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A REVIEW ON SMART HOME DESIGN AND TECHNOLOGY FOR ELDERLY

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Abstract:

The global elderly population is rapidly increasing, presenting significant challenges in providing suitable housing and care services, particularly in Eastern and South-Eastern Asia. This study explores the potential of smart home technologies, Internet of Things (IoT), and artificial intelligence (AI) in addressing the needs of the aging population, focusing on enhancing quality of life and supporting aging in place. The research examines three key areas: (a) architectural design considerations for elderly-friendly smart homes, emphasizing ergonomics, accessibility, and psychological well-being, (b) integration of IoT technologies for health monitoring, safety features, and emergency response systems, and (c) the role of AI in predictive healthcare and enhancing overall care delivery. The study also addresses ethical considerations, implementation challenges, and the importance of user-centered design in the adoption of these technologies.

Keywords:

Smart Home, Elderly, Internet of Things, Artificial Intelligence

Introduction

An older person or older adult or elderly is defined as a person who aged over 60 years old by United Nations (UNHCR, 2024). The size and proportion of elderly in the population are growing in nearly every country across the globe. In 2019, there were 703 million individuals

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aged 65 years or older worldwide (United Nation, 2019). It is projected that this number will double to 1.5 billion by the year 2050, as it creates financial challenges for countries in terms of providing suitable housing and services for their elderly citizens which is being major political issue (Mnea et al, 2023). The global share of the population aged 65 years or older has increased from 6 percent in 1990 to 9 percent in 2019, reported in World Population Ageing 2019 by United Nations in (United Nation, 2019). This proportion is expected to further rise to 16 percent by 2050, indicating that one out of every six people in the world will be aged 65 years or older (United Nation, 2019). The process of population aging has been most rapid in Eastern and South-Eastern Asia. In Eastern and South-Eastern Asia, the proportion of the population aged 65 years or over nearly doubled, increasing from 6 percent in 1990 to 11 percent in 2019 (Mnea et al, 2023). Figure 1 and 2 shows the percentage for population of elderly aged 65 or over in Eastern and South-Eastern Asia in 2019 and predicted number in 2030. By comparing those two Asia's regions, Japan is the highest of 30.9% by 2030, while Republic of Korea accelerate from 15.1% to 24.7%, increasing about 63.6%.

