ENABLING ARCHITECTURE THROUGH TECHNOLOGY: OVERVIEW OF SMART HOME TECHNOLOGY SYSTEMS AND DEVICES AS SUPPORT FOR PEOPLE WITH DISABILITIES AND THE ELDERLY

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ABSTRACT

The rapid development of digital technologies and their application in various aspects of everyday life have led to the emergence of smart homes. Smart homes are not merely technological advancements; they represent a step toward a new way of living, where comfort, safety, and assistance converge to create an environment tailored to the individual needs of each user. The Internet of Things (IoT) technically supports this housing concept, integrating various devices and systems within the living space. Older people and people with disabilities often face obstacles that threaten their independence and safety in their own homes. In the context of an ageing global population and increasing needs for disability support, smart homes equipped with advanced monitoring, automation, and assistance can potentially enhance the quality of life for these groups.

In architectural discourses, integrating smart home technology with architecture to enable the adequate use of spaces has yet to be covered, pointing out a notable research gap. The aim of this research is to understand these technologies and their specific applications in supporting people with disabilities and the elderly through a lens of architects. This paper will methodologically review literature focused on smart home technologies and assistive technologies, as well as research examining smart home technologies as assistive technologies. It will define the main challenges faced by people with disabilities at home and identify the technologies that overcome those challenges. The results include a systematisation of technologies based on the problems they address and the impact of these technologies on users, along with a discussion and conclusion on the potential of these technologies in architecture. The results aim to serve as a foundation for further research on this topic through scientific papers and project.

KEYWORDS _ *Smart homes, disability, elderly, internet of things*

INTRODUCTION

The rapid development of digital technologies and their application in various aspects of daily life have led to the emergence of smart homes. The Internet of Things (IoT) technically supports this housing concept by integrating various devices and systems within the home, creating an interconnected system that responds to the user's needs (Hassan, Ali, & Khaleel, 2022). **Smart homes** are not just a technological achievement; they represent a step towards a new way of life, where comfort, security, and assistance are combined to create an environment tailored to the individual needs of each user. In the context of the ageing of the world's population and the growing need for support for people with **disabilities**, smart homes represent unique opportunities to improve the **quality of life** of these groups. According to United Nations estimates, by 2050, more than 2 billion people will be over 60 (Zubair, Olu-Flourish, & Nnaukwu, 2022), which poses a significant challenge to health and social care systems worldwide.

Older people and people with disabilities often face barriers that limit their ability to remain independent and safe in their own homes. In this context, smart homes, with their advanced monitoring, automation, and assistance systems, can support these groups, enabling them to maintain their autonomy and dignity for a longer time (Cleland, Hutchinson, Williams, Manuel, & Laver, 2023). The issue of implementing smart home technology as part of supporting people with disabilities and the elderly is a problem that can be examined from 3 aspects: **technology, medicine/psychology, and architecture**. In previous research, the architectural aspect has been the least represented. In addition to technological aspects, it is important to consider the impact of integrating smart systems into residential spaces from an architect's perspective. Adapting spaces to the needs of the elderly and people with disabilities requires innovative design approaches, and smart homes can offer the necessary flexibility. This paper will methodologically review literature focused on smart home technologies and assistive technologies, as well as research examining smart home technologies through the lens of assistive technologies. It will define the main challenges faced by people with disabilities at home and identify the technologies that overcome those challenges. The research results include a systematisation of technologies based on the problems they address, along with a discussion and conclusion on the potential of these technologies.

There are several terms related to smart home technology that carry similar meanings. The authors use the terms smart home (SH), assisted living (AL), home automation, internet of things (IoT), and assistive technologies. Some of the technological solutions implemented in smart homes, such as fall detection sensors (Kolobe, Tu, & Ovolavi, 2022), health monitoring systems (Willingham, Stowell, Collier, & Backus), voice controls, and home appliance automation (Hussein, Adda, Atieh & Fahs, 2014), have significant potential in reducing risks and improving the quality of life of users. However, despite rapid progress, **challenges** accompany the implementation of these systems. Questions arise regarding data security (Andone et al., 2020), user privacy, as well as the technological reliability of these systems (Jamval, Jarman, Roseingrave, Douglas, & Winkler, 2020), which must be resolved in order to ensure the broader application of these technologies.

