

The Future of Smart Elderly Care: Significance and Pathways of AI Integration in Age-Friendly Spaces

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ABSTRACT

With the global trend of an aging population intensifying, providing high-quality and sustainable elderly care has become a crucial challenge for governments and societies worldwide. The rapid development of Artificial Intelligence (AI) presents new opportunities for enhancing traditional age-friendly space design and eldercare models. AI enhances daily convenience and safety for older adults through diverse sensing and interactive approaches, alleviates the caregiving burden on families and society, and drives interdisciplinary innovation in the eldercare industry. Drawing on literature reviews and case studies, this paper explores the practical value, challenges, and potential responses to AI integration in age-friendly spaces. From the perspectives of spatial planning, interaction design, and ethics, we critically examine AI's potential benefits and pitfalls. Based on these insights, we propose phased, multi-layered strategies and design recommendations for the effective implementation of AI in future smart elderly care environments, offering a reference point for academic inquiry and practical application.

Keywords: smart elderly care, artificial intelligence, age-friendly spaces, interior design, cross-disciplinary integration, human-computer interaction

INTRODUCTION

Research Background

With ongoing advancements in global healthcare and declining fertility rates, many countries are experiencing an unprecedented acceleration in population aging. According to the World Health Organization (WHO, 2020), the proportion of people aged 65 and over is projected to rise significantly in the coming decades. This demographic shift increases the demand for healthcare, social welfare, and caregiving services while imposing higher requirements on urban planning, architectural design, and the interior environment to accommodate the needs of older adults [1].

Artificial Intelligence (AI) is increasingly found to bring profound changes across many industries, such as healthcare, finance, transportation, and education. Recent breakthroughs in image recognition, natural language processing, and machine learning have opened the way to the real potential of sophisticated applications in cities, homes, and daily living [2]. In eldercare, AI can increase or replace human labor in supervising and assisting older adults, thereby reducing shortages in the workforce and increasing the quality and efficiency of eldercare services [3].

The application of AI in designing age-friendly environments involves multidimensional challenges. While the design needs to judiciously balance aesthetic and functional values with the actual diverse physical and psychological requirements of older adults, there are also technical considerations such as sensor deployment, data analytics, system security, and reliability issues[4]. Equally important, though, are the social and ethical issues that address privacy concerns and the psychological adaptation of older adults[5]. The current paper presents the concept of "smart elderly care" to enhance interdisciplinary dialogue and enable further innovations in applying AI technology within the senior living environment [4].

Research Objectives and Significance

This study explores the practical value and feasible pathways of integrating AI technology into age-friendly spaces through a cross-disciplinary lens of interior design and artificial intelligence. Specific research questions include: This paper contributes a unique interdisciplinary framework by bridging interior design and AI-driven technologies—an area rarely synthesized in existing literature.

What incremental functionalities and user experience enhancements does AI bring to age-friendly spaces?

What are the primary challenges and potential risks during AI integration?

How can stakeholders collaborate to develop sustainable strategies for addressing these challenges?

How will AI-empowered age-friendly spaces influence future models of elderly care in interior design, architecture, and urban planning?

The significance of this research extends beyond offering practical solutions for designers, developers, and policymakers. It aims to broaden the academic debate surrounding “AI + Elderly Care” by providing a multi-perspective theoretical underpinning and a humanistic approach.

Research Methods and Paper Structure

This paper includes a literature review and some case studies. An analysis of literature and related industry reports has been carried out to trace the current trends of research, possible technical pathways, and their application to the real world while dealing with smart elderly care and age-friendly design. Two case studies have been performed to derive the principles of design that can serve as replicable models and identify their limitations. Critical reflections evident in the paper look at the gaps and issues which remain to be fully elaborated by academics.

The paper is structured as follows: Section 2 reviews the literature on smart elderly care and age-friendly design. Section 3 discusses theoretical foundations and application scenarios of AI in age-friendly spaces. Section 4 presents case studies and critical analysis. Section 5 examines challenges and response strategies. Section 6 concludes the study and offers future prospects.

LITERATURE REVIEW

Origin and Development of Smart Elderly Care

The concept of “smart elderly care” originates from the application of the Internet of Things (IoT) and cloud computing in eldercare services. Early systems focused on digitalizing senior services, leveraging basic sensors for monitoring and response [6]. With the maturation of AI technologies like big data analytics, deep learning, and computer vision, the focus shifted from information-based to intelligence-based elderly care [7]. This evolution emphasizes personalized services, risk prediction, fall detection, emotional support, and social connectivity [8].

