Intelligent Robots for Elderly Care: Categories, Application Scenarios, and Challenges

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Abstract. Aging populations have increased the demand for intelligent, personalized, and emotionally supportive elderly care services. Traditional care models often face limitations such as high labor costs, insufficient service continuity, and limited emotional support. Deep learning-driven elderly care robots provide a promising solution by integrating perception, decision-making, human-robot interaction, and adaptive service functions. This paper reviews the major categories of intelligent elderly care robots, including rehabilitation robots, nursing robots, and companion robots. It further discusses their application scenarios in home care, nursing homes, and community-based care. Existing studies show that deep learning, machine vision, multimodal sensing, and large language models can improve motion assistance, health monitoring, emotional interaction, and personalized companionship. However, several challenges remain, including technical reliability, data privacy, ethical risks, high deployment costs, and user acceptance among older adults. Future development should focus on lightweight models, multimodal fusion, privacy-preserving learning, and human-centered design. Intelligent elderly care robots should not replace human caregivers, but should support them in providing safer, more efficient, and more compassionate care.

Keywords: Deep Learning, Elderly Care Robots, Application Scenarios, Risks, Future Development.

1. Introduction

The aging population has made elderly mental health and quality of life an increasingly important social issue, increasing the need for continuous care, emotional support, and technology-assisted services [1, 2]. Many older adults need continuous physical assistance, health monitoring, cognitive support, and emotional companionship, while traditional elderly care models often face high labor costs, limited-service continuity, insufficient personalization, and inadequate emotional support. Therefore, intelligent robots for elderly care are expected to become an important technological supplement to human caregivers by providing safer, more adaptive, and more personalized services.

Early socially assistive robots for elderly care were mainly used for simple dialogue, reminders, and basic interaction. However, these systems often had limited abilities in subtle emotion recognition, multimodal perception, long-term personalization, and cultural adaptation. These limitations show that elderly care robots need more advanced perception, decision-making, and human-robot interaction capabilities rather than only pre-set commands or fixed responses.

To address these problems, deep learning-, machine learning-, and multimodal sensing-driven elderly care robots have developed rapidly in health monitoring, emotion recognition, and adaptive interaction [3, 4, 5]. By integrating visual, auditory, tactile, physiological, and contextual information, these robots can better recognize users' physical states, emotional changes, and individual preferences. The combination of intelligent technologies and human-centered design shifts elderly care robots from simple labor-saving tools to assistive systems that support human care, emotional communication, and personalized services.

This article reviews the main categories of intelligent elderly care robots, discusses their application scenarios, and summarizes the major risks, challenges, and future development directions.

2. Categories Of Intelligent Elderly Care Robots

2.1. Intelligent Rehabilitation Robots in Elderly Care

2.1.1. Exoskeleton Robot

Exoskeleton robots are an important type of intelligent rehabilitation robot. They are usually driven by motors or actuators and are designed according to bionic and ergonomic principles. By connecting the device with the user's limbs or body, exoskeleton robots can assist movement, reduce physical burden, and support rehabilitation training. For older adults with mobility limitations, such systems can function as a supportive 'second skeleton' and help them perform daily activities more safely.

Christensen et al. designed a powered full-body exoskeleton for the physical assistance of elderly users, showing that exoskeleton systems can support daily activities such as walking, standing, bending, lifting, and carrying [6]. Zheng et al. further investigated flexible wrist and elbow joint actuators for upper limb exoskeleton rehabilitation robots, with attention to joint coordination and control performance [7]. These studies suggest that exoskeleton robots can improve mobility assistance and rehabilitation efficiency through mechanical design, ergonomic adaptation, and intelligent control. Future research should further improve lightweight materials, mechanical compatibility, adaptive control algorithms, and long-term clinical evaluation.

2.1.2. Lower Limb Assistive Walking Robot

Assistive mobility devices, including smart walkers and robotic rollators, are designed to support body weight, improve balance, and assist walking in older adults [8]. A lower-limb walking assistance robot is usually a lightweight and integrated robotic device that aims to improve or restore a user's mobility. Moustris et al. presented the i-Walk lightweight assistive rollator, which integrates sensors, navigation support, gesture recognition, and speech-related interaction to provide both mobility and cognitive assistance [9]. Such systems can help older adults move more safely and reduce difficulties in daily walking activities.