RESEARCH OBJECTIVE AND RESEARCH QUESTIONS

This study aims to explore architectural aspects of smart homes in the context of their application for supporting people with disabilities and the elderly. The architectural aspects in this study are defined as spatial consequences of smart home interventions for people with disabilities, as well as guidelines for space organisation or housing prototypes. The architectural aspects also encompass the impact of these technologies on users. The research questions are addressed through a literature review and an analysis of existing studies that examine the application of smart home technology for people with disabilities. The study aims to answer two primary research questions:

1) What is the impact of implementing smart home systems on spatial organisation and the quality of life of users?

2) Which smart home tools are significant for people with disabilities?

METHODS AND MATERIALS

The literature review in this study follows the five-stage integrated review method presented in the paper by Turjamaa, Pehkonen, and Kangasniemi: *How Smart Homes Are Used to Support Older People: An Integrative Review (2019*). The stages of integrated review consist of defining the research **problem**, data **collection**, **evaluation** of data, data **analysis** and **interpretation** and presentation of the results. A clear algorithm is essential for establishing a well-defined research scope. Compared to the referenced study, the first step of this research involves formulating the **research questions** that guide the subsequent research phases. An initial research is required to assess the fundamental quality of existing studies and the breadth of the topic. The second step involves **collecting materials** for analysis, i.e., relevant scientific papers. Research platforms ResearchGate, Kobson, and Google were searched using keywords related to architecture, spatial accessibility for people with disabilities, and architectural technologies. The terms "disability," "construction materials," "wheelchair," and "accessibility" were initially used but yielded irrelevant results due to the multiple meanings of "accessibility," "architecture," and "materials." After further research, a refined combination of terms—"smart homes," "ambient assisted living," "geriatrics," and "disability"—was selected, as it provided relevant studies directly related to the research topic. To ensure the relevance of the analysed papers, the publication period was limited to works published between 2014 and 2024. The search was restricted to scientific papers fully available in English. Initially, papers containing "disability" and "smart homes" in their titles were reviewed, followed by those containing the selected keywords. The goal was to find studies examining smart home applications in the context of architecture. The third phase involved a **data evaluation** based on necessary criteria. Abstract analysis was used to filter papers relevant to architecture or user experiences in space and those describing specific technologies applicable to smart homes. A total of 12 papers were selected, with 8 meeting title criteria and an additional 4 chosen based on key terms. The selected papers were **analysed** through 2 aspects:

1) Impact of smart homes on accessibility in architecture, examining how smart home systems influence spatial accessibility.

2) Contemporary trends in technology, highlighting the latest advancements in smart home solutions

The selected papers were tabulated, highlighting the authors' origins, research areas, and publication periods (Table 1). In the column **area**, "CS" stands for computer sciences, "MED" stands for medical care research, and "EL" stands for electrical engineering. In columns **Arch.** and **Tech. +** implies that architectural/ technological aspects were discussed within the paper. The column type indicates if the paper is primarily a prototype presentation **(P)**, review paper **(R)**, or review paper based on an interview **(I).** The fifth phase involved the interpretation and presentation of synthesised conclusions through discussion.

Table 1: Overview of reviewed papers and their primary characteristics

Authors	Title of reviewed paper	Year	Area	Type	Arch.	Tech
Alam, S., Mahmud, S., & Yeasin, M.	Toward Building Safer Smart Homes for the People with Disabilities	2020	CS	P	/	+
Andone et al.	Current aspects regarding "smart homes"/ ambient assisted living (AAL) …	2020	MED	R	+	+
Cleland, J., Hutchinson, C., Williams, P. A., Manuel, K., & Laver, K.	The Experience of Using Home Automation by Individuals with Disability	2023	MED	I	+	+
Eren, D., Erdem, K., Radosveta, S., & Burhan, Ş.	Smart Home Assistant for Ambient Assisted Living of Elderly People with Dementia.	2017	EL	P	/	+
Hassan, M. M., Ali, I., & Khaleel, A.	Smart Homes for Disabled People: A Review Study	2022	CS	R	/	+
Hussein, A., Adda, M., Atieh, M., & Fahs, W.	Smart Home Design for Disabled People Based on Neural Networks.	2014	CS	P	/	+
Jamwal, R., Jarman, H. K., Roseingrave, E., Douglas, J., & Winkler, D.	Smart Home and Communication Technology for People with Disability: A Scoping Review.	2020	MED	R	+	+
Kolobe, T. C., Tu, C., & Owolawi, P. A.	A Review on Fall Detection in Smart Home for Elderly and Disabled People.	2022	CS	R	/	+
Turjamaa, R., Pehkonen, A., & Kangasniemi, M.	How Smart Homes Are Used to Support Older People: An Integrative Review.	2019	MED	R	+	+
Unaldi, S., Yalcin, N., & Elci, E.	An IoT-Based Smart Home Application with Barrier-Free Stairs for Disabled/ Elderly People	2023	EL	P	/	+
Willingham, T. B., Stowell, J., Collier, G., & Backus, D. n.d.	Leveraging Emerging Technologies to Expand Accessibility ….	2024	MED	R	/	+
Zubair, A. R., Olu-Flourish, E. S., & Nnaukwu, M. O.	…… Support at Old Age and Support for Persons with Disabilities: Speech Processing for Control of Energy.	2024	EL	P	/	+

