Theory and Practice of Science and Technology
2025, VOL. 6, NO. 11, 31-33
DOI: 10.47297/taposatWSP2633-456906.20250611

Research on Application Models of Intelligent Technologies in Age-Friendly Space Design

Yijun Zhang

Korea National University of Arts, Graduate School of Technology Design, Seoul, 02707, Republic of Korea

ABSTRACT
Due to declining physical functions, older adults have unique spatial needs that traditional age-friendly designs struggle to address fully. Recent advancements in intelligent sensing, human-computer interaction, and data analytics have made it feasible to create innovative living environments that proactively adapt to elderly needs. This paper analyses older people's behavioural characteristics and spatial requirements, details the application of key technologies such as intelligent sensing, health monitoring, and natural interaction, and validates their effectiveness through case studies. It aims to provide design insights for enhancing older people's quality of life and well-being.

KEYWORDS
Intelligent technology; Age-friendly spaces; Elderly needs; Environmental sensing; Health monitoring

1 Introduction

In recent years, China's aging population has become increasingly severe, with the elderly population showing an annual growth trend. Elderly care has emerged as a hot topic, directly impacting society's harmonious and stable development. As individuals enter old age, their physiological functions inevitably decline, with reduced vision, hearing, muscle strength, and balance becoming commonplace. Consequently, they require greater assistance and care in daily life. However, analysis of traditional elderly care spaces reveals they fail to account for these changes, leaving safety risks such as falls prevalent. Against rapid technological advancement, intelligent sensing, environmental regulation, and natural interaction technologies are increasingly integrated into traditional elderly care settings. These innovations enable timely responses to seniors' needs, enhancing their autonomy and sense of security. This paper explores application strategies for innovative technologies in elderly care space design, presenting concrete case studies to foster the creation of senior-friendly environments that deliver comfortable, intelligent experiences for the aging population.

2 Overview of Smart Technologies and Age-Friendly Space Requirements

2.1 Analysis of Elderly Behavioural Characteristics and Spatial Usage Patterns

With advancing age, older adults experience progressive muscle weakness, reduced joint flexibility, and diminished balance. Consequently, they require greater support while walking and exercising and heightened caution when navigating stairs. Observations indicate that seniors move at a slower pace indoors, frequently using walls and furniture as support points. This reliance on continuous handrail installations within spaces also necessitates higher slip-resistance requirements for flooring materials [1]. Sensory functions like vision, hearing, and touch also vary. Visually, they become more sensitive to glare and experience reduced colour discrimination, necessitating careful lighting system design. Hearing loss diminishes perception of high-frequency sounds, while some seniors exhibit significantly reduced tactile sensitivity, increasing risks of accidental burns or slips. Space design must therefore ensure timely environmental information reception. Additionally, older adults often engage in social activities at fixed times in designated locations. Spaces like neighbourhood gardens and community activity rooms must offer good visibility and accessibility, with seating arrangements conducive to conversation.

2.2 Overview of Smart Sensing and Interaction Technology Systems

In age-friendly spatial design, various sensors are indispensable for effectively and accurately capturing changes in older people's surroundings and personal information. Standard sensor devices include motion detectors, pressure sensors, and eye-tracking systems. Motion sensors are typically installed in lobbies or entryways to track seniors' routes and record their movement patterns. Pressure sensors are usually fixed to floors or beneath sofas, analyzing pressure distribution to predict physical conditions and lifestyle information. Finally, eye trackers detect sudden falls or prolonged immobility. Utilizing deep learning for data processing, their recognition accuracy increases with more training samples. As a significant branch of interactive technologies, voice interaction technology also facilitates seniors in fulfilling their care needs [2]. Because some seniors may have slurred or slower speaking rates, voice interaction systems require robust speech recognition and semantic understanding capabilities. Simultaneously, gesture interaction is indispensable. This technology enables seniors to operate devices by recognizing specific hand motions. Voice control dominates in bedroom environments, while gesture and tactile interactions prevail in humid spaces like bathrooms. Seniors can naturally communicate with the innovative climate, significantly enhancing convenience and safety in daily life.

