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RESEARCH ON DEEP LEARNING-BASED SENSOR TECHNOLOGY FOR FALLS IN ELDERLY COMMUNITIES

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Abstract:
Purpose: Artificial intelligence (AI) is being increasingly explored for its potential applications in disease prevention and clinical medicine. This article studies the characteristics of falls in the elderly, summarizes the research on non-contact sensor-based machine learning, and discusses issues and suggestions related to fall prevention. It evaluates the living conditions of the elderly and provides a theoretical basis for preventing fall risks. The article also discusses the advantages, disadvantages, and prospects of applying AI in mental health, aiming to provide a reference for future research. Results: A systematic introduction to applying sensor technology in fall prevention equipment, such as millimeter-wave radar, inertial, and MEMS sensors.Conclusion: AI is developing rapidly and can complement manual diagnosis, but it also has limitations like algorithm bias and ethical issues. Mental health practitioners should actively adapt to and promote the further development of AI in this field.

Keywords: Elderly fall prevention, Non-contact sensor technology, AI applications in mental health Machine learning for fall detection

I. INTRODUCTION

As an elderly population group, the incidence of falls is high, and falls can lead to fractures or other serious consequences, bringing great pain to the elderly themselves and their families. At the same time, falls in the elderly also bring a tremendous economic burden to society. With the development of an aging population, the security of the elderly will become an important issue.

Multimodal sensor technology based on deep learning has achieved remarkable object and behavior recognition results. Suppose it is applied to the elderly fall warning system. In that case, it is expected to significantly reduce the risk of falls in the elderly community and improve the quality of life of the elderly. This will become a typical application of deep learning in healthcare.

II. RESEARCH OBJECTIVES

By studying the application of existing deep learning algorithms in multimodal sensor data, explore their potential value in predicting falls in the elderly. Evaluate the prediction accuracy and practicality of the constructed model in the elderly community, analyze the advantages and disadvantages of the model, and provide references for its industrial application. While ensuring the safety of the elderly, explore how to improve the robustness and scalability of deep learning models in the elderly community environment.

III. RESEARCH RESULTS

1. Overview of Deep Learning Technology

Deep learning is an essential branch of machine learning algorithms based on artificial neural networks. Compared with traditional machine learning methods, the advantage of deep learning lies in its ability to automatically learn the high-level feature representation of data without manual feature engineering; it adopts a deep non-linear network structure to learn more abstract and complex data patterns, and it can handle various data types such as speech, image, and video, with a wide range of applications. Deep learning technology has made significant breakthroughs in image and natural language processing.

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2. Related Research on Sensor Technology

One-third of the elderly aged 65 and above in China fall every year. Acute or chronic pain, fear of falling, and severe injury pose a significant threat to successful aging and independent living. There are two main issues worth focusing on in community falls: one is how to prevent falls, and the other is to monitor the danger of falls and report to the community or medical staff so they can be dealt with promptly. The entire falling process comprises the pre-fall phase, the impact phase, and the post-fall phase. Current research on fall detection is relatively limited, and most sensors are applied to wearable devices to detect falls because wearable devices can obtain real-time motion data and integrate fall protection systems to provide timely protection when a fall is predicted. The current research focuses mainly on three types of sensors: millimeter-wave radar sensors, inertial sensors, and MEMS sensors.

2.1 Fall Detection Based on Millimeter-wave Radar Sensors

Millimeter waves are a new non-contact vital sign detection method that can detect the relevant vital sign signals generated by human cardiopulmonary activities[1]. Compared with traditional electrocardiograms and pulse detectors, it has non-contact characteristics and specific penetrating power to detect through clothes, blankets, and other obstacles. As an active microwave detection device, millimeter-wave radar sensors have the characteristics of high spatial resolution, small size, lightweight, and all-weather, all-time operation. They can be used for fall detection to protect the detected object's privacy[2], overcome factors such as light, smoke, fog, and dust, and are not affected by surrounding environmental factors such as temperature, humidity, and brightness. Millimeter waves are located in the overlapping wavelength range of microwaves and far-infrared waves, so they have the characteristics of both wave spectra. They can accurately detect various behaviors of the elderly in the living environment, such as static, moving, falling, and sleeping, as well as vital signs such as heart rate and breathing. When any of these indicators change in the elderly, the potential safety risks to life can be identified, judged, and alarmed through the intelligent analysis of AI. Even if the elderly have an accident behind the sofa or cabinet, the millimeter-wave radar can still detect the situation and give an alarm[3], realizing comprehensive and no-dead-angle intelligent care. Millimeter-wave radar fall detection can obtain target information such as personnel position, speed, and posture and realize non-contact detection, which is suitable for indoor and bathroom fall detection applications[4].