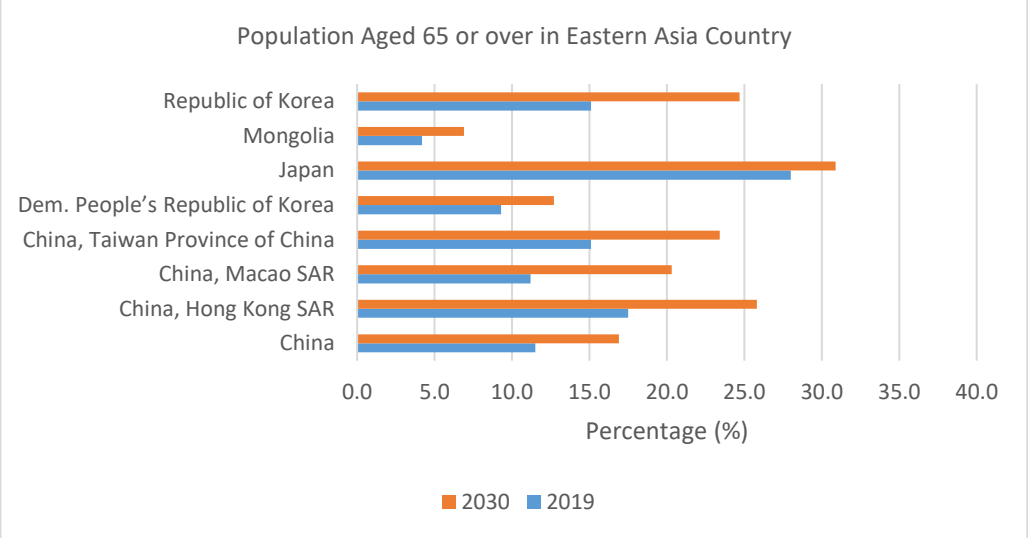

Figure 1: Percentage Population Ages 65 Or Over In Eastern Asia Country

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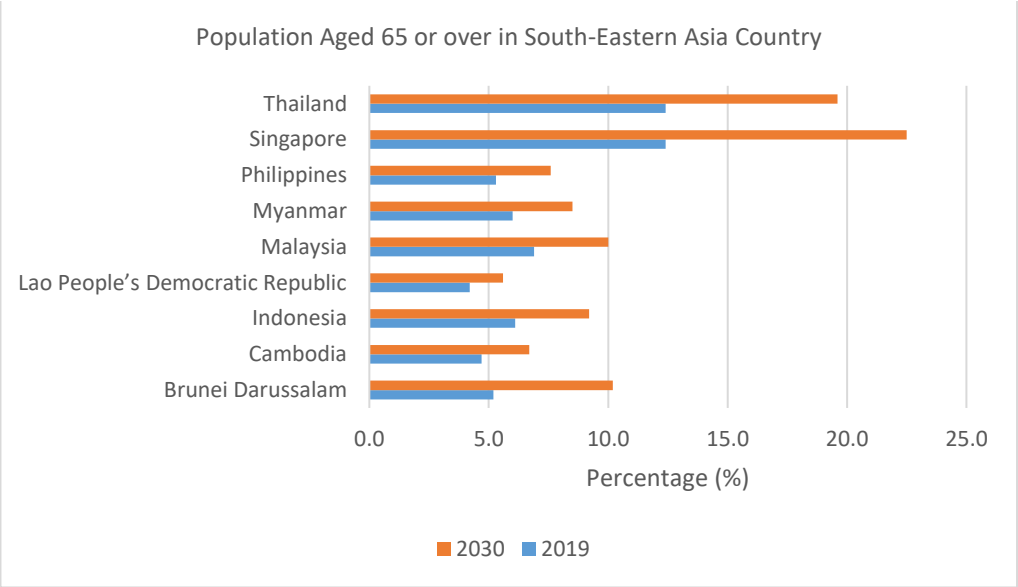

Figure 2: Percentage Population Ages 65 Or Over In South-Eastern Asia Country

The Eastern and South astern Asian regions are witnessing a significant increase in their aging population, a demographic shift that presents unique challenges. Compounded by cultural and societal changes, a growing number of elderly individuals find themselves living alone, often lacking the support and assistance they need. In the western region of China, 18.85% (487 out of 2,584) of the elderly population were found to be housebound within their communities (Zhao et al., 2016). This indicates that the condition of being housebound can potentially contribute to frailty (Katsura et al., 2018). This is portraying that the older people prefer to stay at their own homes. In Ningxia, China the number of older adults experiencing limitations in activities of daily living (ADL) is higher compared to the national average in China. This higher prevalence is associated with factors such as advanced age, ethnic minority status, low education level, low income, absence of a spouse, and the presence of diseases (Wang et al., 2023). Aging in place refers to the ability of individuals to continue residing in their own homes as they age, even as their health and mobility may change (Vanleerberghe et al., 2017). The concept of aging in place aims to fulfil people's desires by providing suitable services and support, enabling them to maintain a relatively independent lifestyle within their community. This may involve remaining in their current home or transitioning to appropriate housing options, depending on their level of autonomy (Davey et al., 2004). In this context, implementing smart home solutions tailored to the needs of the elderly can play a crucial role in addressing these challenges and improving their quality of life.

The concept of smart homes emerged in the early 20th century, predating and existing independently from the revolution of information and communication technologies (Doty et al., 2020). It is started with mechanized household, where these devices are stand alone and not connected to the Internet and Internet of Things (IoT) (Doty et al., 2020). The concept of a smart home is known by various terms, including "Home Automation," "Assistive Technology," "eHealth," "Digital In-house," "Smart Environment," "Automated House," "Smart Connected Home," and "Intelligent Living" (Hamdan, 2021). Smart home technologies play a crucial role in enhancing the quality of life for elderly. A smart home can be defined as the integration of technology and services within a home network, aimed at improving the

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overall living conditions (Maswadi et al., 2020). When implemented effectively, these technologies have the potential to enhance the quality of life for the elderly while supporting caregivers in providing essential services. It is undeniable that senior citizens require attention and assistance to carry out their daily activities. By focusing on healthcare, safety and security and leveraging cost savings, smart home technologies can create favorable living environments for the elderly.

Architectural Design

The architectural design of smart homes for the elderly is a critical aspect of enhancing their quality of life and ensuring their mental well-being. As populations age, particularly in countries like Japan, the integration of smart technologies into residential environments can significantly improve the living conditions of older adults. This response synthesizes various studies and findings to outline the essential features and considerations for designing smart homes tailored to the elderly.