RESULTS

Overview of Technologies Relevant to People with Disabilities

This paper intersects two fields: the first is smart home (SH) technologies, and the second is assistive technologies (AT). **Smart home** technologies (SH) are systems that enable the automation of activities within the home (Hassan, Ali, & Khaleel, 2022). Home automation encompasses automatic or remote control of devices and programs connected via wired or wireless networks. These systems can manage doors, blinds, heating and cooling, lighting, windows, faucets, showers, and televisions using smartphones, tablets, or voice controls (Cleland, Hutchinson, Williams, Manuel, & Laver, 2023). The **Internet of Things (IoT)** refers to a system of interconnected machines, devices or objects that enable interaction with the physical world (Unaldi, Yalcin, Elci, 2014). Smart home technologies, IoT, and home automation are also applied in environments used by non-disabled individuals and living in such space is defined as Ambient Assisted Living (AAL).

Assistive technology (AT) is a broad term that encompasses any item, piece of equipment, software program, or product system used to increase, maintain, or improve the functional abilities of people

with disabilities. (Atia.org, 2025) These technologies include low-tech devices, such as eyeglasses or wheelchairs, as well as high-tech devices such as IoT and SH. A wide range of devices and systems is currently in use for this purpose, reflecting the broad spectrum of disabilities they are designed to accommodate, and in most cases, a single device is used to address multiple issues (Jamwal, Jarman, Roseingrave, Douglas, & Winkler, 2020). Devices used in smart homes can be categorised into two main groups. The first group consists of active devices, such as control panels and switches, with which the user directly interacts. The second group includes passive devices, such as sensors and radio receivers, with which the user does not directly interact (Andone et al., 2020). **Sensors** can be wearable or integrated into the home environment. Wearable sensors have expanded the possibilities for non-invasive monitoring of various psychological and physiological activities. New technologies enable the integration of multiple sensors into a single device, including accelerometers and optical sensors. These devices can track movement, activities, and heart rate (Willingham, Stowell, Collier, & Backus). Depending on the level of disability, in addition to **controlling** devices via smartphones and tablets, control can also be performed using lips, eyes, or other methods (Jamwal, Jarman, Roseingrave, Douglas, & Winkler, 2020). For example, a **brain-computer interface (BCI)** allows for reading electronic brain activity using electroencephalography (EEG). By monitoring these activities and linking them to external devices, users can control SH, home appliances, and assistive technologies such as wheelchairs and prosthetic limbs (Hassan, Ali, & Khaleel, 2022).

In addition to hardware, researchers are working on developing **software** solutions, including artificial intelligence systems such as neural networks (Hussein, Adda, Atieh, & Fahs, 2014). Several studies highlight the importance of **machine learning** (Hassan, Ali, & Khaleel, 2022; Turjamaa, Pehkonen, Kangasniemi, & Kangasniemi, 2019; Willingham, Stowell, Collier, & Backus) in adapting systems to users' specific needs. Machine learning (ML) enables smart home systems to "learn" user behaviour and adjust accordingly. A threat detection system, **SafeAccess** uses machine learning (Hussein, Adda, Atieh, & Fahs, 2014) to identify hazards in the user's home, while voice recognition software can learn to follow users' voice commands (Zubair, Olu-Flourish, & Nnaukwu, 2022), thereby simplifying smart home control for users with mobility impairments.

