needed regarding hardware aspects, algorithms, privacy policies, and clinical trials to maximize the benefits of the IOHT model for elderly health. This should be considered in future research endeavors.

Conclusions

Based on the literature review regarding the design of the Internet of Health Things (IOHT) model for detecting fall risks among the elderly at home, several important points can be concluded:

- (1) Falls are a serious health issue among the elderly with various internal, environmental, and balance activity risk factors.
- (2) IOHT has great potential to enhance real-time health monitoring of the elderly and provide early interventions through fall risk detection.

Overall, the IOHT model design holds promising prospects in supporting efforts for fall risk prevention and early detection among the elderly. However, further development is needed regarding hardware aspects, algorithms, and clinical trials.

References

- Alabdullgader, A. and Rabbani, U. (2021). Prevalence and risk factors of falls among the elderly in unaizah city, saudi arabia. *Sultan Qaboos University Medical Journal [Squmj]*, 21(1), e86-93. <https://doi.org/10.18295/squmj.2021.21.01.012>
- Coelho, K., Nogueira, M., Marim, M., Silva, E., Vieira, A., & Nacif, J. (2022). Lorena: low memory symmetric-key generation method for based on group cryptography protocol applied to the internet of healthcare things. *Ieee Access*, 10, 12564-12579. <https://doi.org/10.1109/access.2022.3143210>
- Fan, B., Yerebakan, M., Dai, Y., Wang, W., Li, J., Gao, S., ... & Boyi, H. (2022). Imu-based monitoring for assistive disease diagnosis and management of ioh: a review.. <https://doi.org/10.36227/techrxiv.19200482>
- Fan, X., Wang, H., Zhao, Y., Huang, H., Wu, Y., Sun, T., ... & Tsui, K. (2022). Automatic fall risk assessment with siamese network for stroke survivors using inertial sensor-based signals. *International Journal of Intelligent Systems*, 37(9), 6168-6184. <https://doi.org/10.1002/int.22838>
- Geetha, A. (2020). Survey on fall detection system cnn based fall detection and health monitoring system using iot. *International Journal for Research in Applied Science and Engineering Technology*, 8(4), 395-398. <https://doi.org/10.22214/ijraset.2020.4062>
- Gheshlaghi, L. (2023). Analysis of the home accidents and their risk factors in iran: a systematic review and meta-analysis. *Iranian Journal of Public Health*. <https://doi.org/10.18502/ijph.v52i9.13568>
- Hassan, F., Mehmood, M., Younis, B., Mehmood, N., Imran, T., & Zafar, U. (2022). Comparative analysis of machine learning algorithms for classification of environmental sounds and fall detection. *International Journal of Innovations in Science and Technology*, 4(1), 163-174. <https://doi.org/10.33411/ijist/2022040112>
- Jitpattanakul, A. (2022). Fallnext: a deep residual model based on multi-branch aggregation for sensor-based fall detection. *Ecti Transactions on Computer and Information Technology (Ecti-Cit)*, 16(4), 352-364. <https://doi.org/10.37936/ecti-cit.2022164.248156>
- Junaid, S., Imam, A., Shuaibu, A., Basri, S., Kumar, G., Surakat, Y., ... & Alazzawi, A. (2022). Artificial intelligence, sensors and vital health signs: a review. *Applied Sciences*, 12(22), 11475. <https://doi.org/10.3390/app122211475>
- Khan, M., Rehman, S., Uddin, I., Nisar, S., Noor, F., Alzahrani, A., ... & Ullah, I. (2020). An online-offline certificateless signature scheme for internet of health things. *Journal of Healthcare Engineering*, 2020, 1-10. <https://doi.org/10.1155/2020/6654063>