Concepts and Evolution of Age-Friendly Design

Age-friendly design within architecture and interior environments emphasizes a holistic approach in catering to older adults in the dimensions of physical, psychological, and social needs. In early models, attention had been paid to the most basic elements concerning safety and accessibility: non-slip flooring, handrails, and appropriate amounts of light—to minimize the risk of a fall and enhance ease of movement [9]. However, these emerged as foundational elements and turned, with the passage of time, into far more inclusive strategies, encompassing activity areas in community, engagement with other members of the community, and mental wellness spaces [10]. Thus, contemporary practice affords to include spaces such as multipurpose rooms for group exercise or hobby classes, warm lounges suitable for informally gathering, and quiet places supportive of relaxation or meditation. Further, detail has emerged in matters indirectly concerning sensory comfort, like acoustics, air

quality, and biophilic elements—indoor plants and natural light—conducive to better psychological well-being [11].

Equally important was the never-ending procession that would characterize smart home technologies and interior design as a hallmark element of age-friendly environments [11]. By using IoT sensors, voice-activated devices, and automated controls on environmental variables, designers can envision settings that buffer physical risks—for instance, systems that automatically detect falls—and also foster autonomy and social and cognitive engagement [11]. In practical terms, this convergence may result in intelligent lighting systems that adjust in brightness to the daily rhythm of an older adult, voice assistants reminding residents of appointments and medications, or telehealth stations providing on-demand medical consultations [11]. Thus, age-friendly designs today are well beyond any immediate safety concerns and are meant to be seamless in all three realms of physical infrastructure, technological innovation, and social programming to continue to encourage active aging and maintain quality of life [11].

Current Status of AI-Driven Smart Elderly Care Practices

AI-driven innovations in smart elderly care have evolved rapidly in recent years, with applications typically categorized into four main areas. Nonetheless, ongoing research suggests that many of these solutions remain loosely integrated into overall design strategies, leaving room for more holistic, user-centered approaches[12].

Intelligent Monitoring and Health Management Leveraging computer vision, sensor fusion, and big data analytics, intelligent monitoring systems capture real-time information about older adults' location, physical activities, and vital signs [13]. When abnormal conditions arise—such as a sudden spike in blood pressure or a fall—the system instantly alerts caregivers or family members, enabling prompt interventions [14]. Some advanced solutions also incorporate predictive analytics to identify changes in behavioral patterns, potentially detecting early signs of deteriorating health and allowing for preventive care[12]. However, these systems require robust data governance measures to ensure privacy and security, as older adults' sensitive health information is continuously collected and analyzed [13].

Daily Living Assistance and Smart Home Applications Voice assistants and smart home devices, built on voice recognition and natural language processing (NLP), significantly simplify everyday tasks[12]. Seniors can control various home elements—lighting, temperature, music—through verbal commands, and receive reminders for taking medications or attending appointments[12]. Beyond convenience, these technologies can enhance autonomy for those with reduced mobility or cognitive challenges, enabling task completion without assistance[12]. However, developers should be aware of usability and the digital divide, as most older adults have little experience using high-tech interfaces and may need explicit training or simpler interfaces to maximize adoption[12].

Emotional Companionship and Social Support More sophisticated AI robots use speech, text, and even expression recognition to give the most rudimentary form of companionship to older adults and help reduce their loneliness [15]. Such robotic companions engage in simple dialogue, play games, or provide reminiscence therapy, thus helping to support mental health and reduce caregiver burden [15]. While some early studies and anecdotal evidence have suggested associated benefits—reduced anxiety and increased social activity for instance—many older adults remain ambivalent for various reasons, including privacy concerns and the belief that interaction with humans will be replaced by machines [15]. It then somewhat follows that setting clear boundaries, ensuring that AI is used to augment rather than replace all personal relationships, is one important consideration [15].

Telemedicine and Rehabilitation Training Telehealth has now integrated wearable devices and digital health platforms to provide teleconsultations, personalized treatment recommendations, and home-based remote rehabilitation directly to the elderly[12]. Motion capture systems based on AI then track the movement, enabling real-time corrections either by adjusting the degree of difficulty or providing postural correction, which in turn allows exploiting the maximum potential of the therapy[12]. It would reduce the expenses and risks associated with traveling for an appointment too often but would also empower older adults to become more proactive in managing their health issues [12]. On the other hand, the internet infrastructure and the level of digital literacy

achieved so far would be grounds on which the limiting factors regarding telemedicine are based and would make needed policy and community-level supports a necessity[12].