3 Specific Applications of Intelligent Technologies in Age-Friendly Space Design

3.1 Environmental Sensing and Adaptive Lighting Control Solutions

The effectiveness of environmental sensing technology in age-friendly spaces relies on the coordinated operation of multiple sensors. Light sensors precisely measure illumination levels at different locations; motion sensors detect human presence and movement trajectories within the space, with infrared detection ranges covering areas where seniors frequently move. Operating continuously around the clock, these sensors provide critical data for intelligent lighting adjustments. Adaptive lighting systems automatically detect natural light conditions and adjust artificial illumination accordingly. When sufficient daylight is detected, the system reduces artificial light intensity, ensuring adequate brightness while achieving energy savings [3]. For seniors with limited mobility, the adaptive lighting system identifies their movement patterns. It preemptively activates lighting in areas they are about to enter, enhancing walking safety and reducing fall risks. Additionally, the system offers personalized settings based on each senior's visual condition and usage habits. The system appropriately increases overall illuminance for those with cataracts to improve visibility; for seniors with better vision, it maintains standard lighting levels.

3.2 Smart Health Monitoring and Safety Alert System Design

Intelligent health monitoring systems play a vital role in age-friendly space design, functioning through various sensors to collect data without imposing additional burdens on seniors. The system automatically gathers health metrics as they go about their daily routines. Pressure sensors embedded in innovative mattresses monitor heart rate, respiratory rate, and turning frequency by detecting subtle bodily vibrations to extract physiological signals. Smart bathroom scales utilize bioelectrical impedance analysis to measure body composition data such as body fat percentage and muscle mass. Collected data is transmitted to a central processing system, generating a continuous health status record for each resident [4]. If abnormal nocturnal heart rate spikes are detected continuously, this may indicate cardiac overload in older people. Rapid short-term weight gain can sometimes signal edema or heart failure. Caregivers can intervene promptly with medical measures, minimizing life-threatening risks. The safety alert system employs fall detection sensors installed at key indoor locations. These analyze the older adult's posture and trajectory to identify fall events accurately. Upon detecting a fall, the system verbally checks the older adult's condition. If no response is received, it automatically contacts pre-designated emergency contacts and community healthcare providers [5].

3.3 Integration of Voice/Gesture Interaction in Furniture and Facilities

Given that many elderly individuals speak with accents or have unclear pronunciation, age-friendly space design necessitates integrated voice recognition systems. This system employs noise reduction technology to recognize voice commands accurately even in noisy environments. Seniors can adjust devices with simple voice instructions—for example, saying "Turn on the bedroom light" activates the lighting system, while "Increase the temperature" automatically adjusts the air conditioning. To reduce complexity, the system includes a preset set of standard commands that are concise and explicit, aligning with seniors' language habits [6]. Gesture interaction offers seniors an alternative intuitive control method. The gesture recognition system presets a series of simple, memorable gestures, each corresponding to a specific function: in the bedroom, a wave of the hand turns lights on or off; in the living room, a circular motion adjusts TV volume. The system records users' most frequently used gestures and confirms successful operation through visual cues like light flashes or gentle device vibrations. Furthermore, considering varying levels of technological acceptance among users, the system retains traditional manual controls as a backup option. Field observations confirm that this natural interaction approach reduces psychological barriers to learning new technologies. Seniors can accomplish tasks using the most natural methods—speaking or gesturing—which markedly enhances their satisfaction and comfort levels.