One of the primary goals of smart home design for the elderly is to promote independence while ensuring safety and comfort. Smart homes can incorporate various technologies, such as health monitoring systems, automated lighting, and emergency response features, which are essential for elderly residents who may face mobility challenges or health issues (Zhang et al., 2020; Cantone, 2023). For instance, health monitoring systems can track vital signs and alert caregivers in case of emergencies, thus providing peace of mind to both the elderly and their families (Mao et al., 2021; Erfanmanesh et al., 2019). The design must also consider ergonomic principles to ensure that spaces are accessible and user-friendly, accommodating the physical limitations that often accompany aging (Zhou et al., 2022).

Moreover, the psychological needs of the elderly should be a focal point in architectural design. Research indicates that environments that are aesthetically pleasing and functionally appropriate can significantly enhance the residents' sense of home and belonging (Zhao, 2024). The use of color, natural light, and biophilic design elements can create a more inviting atmosphere that promotes mental well-being (Delcampo-Carda et al., 2019; Lee & Park, 2020). For example, incorporating green spaces or views of nature within the home can reduce stress and improve mood, aligning with the concept of biophilic design, which emphasizes the human connection to nature (Lee & Park, 2020).

In addition to physical and psychological considerations, the integration of cognitive sensor networks can enhance the functionality of smart homes. These networks can facilitate real-time monitoring of the elderly's activities and health status, allowing for timely interventions when necessary (Suh et al., 2015). However, it is crucial that these technologies are designed with the elderly in mind, ensuring that they are intuitive and easy to use. Training programs may be necessary to help older adults become familiar with these technologies, thereby increasing their acceptance and utilization (Yuan, 2023; Maswadi et al., 2022).

Furthermore, community integration is vital for the success of smart home designs for the elderly. Homes should not only cater to individual needs but also facilitate social interactions and connections with the community. Designing spaces that encourage social engagement, such as communal areas or shared gardens, can help combat loneliness and promote a sense of community among elderly residents (Sanchez et al., 2020; Sun, 2024). The architectural design

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should thus reflect a balance between private living spaces and communal areas that foster social interaction.

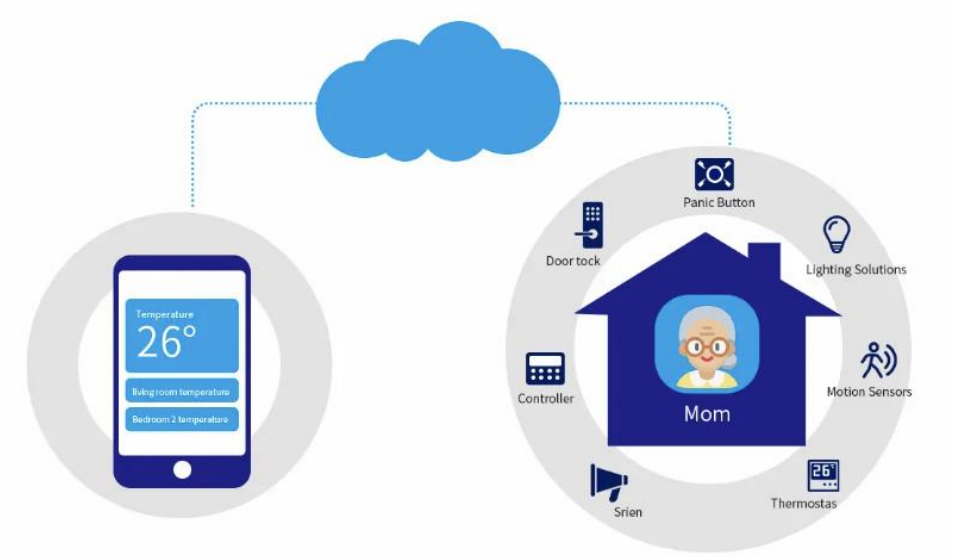

Figure 3: IoT Application for Elderly Smart Home (Norah H., 2023)

Smart Home and Internet of Things

The integration of smart home technologies and the Internet of Things (IoT) in elderly care represents a significant advancement in enhancing the quality of life for older adults. Smart homes equipped with IoT devices can provide a supportive environment that promotes independence, safety, and health monitoring for the elderly population, as shown in Figure 3. The literature indicates that these technologies can facilitate better living conditions through various applications, including health monitoring, emergency alerts, and social interaction enhancements.