Despite the promise of these AI-based solutions, many current implementations treat technology as an external “plugin,” only added after most spatial or care design choices are made. In practice, truly “smart” elderly care environments require integrating AI considerations from the earliest planning stages, where space layout, sensor placement, user flow, and data management protocols are developed in tandem[12]. This holistic approach can foster a seamless user experience—one where technology naturally fits within day-to-day routines and architectural design—ultimately improving adoption rates, lowering operational costs, and enhancing quality of life for older adults[12].

Theoretical Foundations and Application Scenarios of AI in Age-Friendly Spaces

Theoretical Foundations: Human-Machine Symbiosis and Environment-Behavior Studies

The role of AI in creating age-friendly environments thus pivots on the pivotal two theoretical underpinning pillars: the theory of human-machine symbiosis and the theory of environment-behavior studies. Both provide crucial insights that guide the implementation of AI in upgrading elderly care environments through seamless AR interplay and adaptive spatial designs per the needs of the AGET_USER community. The technical perspective of such AI systems invariably includes NLP, CV, and SIS, which have been outlined as an unprecedentedly interactive ecosystem in which elder users will be able to participate.

Human-Machine Symbiosis: Enhancing Usability and Adaptability Complementarity builds on rather unique premises, defining an intelligent system as one that performs only part of the tasks assigned, becoming increasingly more capable of dynamically changing in response to changes in user behavior and his environment. An AI-infused AAL system, as previously shown, does not operate according to preordained rules; it learns and develops from continual interaction with users and, thus, may serve much better the needs of older adults in emerging situations.

User-centered interfaces bridge the current gap between seniors and AI solutions. Many older users experience sensory impairment (such as losing vision or hearing) or reduced mobility, making digitalized interfaces challenging. Human-machine symbiosis thus demands a multimodal interaction strategy incorporating:

System voice commands ease operation (e.g., setting light, calling help).

Gesture recognition and touch-free operation for those with reduced dexterity.

Large, highly contrasting visuals with simplified menus for readability and ease of use.

The catch lies in balancing technological sophistication against ease of use: while sufficiently sophisticated to provide individual services, they must be easy to operate without exceeding the cognitive overload threshold. Poorly designed interfaces will discourage the elderly from using smart technologies, negating all possible advantages. In this context, ethical issues of trade transparency, privacy-protected personal data, and users' consent become part of the service design process, allowing a set of exchanges for trust and acceptance.

Environment-Behavior Studies: AI as an Adaptive Design Tool

Environmental-behavior studies involve a complicated interplay involving humans and their environments. The underlying premise establishes a critical basis for determining how the quality of physical space can be manipulated to suit human activity and, ultimately, their well-being. With such an environment-behavior approach, age-friendly design could well support altered environmental fit with the session's physiologic, psychological, and social changes. On a more sophisticated level, AI adds to the recognition of behavioral patterns from real-time data to continually adjust the environment for optimal comfort and usability.

To this, consider the following:

Day-Night Activities Adjustments: AI differentiates day from night, and it sees the variation in activity patterns through time. Consequently, such sensitivities permit proper corrections in environmental parameters. In other words, if pathway lighting is motion-activated, it is set for nighttime alone; this minimizes the risk of falls while circulating brightening systems at night on a circadian basis.

Personalized Climate Control: AI also learns the temperature preference of an individual; that is, it automatically adjusts HVAC systems to provide thermal comfort without any intervention.

Cognitive Stimulation and Engagement: AI-assisted design can incorporate interactive spaces that respond to social behaviors—for instance, smart communal areas where lighting and background music adjust based on group size and noise levels to foster interaction.

However, a key challenge remains: AI-driven space adaptations must prioritize user autonomy. Over-reliance on automation can lead to feelings of loss of control among older adults, potentially reducing overall acceptance. The ideal balance involves AI-assisted, user-customizable environments, where seniors retain control over major adjustments while benefiting from system-generated recommendations [16].

Application Scenarios: From Home to Public Facilities

AI applications in age-friendly environments extend across multiple spatial contexts, including private homes, community-based eldercare facilities, and rehabilitation centers. These implementations offer enhanced safety, efficiency, and personalized care, but they also raise concerns regarding cost, accessibility, and ethical implications.

Home Environments: Personalized AI-Assisted Living

The home is the primary setting where older adults prefer to age, making AI-enhanced smart home technologies essential for prolonging independence and improving safety.

AI-driven environmental sensing monitors indoor air quality, detects hazards (e.g., smoke, gas leaks), and alerts caregivers if intervention is needed.

Voice interaction systems enable seniors to control home appliances hands-free, reducing the need for physical exertion.