2.2. Intelligent Nursing Robots in Elderly Care

2.2.1. Urination and Defecation Care Robot

Daily nursing tasks such as eating, toileting, bathing, and transferring can create physical and psychological burdens for both older adults and caregivers. Toileting assistance is especially sensitive because it involves privacy, safety, and dignity. Therefore, urination and defecation care robots should not only provide physical support but also protect users' privacy and reduce caregivers' workload.

2.2.2. Bathing Assistance Robot

Bathing assistance robots are designed to help older adults wash, bathe, or receive bed-based cleaning support. They can reduce the risk of falls during bathing, lower caregivers' physical burden, and better protect older adults' privacy and dignity. Current designs may include portable bathing systems, assisted showering devices, and robotic platforms for bed or bathroom care.

Zlatintsi et al. proposed I-Support, a robotic platform for assistive bathing that integrates perception, cognition, actuation, and control modules to support assisted daily living tasks [10]. Zhao et al. proposed an auxiliary excretion approach for a lavatory robot, emphasizing safety and robustness in toileting assistance [11]. These studies show that nursing robots can support sensitive care tasks such as bathing and toileting, but their design must carefully consider safety, comfort, privacy, and human supervision.

Bezerra et al. proposed Bath-Ambience, a mechatronic system for assisting caregivers of bedridden people [12]. The system was designed to support bathing routines without requiring bedridden users to be moved to another place. This work shows how mechatronic design and smart-home integration can improve safety and convenience in bathing care.

2.2.3. Health-Monitoring Robot

Health-monitoring robots integrate sensors, communication modules, and intelligent analysis methods to support continuous observation of older adults' physical conditions. These robots may collect physiological signals, monitor daily activity, detect abnormal states, and send feedback to caregivers or medical staff. When combined with machine learning and wireless sensing, health-monitoring robots can provide more timely and personalized support for elderly care.

Gowri et al. designed and developed a machine learning-enabled robot-assisted virtual health monitoring system [4]. Their system combined artificial intelligence, robotic assistance, sensors, wireless technology, and fuzzy analysis to support continuous health monitoring. Such health-monitoring robots can collect physiological information, analyze users' health conditions, and provide timely feedback for caregivers and elderly users, which makes them useful for home care and institutional elderly care.

2.3. Intelligent Companion Robots in Elderly Care

2.3.1. Emotion-Aware and Personalized Design

Companion robots are intelligent systems that provide emotional care, daily living support, and social interaction in homes or care institutions. They are usually based on artificial intelligence, robotics, and human-robot interaction technologies. For elderly users, companion robots should not rely only on simple commands, but should be able to perceive emotional changes, understand multimodal signals, and respond in a warm and personalized way.

Chu et al. designed and evaluated an AR-based adaptive human-computer interaction cognitive training system for elderly users, demonstrating that adaptive interaction strategies can support personalized cognitive training [13]. Irfan et al. provided recommendations for designing conversational companion robots with older adults through foundation models, emphasizing the importance of adapting robot responses to older users' speech, behavior, preferences, and interaction needs [2]. These studies indicate that companion robots should move beyond simple commands and support more natural, personalized, and emotionally sensitive interaction.

2.3.2. Multimodal Emotion Recognition and Adaptive Interaction

Multimodal emotion recognition and adaptive interaction are important functions of companion robots because they help robots perceive older users' emotional states, remember short-term interaction context, and provide more personalized responses. One approach is to build an autonomous emotion recognition system for elderly users by combining multiple types of information and deep learning models. Sreevidya et al. proposed an elder emotion classification method based on multimodal fusion and cross-modal transfer learning, providing a useful reference for multimodal emotional understanding in elderly care robots [5]. The related model structure is shown in Figure 1.