2.2 Fall Detection Based on Inertial Sensors

The fall prevention research focuses on identifying and controlling fall risk factors. 53% of fall patients report falling due to stumbling; therefore, targeting patients' gait patterns may address most fall-related events and significantly reduce falls. Inertial sensing technology plays two leading roles in fall detection applications. On the one hand, it is used for real-time monitoring of the elderly's daily activities. On the other hand, it uses relevant posture algorithms to analyze and judge the occurrence of fall behavior. Inertial sensors are mainly applied to wearable devices. When the older adult's body falls, the body experiences a downward acceleration, and the acceleration of various body parts will also change to varying degrees. In order to be able to describe various variables during the elderly's fall process conveniently, a spatial coordinate system must be established. Therefore, in elderly falls, accelerometers and gyroscopes in three-dimensional space are mainly used through inertial sensors to detect acceleration values and body tilt angles and analyze and judge the occurrence of body falls[5]. The fall alarm can use a six-axis motion sensor to detect the fall of the human body and use a combination of GPS and base station positioning (LBS) to track the movement trajectory of the elderly in real-time, realize fall alarm, trajectory query, and other functions, and also has a one-key SOS emergency call function, with the advantages of stability, reliability, and convenient portability[6].

2.3 MEMS Sensors

MEMS sensors are mainly used in smart homes, wearable devices, and intelligent healthcare fields. It is mainly divided into two parts: the sensor, which is the familiar accelerometer and gyroscope, and the actuator, which is also an essential component of MEMS. At the current stage, MEMS faces two significant challenges: low power consumption, which requires the gyroscope to have higher output. The other is the challenge of high performance, and the precision problem and advanced level require higher core technologies as the sensor volume becomes smaller and smaller. However, it has advantages such as small volume, integration, intelligence, low cost, high reliability, low power consumption, and high sensitivity.

The fall detection process mainly analyzes and judges the fall process of the elderly through angular velocity, acceleration in any direction, and magnetic field strength and direction. Compared with inertial sensors, its accuracy is higher, and the influencing factors are smaller. The leading MEMS sensor solution is the abnormal fall detection system based on attitude estimation, which uses MEMS sensors and cameras to synchronously obtain attitude data, extract fall features after preprocessing, and use the improved fall detection algorithm for judgment. At the same time, caregivers can track the real-time status of the elderly through the user interaction interface to achieve comprehensive indoor monitoring[7].

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2.4 Latest Developments in Deep Learning Technology

1) Data Collection and Analysis: The sensor system will collect motion data from the elderly and use deep learning algorithms to analyze and process the data. Through learning a large amount of data, deep learning models can identify patterns and features related to falls, such as unstable posture and abnormal gait[8].

Current technology can automatically learn complex features from data without requiring manual feature design and perform automatic feature extraction for different modalities such as images and actions. Shaobing Wang proposed a fall detection method based on wearable sensors called the Patch-Transformer Network (c), which can detect falls in the elderly population in a timely and accurate manner. The PTN algorithm consists of a convolutional layer, a Transformer encoding layer, and a linear classification layer. The convolutional layer extracts local features and then projects them onto the feature matrix. The multi-head self-attention mechanism in the Transformer encoding layer is used to learn the global features of falls[9].

Deep learning can effectively predict temporal data, such as motion and physiological signals, by automatically learning the correlation between data samples. At the same time, deep learning supports the profound fusion of multimodal data, integrating data from different sources and sequences to improve prediction performance. With improved models and computing power, deep learning has more robust processing capabilities for large-scale sample data. In addition, deep learning models have good scalability, and the model structure can be continuously optimized through reinforcement learning as new data is collected, thereby increasing the robustness of predictions. In summary, deep learning brings many unique advantages to fall detection and early warning, and it will play a more significant role in this field.

2)Fall Detection and Early Warning: Sensor technology based on deep learning can monitor the movement status of the elderly in real-time and perform fall detection through algorithms[10]. Once a fall event is detected, the system can issue an alarm through sound, light, or wireless communication to alert the elderly or relevant caregivers.

Deep learning models can automatically learn the feature representation of fall actions from video and motion data, such as human posture and its changes, without manually extracting complex features. With sufficient data training, these models can learn various postures and action patterns that may lead to falls and perform real-time detection and recognition. This end-to-end learning approach supports modeling temporal data, such as video streams and can learn motion features and predict fall events.