Furthermore, Malarvizhi et al. discuss how IoT technologies can revolutionize healthcare processes, particularly for elderly patients with non-communicable diseases (NCDs), by enabling continuous monitoring and timely interventions (Malarvizhi et al., 2021). The benefits of smart homes extend to safety and security, which are critical concerns for the elderly. Seven notes that advanced safety features, such as remote monitoring and emergency alerts, can prevent accidents and provide peace of mind to both the elderly and their families (Seven, 2023). This is echoed by Pal et al., who assert that the integration of IoT in smart homes can facilitate various healthcare and social support services, thereby addressing the unique needs of the aging population (Pal et al., 2019). Moreover, the use of wearable sensors and IoT-enabled devices allows for real-time health monitoring, which is crucial for managing chronic conditions and ensuring timely medical responses (Ho et al., 2022).

Despite the promising advantages, the implementation of IoT technologies in elderly care faces several challenges. Tun et al. point out that data security and privacy concerns, along with the need for standardization, are significant barriers to the widespread adoption of IoT applications in healthcare (Tun et al., 2020). Additionally, the practical dilemmas surrounding smart home care models, as discussed by Wang et al., indicate that many regions still lack a comprehensive understanding of the needs and preferences of elderly individuals regarding smart home

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technologies (Wang et al., 2022). This gap in knowledge can hinder the effective deployment of these systems.

The Role of AI, Ethical Consideration and Challenges

The integration of smart home technology, mHealth, and artificial intelligence (AI) presents a transformative opportunity for elderly care, particularly in enhancing their independence, safety, and overall quality of life. Smart homes equipped with advanced technologies can significantly improve the living conditions of older adults by providing a supportive environment that caters to their unique needs.

The role of AI in smart homes extends beyond mere monitoring; it encompasses predictive analytics that can anticipate health-related incidents based on behavioral patterns. For example, systems can analyze data from various sensors to detect anomalies in daily routines, such as falls or unusual inactivity, thereby alerting caregivers or family members (Erfanmanesh et al., 2019; Almutairi et al., 2022). This proactive approach not only enhances safety but also alleviates feelings of isolation among the elderly, promoting a sense of security and connectedness (Erfanmanesh et al., 2019; Yu et al., 2020).

Moreover, the ethical considerations surrounding smart home technologies must be addressed to ensure that they are implemented in a manner that respects the autonomy and privacy of elderly users. Zhu et al. discuss the importance of creating non-invasive systems that empower older adults to maintain their independence while receiving support (Zhu et al., 2021). This balance is crucial, as the acceptance of smart home technologies by the elderly is often influenced by their perceptions of privacy and control over their living environment (Pal et al., 2019).

Despite the promising benefits, challenges remain in the widespread adoption of smart home technologies for elderly care. Issues such as technological literacy among older adults, the need for user-friendly interfaces, and the integration of these systems into existing healthcare frameworks must be navigated (Zhao et al., 2021; Zhang, 2022). Additionally, as highlighted by Hung, the lack of family support and trained personnel in many regions can hinder the effective implementation of smart home solutions (Hung, 2022). Therefore, ongoing research and policy development are essential to address these barriers and enhance the accessibility and effectiveness of smart home technologies for elderly care (Wang et al., 2022; Meng et al., 2020).

The convergence of smart home technology, mHealth, and AI holds significant potential to revolutionize elderly care by fostering independence, enhancing safety, and improving the quality of life for older adults. However, careful consideration of ethical implications and practical challenges is necessary to realize the full benefits of these innovations.

Conclusion

The integration of smart home technologies, IoT, and AI presents a promising solution to the challenges posed by aging populations worldwide, particularly in Eastern and South-Eastern Asia. These technologies have the potential to significantly enhance the quality of life for elderly individuals by promoting independence, ensuring safety, and facilitating health monitoring. The architectural design of smart homes for the elderly must consider both physical and psychological needs, incorporating ergonomic principles, biophilic elements, and spaces

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that encourage social interaction. However, the successful implementation of these technologies faces several challenges. These include concerns about data security and privacy, the need for user-friendly interfaces, and the importance of technological literacy among older adults. Additionally, the lack of comprehensive understanding of elderly needs and preferences in some regions hinders effective deployment. To fully realize the benefits of smart home technologies in elderly care, ongoing research and policy development are crucial. Future efforts should focus on addressing ethical considerations, improving the accessibility and usability of these technologies, and integrating them seamlessly into existing healthcare frameworks. By overcoming these challenges, smart home technologies can play a pivotal role in supporting aging in place and improving the overall well-being of the elderly population.

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