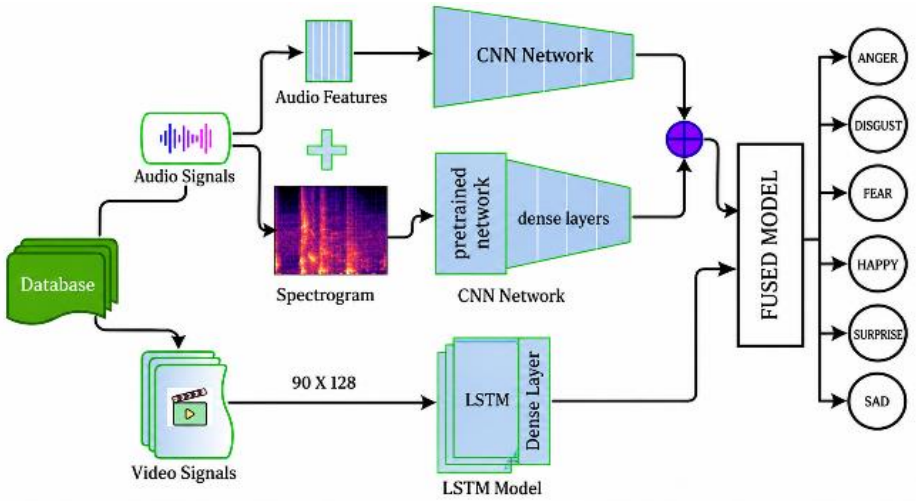


Figure 1: MIMETIC model structure. Adapted from Sreevidya et al. [5].

Arunachalam et al. developed an RNN-based model for intelligent companionship and adaptive assistance in geriatric care [14]. By using recurrent neural networks, LSTM-related modeling, and adaptive interaction logic, such systems can better support long-term memory, short-term context, and emotional response in elderly care scenarios. This provides a technical basis for more personalized emotional care and companionship.

2.3.3. Functional Design and Methodology

QFD, or Quality Function Deployment, is a structured method that transforms customer needs into product design and development requirements. In the design of intelligent companion robots, QFD can help researchers identify what older users truly need and translate these needs into concrete functions, interface designs, and service features.

Based on the Kano-QFD hybrid model, Pan and Ren studied the design of elderly companion robots [15]. Their work used QFD theory to transform older users' needs into product design requirements and assigned different weights to functional modules. This approach provides a structured method for improving the usability, emotional value, and functional design of companion robots for elderly users.

3. Application Scenarios

3.1. Home Care

At home, intelligent elderly care robots are increasingly used to improve quality of life and provide day-to-day support. Their main functions include personalized health management, safety monitoring, reminders, and emotional companionship. Kok et al. implemented a social robot for homecare services and explored how sustainable human engagement can be supported in aging populations [1]. This shows that home-care robots can help reduce loneliness and provide continuous assistance for older adults living at home.

3.2. Nursing Home

In nursing homes, intelligent elderly care robots can support repetitive, physically demanding, and emotionally demanding care tasks. They can also provide structured interaction, health monitoring, and emotional support in institutional environments. Ai et al. constructed a multimodal emotion recognition system based on transfer learning for service robots in elderly care institutions, showing that facial expressions, speech, body language, and physiological signals can be integrated to optimize human-robot interaction [3]. However, further real-world evaluation is still needed before such systems can be widely deployed in nursing homes.

3.3. Community Care

In community-based elderly care, intelligent robots can serve as part of an assisted-living support network. Community scenarios emphasize resource integration, inclusive services, and coordination among home care, community services, and institutional care. Existing studies on homecare social robots and conversational companion robots suggest that elderly care robots can provide reminders, basic health support, social interaction, and rehabilitation guidance while connecting older adults with caregivers and family members [1, 2].

4. Risks, challenges and future development directions

Intelligent elderly care robots have great potential in aging societies, but they also face technical, ethical, and social challenges. Technically, robots may still perform unstably in complex home environments with dim lighting, cluttered objects, background noise, or diverse user behaviors. Ethically, emotional simulation, data collection, privacy protection, and algorithmic transparency require careful regulation. Socially, excessive dependence on robots may reduce human interaction,

and some older adults may still feel uncertain or uncomfortable when using intelligent systems. Future development should focus on reliable multimodal perception, lightweight deployment, privacy-preserving learning, transparent interaction, and safer integration across family, community, and institutional care.

Looking forward, intelligent elderly care robots should balance technological innovation with human-centered values. Future systems need to be more adaptive, trustworthy, privacy-aware, and ethically constrained. More importantly, robots should support rather than replace human caregivers. Only when technology is guided by empathy and responsibility can intelligent elderly care robots become meaningful tools for improving the quality of life of older adults.

5. Conclusions

In summary, deep learning-driven intelligent robots have great application potential in elderly care, including rehabilitation, nursing, health monitoring, and companionship. Existing studies show that these robots can be applied in homes, nursing homes, and community-based care, with different scenarios emphasizing different functions and service needs. Although current systems still face challenges in technical reliability, ethical governance, cost, and user acceptance, continued progress in multimodal perception, adaptive interaction, and human-centered design may make intelligent elderly care robots an important supplement to future elderly care services.

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