Another advantage is that well-trained deep learning models can be deployed on mobile devices or video surveillance systems for online prediction and early warning, significantly shortening the response time. In addition, deep learning can effectively combine different modalities of data, such as video, posture, and physiological signals, and learn these features simultaneously, improving detection accuracy and reducing false alarms. It is worth mentioning that these models can be continuously updated and optimized through Online Learning, and the prediction capability will be enhanced after adding new samples, further improving the system's adaptability[11].

3) Prevention Measures and Interventions: These studies also explore how to provide personalized prevention measures and intervention recommendations for the elderly based on fall risk assessment. For example, they are based on the data provided by the intelligent sensor system, specific exercise plans can be designed, and appropriate assistive devices can be provided for the elderly.

By learning a large amount of patient data, deep learning models can identify the characteristics of high-risk groups, providing decision support for prevention. Secondly, the achievements of deep learning in computer vision can help design intelligent monitoring systems and environments, real-time tracking of human motion, and issuing early warnings. In addition, by combining physiological parameters and behavioral characteristics, deep learning models can learn personalized warning standards, providing more precise prevention strategies for the elderly. It is worth mentioning that some studies also use generative adversarial networks to learn the impact of simulated dangerous scenarios on the risk of falls in the elderly, providing a reference for environmental design.

Deep learning is opening up new possibilities for fall prevention. On the one hand, using model transfer learning technology, deep models can be pre-trained on many labeled safe scenario datasets and then fine-tuned on datasets with fewer samples or no labels of dangerous scenarios to achieve knowledge transfer from safe scenarios to dangerous scenarios[12]. On the other hand, an environment-agent interaction framework can be established using reinforcement learning methods, allowing deep networks to collect samples in simulated virtual environments and gradually learn to judge the fall risk in different scenarios through reward mechanisms.

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In addition, with the help of generative adversarial networks, the generator network can produce more realistic simulated dangerous scenario samples and add them to the training of classification models or regression models, improving the generalization ability of the models in new sample spaces. Furthermore, graph neural networks can be used to establish structured scene models to explore the influence of different factors, such as regions and objects, on the safety of the elderly, thereby improving scene understanding capabilities.

IV. RESEARCH CONCLUSIONS AND RECOMMENDATIONS

According to the relevant data in the "China's National Strategy Research Report on Responding to Population Aging," China's population aging presents the characteristics of sizeable absolute scale, rapid development, significant aging, uneven development, and large fluctuations. Shortly, the demand for elderly care services in China will show a quantitative and qualitative improvement trend, bringing great opportunities and challenges to developing China's intelligent elderly care industry. Due to the gradual improvement of the policy and investment systems, more innovative products have emerged in the technology system.

The China National Committee on Aging released the "Research Report on the Consumption and Demand Willingness of the Elderly from the Demand-side Perspective" in April 2019, which pointed out that there are currently more than 60,000 types of elderly products globally, while Japan has more than 40,000, accounting for more than two-thirds. China has only developed more than 2,000 types of self-developed products. In February 2017, the Ministry of Industry and Information Technology of China, the Ministry of Civil Affairs, and the National Health and Family Planning Commission jointly issued the "Action Plan for the Development of Smart Health and Elderly Care Industry (2017-2020)", proposing to enrich the supply of intelligent health and elderly care service products and targeting different application environments such as households, communities, and institutions, the development of wearable health management devices, portable health monitoring devices, self-service health screening devices, intelligent elderly care monitoring devices, home service robots, and other products to meet the diversified and personalized health and elderly care needs. The intelligent hardware industry can focus on developing intelligent health and elderly care service products supported by the state.

Currently, the vast majority of research still focuses on the research of intelligent elderly care platforms for home-based elderly care systems. Internationally, a comprehensive application of sensors, actuators, the Internet of Things, cloud computing, and other technologies is adopted, emphasizing the platform's expandability and openness. The research content mainly focuses on remote care, telemedicine, health data detection, and intelligent auxiliary equipment.

China's intelligent elderly care products only began to emerge after 2010. Although China's start was relatively late and is still in the exploratory stage, China was one of the earliest to propose the "smart elderly care" policy and encourage and support the practical exploration of competent elderly care. China is gradually catching up with foreign countries regarding innovative elderly care platforms. However, the research on intelligent elderly care platforms is still based on theoretical research, and the research on product applications is relatively one-sided. Many products are also based on foreign technologies and need more innovation. Various smart home devices are emerging in China, such as anti-fall floors, shoe cabinets, headbands, chest straps, and other devices designed for specific applications. However, the elderly often have multiple diseases, so the devices must be more detailed and comprehensive.