- Kim, D., Bian, H., Chang, C., Dong, L., & Margrett, J. (2022). In-home monitoring technology for aging in place: scoping review. *Interactive Journal of Medical Research*, 11(2), e39005. <https://doi.org/10.2196/39005>
- Lee, D., Jun, K., Naheem, K., & Kim, M. (2021). Deep neural network-based double-check method for fall detection using imu-l sensor and rgb camera data. *Ieee Access*, 9, 48064-48079. <https://doi.org/10.1109/access.2021.3065105>
- Lilyana, M. (2023). Sosialisasi tentang pencegahan resiko jatuh dan senam keseimbangan bagi lanjut usia. *Jurnal Kreativitas Pengabdian Kepada Masyarakat (Pkm)*, 6(11), 4695-5004. <https://doi.org/10.33024/jkpm.v6i11.10442>
- Marmamula, S., Barrenkala, N., Challa, R., Kumbham, T., Modepalli, S., Yellapragada, R., ... & Khanna, R. (2020). Falls and visual impairment among elderly residents in 'homes for the aged' in india. *Scientific Reports*, 10(1). <https://doi.org/10.1038/s41598-020-70066-2>
- Márquez, G., Veloz, A., Minonzio, J., Reyes, C., Calvo, E., & Taramasco, C. (2022). Using low-resolution non-invasive infrared sensors to classify activities and falls in older adults. *Sensors*, 22(6), 2321. <https://doi.org/10.3390/s22062321>
- Mutnawasitoh, A. (2021). The effect of otago home exercise programme on decreasing the risk of falling in the elderly. *Gaster | Jurnal Ilmu Kesehatan*, 19(1), 1. <https://doi.org/10.30787/gaster.v19i1.586>
- Nadee, C. and Chamnongthai, K. (2022). An ultrasonic-based sensor system for elderly fall monitoring in a smart room. *Journal of Healthcare Engineering*, 2022, 1-21. <https://doi.org/10.1155/2022/2212020>
- Pandelaki, S., Sitanayah, L., & Liem, M. (2023). Sistem pendeteksi jatuh berbasis internet of things. *Jeecom Journal of Electrical Engineering and Computer*, 5(1), 4-10. <https://doi.org/10.33650/jeecom.v5i1.5802>
- Rajasekaran, A., Azees, M., Maheswar, R., & Lörincz, J. (2022). Blockchain enabled anonymous privacy-preserving authentication scheme for internet of health things. *Sensors*, 23(1), 240. <https://doi.org/10.3390/s23010240>
- Salatong, I. (2023). Hubungan antara forward head posture dengan risiko jatuh pada lanjut usia di kelurahan untia kota makassar. *Indonesian Journal of Physiotherapy*, 3(1), 26-38. <https://doi.org/10.52019/ijpt.v3i1.6272>
- Sarah, M. and Sembiring, E. (2021). Efektivitas hendrich fall scale (hfs) dan morse fall scale (mfs) dengan penilaian risiko jatuh pada lansia. *Jurnal Riset Hesti Medan Akper Kesdam I/Bb Medan*, 6(1), 21. <https://doi.org/10.34008/jurhesti.v6i1.226>
- Shahid, J., Ahmad, R., Kiani, A., Ahmad, T., Saeed, S., & Almuhaideb, A. (2022). Data protection and privacy of the internet of healthcare things (iohts). *Applied Sciences*, 12(4), 1927. <https://doi.org/10.3390/app12041927>
- Sholekah, L. (2022). Hubungan faktor fisiologis pada lansia dengan resiko jatuh di dusun wangil desa sambonganyar kabupaten blora. *Jurnal Keperawatan Dan Kesehatan Masyarakat Cendekia Utama*, 11(2), 174. <https://doi.org/10.31596/jcu.v11i2.1116>
- Soleha, D. (2022). Hubungan antara risiko jatuh dengan activity daily living pada lanjut usia. *Physiotherapy & Health Science (Physiohs)*, 4(2), 105-110. <https://doi.org/10.22219/physiohs.v4i2.23080>
- Song, Z., Ou, J., Shu, L., Hu, G., Wu, S., Xu, X., ... & Chen, Z. (2022). Fall risk assessment for the elderly based on weak foot features of wearable plantar pressure. *Ieee Transactions on Neural Systems and Rehabilitation Engineering*, 30, 1060-1070. <https://doi.org/10.1109/tnsre.2022.3167473>

- Suleski, T. and Ahmed, M. (2023). A data taxonomy for adaptive multifactor authentication in the internet of health care things. *Journal of Medical Internet Research*, 25, e44114. <https://doi.org/10.2196/44114>
- Sumarsih, G., Yeni, F., Mansur, A., & Irdhani, S. (2020). Pelatihan keseimbangan dengan penerapan yoga pada lansia dengan risiko jatuh di panti sosial tresna werdha sabai nan aluih sicincin. *Jurnal Warta Pengabdian Andalas*, 27(3), 203-212. <https://doi.org/10.25077/jwa.27.3.203-212.2020>
- Swandari, A. (2021). Pelatihan senam taichi pada lansia di upts tresna wredha pandaan jawa timur. *Jurnal Pengabdian Masyarakat Kesehatan*, 7(3), 70-74. <https://doi.org/10.33023/jpm.v7i3.806>
- Tang, Y. and Wang, D. (2020). Optimization of sports fitness management system based on internet of health things. *Ieee Access*, 8, 209556-209569. <https://doi.org/10.1109/access.2020.3039508>
- Tian, Z., Zhang, L., Wang, G., & Wang, X. (2022). An rgb camera-based fall detection algorithm in complex home environments. *Interdisciplinary Nursing Research*, 1(1), 14-26. <https://doi.org/10.1097/nr9.0000000000000007>
- Ullah, S., Hussain, S., Alroobaea, R., & Ali, I. (2021). Securing ndn-based internet of health things through cost-effective signcryption scheme. *Wireless Communications and Mobile Computing*, 2021, 1-13. <https://doi.org/10.1155/2021/5569365>
- Wang, L., Ali, Y., Nazir, S., & Niazi, M. (2020). Isa evaluation framework for security of internet of health things system using ahp-topsis methods. *Ieee Access*, 8, 152316-152332. <https://doi.org/10.1109/access.2020.3017221>
- Widowati, D., Nugraha, S., & Adawiyah, A. (2022). Hubungan faktor risiko lingkungan rumah dengan kejadian jatuh pada lansia di kota bandung tahun 2022. *Jurnal Untuk Masyarakat Sehat (Jukmas)*, 6(2), 168-176. <https://doi.org/10.52643/jukmas.v6i2.2472>
- Xu, T. and Han, H. (2020). Prevalence of falls among the rural elderly — three plads of western china, 2017–2018. *China CDC Weekly*, 2(46), 877-880. <https://doi.org/10.46234/ccdcw2020.239>
- Zhu, N., Zhao, G., Zhang, X., & Jin, Z. (2021). Falling motion detection algorithm based on deep learning. *Iet Image Processing*, 16(11), 2845-2853. <https://doi.org/10.1049/ipr2.12208>