AI-powered emergency response systems detect abnormal behaviors (e.g., prolonged inactivity) and initiate wellness checks or automated emergency calls.

However, implementation barriers exist: smart home systems often require high-speed internet, advanced IoT infrastructure, and technical literacy, factors that may limit adoption among seniors in rural or economically disadvantaged areas. Policymakers and designers must therefore focus on cost-effective, low-complexity solutions that cater to a broad demographic.

Community-Based Eldercare Facilities: AI for Social and Medical Support

AI integration in nursing homes, senior community centers, and assisted living facilities focuses on group care efficiency and medical monitoring.

AI-powered resident tracking systems reduce wandering risks, particularly for individuals with dementia.

Robotic assistance in communal spaces facilitates physical therapy, group exercise, and interactive engagement. AI-enhanced telemedicine stations provide remote consultations, reducing dependency on in-person hospital visits. While these innovations improve healthcare efficiency, they also pose privacy concerns. Many residents may feel uneasy about constant surveillance and data collection. Transparency in AI decision-making and clear consent protocols are crucial in addressing these issues.

Rehabilitation and Therapeutic Spaces: AI for Health Recovery

AI-enhanced rehabilitation spaces leverage wearable devices, motion-capture technology, and virtual reality (VR) therapy to assist seniors in recovering from injuries or managing chronic conditions.

AI-driven rehabilitation programs adapt exercises based on real-time motion analysis, ensuring safe and effective therapy.

Neurofeedback AI tools assist cognitive rehabilitation by tracking and stimulating brain activity.

Smart prosthetics and mobility aids integrate AI learning to improve usability and patient adaptation.

Challenges include accessibility and ethical concerns related to bias in AI-driven health diagnostics. If AI rehabilitation tools are trained primarily on younger or more physically capable populations, they may fail to provide accurate recommendations for frail elderly users. Research and design teams must work toward ensuring inclusive and representative AI models for senior healthcare [17].

Critical Perspective and Future Considerations

While AI is undeniably reshaping the landscape of eldercare, several **critical questions** remain:

Accessibility and Equity: How can AI-driven smart care be extended to underprivileged seniors who lack financial resources or digital literacy?

Psychological Impact: To what extent does increasing automation enhance well-being versus fostering emotional detachment by replacing human caregivers?

Regulatory Oversight: How can policies ensure that AI in eldercare remains ethical, fair, and transparent while maintaining data security?

The answers to these questions will determine whether AI in age-friendly design truly benefits all seniors or remains an exclusive privilege for technologically advanced and well-funded institutions. Moving forward, collaboration between designers, engineers, gerontologists, and policymakers will be critical to establishing AI solutions that are not only efficient and innovative but also inclusive and humane.

Case Studies and Critical Analysis

Riverstone High-end Elderly Care Community

Background

In City London, England, a luxury senior apartment complex underwent comprehensive AI-focused renovations, incorporating advanced security systems, voice assistants, behavior monitoring, and telemedicine services. The goal was to provide comfortable yet secure living conditions while addressing medical and social needs.

Key Design and Technological Highlights

Environmental Sensing and Monitoring: Multiple sensors (temperature, humidity, smoke, CO₂) and infrared motion detectors were installed throughout the apartments, connected to a unified cloud platform. If anomalous data (e.g., poor air quality or inactivity) is detected, notifications are sent to caregivers or families.

Voice Interaction System: Voice assistants in living rooms, bedrooms, and community lounges allow occupants to control lights, televisions, curtains, and more by simple verbal commands, as well as request daily information like weather or news updates. **Telemedicine and Health Management:** Partnering with a local tertiary hospital, the apartment offers routine remote consultations. Healthcare providers can track residents' vital signs and activity data through an online interface, offering timely medical advice.

Outcomes and Remaining Issues

Benefits: Increases in safety and convenience have been reported, especially regarding nighttime fall detection and emergency support. Some residents appreciate the hands-free voice control for daily tasks.

Limitations:

High Cost: Both installation and ongoing maintenance are expensive, making it less accessible to middle- and low-income seniors.

User Acceptance: Some older adults found voice commands difficult or encountered inaccurate speech recognition, leading to frustration.

Telemedicine Utilization: Although telemedicine was available, many residents continued to favor in-person consultations, limiting system usage rates.

Community Day-Care Center with Integrated AI Systems

Background

Elderly community in Shanghai, a day-care center serves local elderly residents, providing daily care, meals, and rehabilitation services. With government and private funding, the center partnered with an AI startup to integrate monitoring and support systems.