Presently, the awareness of innovative medical and health hardware in the domestic market is low, and the usage of sensors is relatively low, which brings specific challenges to developing sensors. However, the potential market for platform joint use in China is enormous. Home-based elderly care, where the elderly are cared for by their families, is the most common elderly care service model in China. It has received support from elderly care service policies in various places. Using sensors in home-based elderly care services can help children understand the real-time situation and physical health indicators of their elderly family members and provide first aid in emergencies.

Sensors can also be used in community elderly care and institutional elderly care to improve the integration of elderly data and elderly care resources in the community. It can realize the interconnection between the user end of the elderly group and the service providers such as elderly care institutions and medical institutions. Therefore, the sensor series can be applied to different elderly care models, fully utilizing the advantages of artificial intelligence to alleviate the pressure of elderly care.

Sensors have achieved specific research results in identifying motion status, monitoring exercise intensity, and assistive research on falls. However, there are also problems, such as significant differences in sensor accuracy and how to ensure the accuracy of research-level sensor equipment and reduce cost investment in the community risk prevention application for the elderly.

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With the continuous progress of technologies such as artificial intelligence and the Internet of Things, as well as the continuous development of innovative healthcare, the concept of health and elderly care has taken root in people's minds. With the acceleration of China's aging process, family-based elderly care will undoubtedly become the primary choice for elderly care in China. Sensor equipment in the field of community elderly care has great social value in detecting the daily activity patterns of the elderly and ensuring the indoor safety monitoring of the elderly living alone.

Although sensor technology based on deep learning has shown great potential in preventing falls in the elderly community, further research and practical verification are still needed. These studies are of great significance for improving the safety and quality of life of the elderly and are expected to play an essential role in future elderly care.

REFERENCES

[1] Alhazmi AK, Alanazi MA, Alshehry AH, et al. Intelligent Millimeter-Wave System for Human Activity Monitoring for Telemedicine. Sensors (Basel). 2024 Jan 2;24(1):268. doi: 10.3390/s24010268.

[2] Cheung JCW, Tam EWC, Mak AHY, et al. Night-Time Monitoring System (eNightLog) for Elderly Wandering Behavior. Sensors (Basel). 2021;21(3):704. doi: 10.3390/s21030704

[3] Gholami M, Napier C, Menon C. Estimating Lower Extremity Running Gait Kinematics with a Single Accelerometer: A Deep Learning Approach. Sensors (Basel). 2020;20(10):2939. doi: 10.3390/s20102939

[4] Gharghan KS, Hashim AH. A comprehensive review of elderly fall detection using wireless communication and artificial intelligence techniques. Measurement. 2024;226. doi: 10.1016/j.measurement.2023.113400

[5] Justa J, Šmídl V, Hamáček A. Deep Learning Methods for Speed Estimation of Bipedal Motion from Wearable IMU Sensors. Sensors (Basel). 2022;22(10):3865. doi: 10.3390/s22103865

[6] Ma Z, Zhang W, Shi K. Improving the Accuracy of Estimates of Indoor Distance Moved Using Deep Learning-Based Movement Status Recognition. Sensors (Basel). 2021;22(1):346. doi: 10.3390/s22010346

[7] Nguyen H, Lebel K, Boissy P, et al. Auto detection and segmentation of daily living activities during a Timed Up and Go task in people with Parkinson's disease using multiple inertial sensors. J Neuroeng Rehabil. 2017;14(1):26. doi: 10.1186/s12984-017-0241-2

[8] Silva J, Monteiro M, Sousa F. Human activity classification with inertial sensors. Stud Health Technol Inform. 2014;200:101-104. doi: 10.3233/978-1-61499-468-5-101

[9] Wang S, Wu J. Patch-Transformer Network: A Wearable-Sensor-Based Fall Detection Method. Sensors (Basel). 2023;23(14):6360. doi: 10.3390/s23146360

[10] Xiang M, Ren W, Li W, et al. High-Precision Vital Signs Monitoring Method Using a FMCW Millimeter-Wave Sensor. Sensors (Basel). 2022;22(19):7543. doi: 10.3390/s22197543

[11] Zeng X, Báruson HSL, Sundvall A. Walking Step Monitoring with a Millimeter-Wave Radar in Real-Life Environment for Disease and Fall Prevention for the Elderly. Sensors (Basel). 2022;22(24):9901. doi: 10.3390/s22249901

[12]Gharghan K S ,Hashim A H . A comprehensive review of elderly fall detection using wireless communication and artificial intelligence techniques[J]. Measurement,2024,226.doi: 10.1016/J.MEASUREMENT.2024.114186