4 Evaluation and Implementation Cases of Smart Technology Applications in Age-Friendly Spaces

4.1 Evaluation Indicator System and Experimental Validation

A comprehensive evaluation framework incorporating multiple factors must be established to assess the effectiveness of innovative technology implementation in age-friendly spaces. This framework evaluates safety protection, accessibility, comfort, and humanistic care. Safety assessments focus on environmental safety conditions, facility accessibility, emergency response capabilities, and system recovery mechanisms during malfunctions. Key considerations include adequate coverage of facilities and the accuracy of fall detection systems for older people. Accessibility, understood as facility convenience, encompasses factors such as entrance widths accommodating wheelchair users and the simplicity and clarity of operational procedures. Comfort refers to the pleasantness of the facilities, including whether the design and technology create a comfortable environment for older people. Humanistic care assesses whether intelligent technology meets the spiritual needs of older people and allows them to feel humanistic care [7]. This paper employs quantitative and qualitative methods to obtain more accurate data: quantitative evaluation utilizes information from sensors installed within the space, with statistical analysis reflecting the effectiveness of the intelligent system application. For qualitative evaluation, a group of elderly individuals were invited to live in a simulated senior-friendly space for a period. Feedback and experiences regarding using various senior-friendly facilities and innovative products were gathered to understand the difficulties encountered during their use, thereby providing a basis for optimizing the application of innovative technologies in the future.

4.2 Case Study

By establishing an innovative elderly care management system, Xicheng District, Beijing, has significantly enhanced home-based and community-based elderly care services. This case demonstrates exemplary value. Currently, the district faces severe aging pressures: data indicate that by the end of 2024, the population aged 60 and above will reach 337,000, accounting for two-thirds of the total residents; those aged 80 and above will reach 67, 000, nearly half of this group. Conventional institutional care models struggled to meet practical needs due to geographical constraints. Xicheng District pioneered a home-based care model centred on families, supported by communities, and enabled by innovative technology.Regarding home modifications, eligible elderly households have been equipped with IoT monitoring systems to track daily activities and health status. Safety handrails have been installed along common pathways, and floors treated with anti-slip surfaces. Additionally, elderly care resources across 15 subdistricts and 263 communities have been integrated. Seniors can access care services by swiping their ID cards or senior citizen cards or booking appointments via WeChat. This district has been consecutively honoured as "China's Happiest Urban District" for two years, providing a model reference for other regions exploring age-friendly spatial design [8].

5 Conclusion

Among innovative technologies, intelligent lighting systems automatically adjust based on seniors' activity patterns and environmental changes, meeting visual needs while avoiding harsh light stimulation. Health monitoring systems utilize non-invasive sensors to detect abnormalities, supporting health risk prevention promptly. Natural interaction methods enable seniors to enjoy the conveniences of innovative technology effortlessly. Xicheng District's case demonstrates that integrating smart upgrades with traditional age-friendly design creates living environments that align with seniors' physical and mental characteristics while incorporating technological advancements. Future developments in bright age-friendly spaces will increasingly emphasize age-appropriate technology and human-centred design, significantly addressing population aging.

About the Author

Yijun Zhang , PhD. Candidate, Research Focus: Environmental Design, Spatial Studies.

References

[1] Hao, R. (2022). Research and practice on age-friendly intelligent residential space environment design (Unpublished master's thesis). Hebei University of Geosciences.

[2] He, C., & He, Y. (2022). Research progress and framework construction of age-friendly rural community environments in China. Architectural Journal of China, (S1), 45–50.

[3] Hu, B., & Yang, Z. (2025). Design research on age-friendly intelligent public rest facilities from a spatial syntax perspective. Silk Screen Printing, (15), 84–86.

[4] Li, H., Chen, C., Liu, X., et al. (2024). Spatial effects of urban street age-friendliness levels combining human-perceived street view images and machine learning. Journal of Geoinformation Science, 26(6), 1469–1485.

[5] Shen, Z. (2023). Research on age-friendliness survey and optimization strategies for Suzhou metro transfer space wayfinding systems. Research on Urban Rail Transit, 26(9), 285–286.

[6] Wang, Y. (2022). Application research on age-friendly sanitary facility design (Unpublished master's thesis). Jingdezhen Ceramic University.

[7] Wu, H. (2024). Research on age-friendly planning methods for old urban public spaces based on spatial syntax. Journal of Inner Mongolia Agricultural University (Natural Science Edition), 45(4), 28–36.

[8] Yan, X., Wang, X., Du, Y., et al. (2021). Research and application of age-friendly smart home systems. Construction Economics, 42(S1), 34–38.