Key Design and Technological Highlights

Facial Recognition and Behavior Monitoring: Cameras placed at key points in the facility identify visitors and track residents' movement within the space. If prolonged inactivity or wandering outside safe areas is detected, staff receive alerts.

Activity Management: Using data on residents' interests and health statuses, the AI system recommends suitable social or rehabilitative group activities. Staff can review these suggestions through a centralized dashboard.

Family Coordination: The center's AI system partially synchronizes with at-home monitoring devices (like wearables), providing relatives real-time updates on the seniors' day-care attendance and well-being.

Outcomes and Remaining Issues

Benefits: The system greatly enhanced operational efficiency, reducing manual checks and lowering risks of missing or overdue interventions. Some seniors responded positively to personalized activity recommendations.

Limitations:

Maintenance and Reliability: Maintenance costs remained relatively high, stressing the limited community budget.

User Adoption: Differences in technology skills among staff and seniors sometimes led to misuse or avoidance of the system.

Privacy Concerns: Family members and some seniors expressed unease about facial recognition and data collection, worrying about data breaches or misuse.

Challenges and Response Strategies

Achieving smart elderly care through AI in age-friendly spaces involves a series of interlocking challenges—technical, economic, social, and ethical. A multi-level response, embracing all stakeholders, is imperative.

Technical Challenges

Reliability and Maintainability AI systems must function consistently, given the increased vulnerability of older adults to system malfunctions. Redundancies and fail-safe features are recommended for life-critical features such as emergency calls or health monitoring. Dedicated maintenance teams or service contracts can ensure regular inspections, updates, and technical support [18].

Multi-Modal Interaction and Interface Friendliness Many older adults experience varying degrees of hearing, vision, or cognitive decline. AI systems should integrate voice, visual, and tactile feedback, adopting large fonts, high-contrast color schemes, and simplified user flows to make usage more intuitive [19].

Data Security and Privacy Protection Robust encryption and access control protocols are necessary for safeguarding sensitive data. A combined cloud-local architecture may help compartmentalize critical health data. AI solutions must adhere to relevant data protection laws (e.g., GDPR, HIPAA) and give users transparent mechanisms for data access, correction, and deletion [20].

CONCLUSION AND FUTURE PROSPECTS

Research Summary

This paper addresses the theme “The Future of Smart Elderly Care: Significance and Pathways of AI Integration in Age-Friendly Spaces,” elucidating the broader context of population aging, the evolution of age-friendly design, and the cutting-edge AI technologies deployed in eldercare. From this review and analysis, it is evident that AI can offer a myriad of benefits, such as:

Substantially improving safety, convenience, and quality of life for seniors;

Easing the caregiving burden on families and society;

Driving industrial upgrades through cross-disciplinary synergy.

However, significant challenges remain, including technical reliability, economic barriers, social acceptance, privacy concerns, and gaps in legal or ethical frameworks. This paper’s proposed strategies span the technical, economic, social, and ethical arenas, underscoring the need for collaborative efforts among government, industries, care institutions, designers, and seniors themselves.

RESEARCH LIMITATIONS AND FUTURE OUTLOOK

Several limitations in this study warrant acknowledgment:

Scope of Case Studies: Only two cases—one upscale residence and one community-based center—were examined. Other environments, such as rural eldercare settings or specialized nursing hospitals, remain underrepresented.

Longitudinal Data Insufficiency: AI’s effectiveness and impact often unfold over extended periods. Short-term observations may not capture the sustainability or cost-efficiency outcomes accurately.

Depth of Cross-Disciplinary Analysis: While bridging interior design, AI, and socio-ethical considerations, more granular insights from technical, psychological, and policy-oriented domains could further refine the discussion.

Future research efforts could concentrate on:

Granular User-Centered Studies: Investigating variations by age, gender, health status, and sociocultural factors to customize AI applications.

Comparative Multi-Site Analyses: Conducting cross-regional, cross-cultural, and cross-income-level comparisons to identify universal design standards and scalable technologies.

Comprehensive Economic Assessments: Incorporating cost-benefit models and outcome-based evaluations to guide government and private sector investments.

Regulatory Frameworks and Governance Models: Collaborating with legal experts to create robust guidelines ensuring data security, fair algorithms, and transparent operations in AI-based elderly care.

When AI is more deeply integrated into the architectural blueprint of age-friendly spaces, “smart elderly care” will surpass the scope of mere functional assistance. It can evolve into a holistic program that addresses older adults’ physical, emotional, and social needs, thereby benefitting societies grappling with the realities of global aging.

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