Impact of Smart Homes on Space and Users – Disabled people

Most studies indicate that smart homes and communication technologies have a **positive impact** on both older users and people with disabilities, enabling increased independence and participation in daily activities. These technologies allow for a longer life in a home environment by delaying entry into nursing homes or hospitalisation, which positively affects the users' mental and physical health. In the study by Cleland, Hutchinson, Williams, Manuel, and Laver (2023), interviews revealed that most participants felt home automation reduced their dependency on caregivers, as they no longer had to wait for someone to perform tasks like opening windows, lowering blinds, or turning lights on and off. This reduced dependency lessens economic burdens, contributes to improvements in physical and psychological health, and creates a sense of dignity. Smart home technologies impact people with **disabilities, older adults**, and **caregivers**—including healthcare professionals, family members, or paid non-medical staff. Caregivers play a significant role as primary users of these technologies, which have the potential to reduce their workload. Caregivers of people with disabilities report that the technology has given them a greater sense of control and has simplified their obligations (Jamwal, Jarman, Roseingrave, Douglas, & Winkler, 2020). Family members of older adults also consider smart home technologies to be beneficial and have generally expressed more positive attitudes compared to the older participants themselves. Additionally, these technologies enable healthcare workers to monitor daily activities, which can help in tracking health and providing necessary care to patients (Turjamaa, Pehkonen, Kangasniemi, & Kangasniemi, 2019).

All review articles emphasise the special importance of smart home technology regarding user **safety**. Older adults and people with disabilities represent vulnerable social groups, making them

more prone to accidental injuries and at greater risk of **violence** (Hussein, Adda, Atieh, & Fahs, 2014). Several studies also highlight the risk of **falls** and the importance of sensors and Ambient Assisted Living (AAL) systems in fall incidents. A prompt response to falls can reduce treatment costs and the number of fatalities caused by falls (Kolobe, Tu, & Owolawi, 2022).

However, smart home technologies' implementation and positive impact do not come without challenges. Caregivers of people with disabilities have expressed concerns regarding safety and the accessibility of inappropriate content that may be encountered online, and the use of such technology may increase dependency on caregivers for its setup and maintenance (Jamwal, Jarman, Roseingrave, Douglas, & Winkler, 2020). Furthermore, **ethical concerns** are raised regarding continuous **monitoring** of users, as there is a fine line between enhanced safety and the loss of privacy rights. One negative aspect is the vulnerability of these systems to **hacker attacks** and viruses, since smart home systems are always online (Andone, et al., 2020). Although many users believe that smart home technologies increase their overall security, they do not necessarily feel safer when alone. Many have stated that, in the event of an accident, they would prefer to have a spouse or caregiver present (Turjamaa, Pehkonen, Kangasniemi, & Kangasniemi, 2019). The **reliability** of devices often depends on external factors such as internet connectivity, and many smart home technology users express frustration when the technology malfunctions or does not integrate well with other smart home devices (Cleland, Hutchinson, Williams, Manuel, & Laver, 2023).

DISCUSSION

Presented technology concepts share both common and distinct characteristics. **Assistive technologies** represent the broadest category, encompassing a greater number of aids, while SH and IoT can serve as assistive technologies. On the other hand, IoT and SH are also used beyond assistive technology to facilitate everyday life and increase comfort for non-disabled individuals, which was their primary development goal. Home automation is closely related to **IoT**, but the key difference is that IoT is a system, whereas home automation utilises IoT systems' information and connectivity to enable remote or automatic control. The most crucial characteristic of SH technology as assistive technology is its **flexibility**. Flexibility, in this case, means both a wide range of devices to choose from, regarding a wide range of disabilities, as well as the need for flexibility of particular devices considering progressively worsening conditions, which change the user's needs over time. It is evident that researchers in the field of technology have made the greatest progress in smart home development. Multidisciplinary teamwork plays a critical role in achieving the desired goals. Assistive devices are developed in collaboration with experts from healthcare, rehabilitation and gerontology, as well as computer science and engineering. Notably, none of the papers mentions **architects** as relevant participants in creating these spaces, nor is there any author from the field of architecture. Several studies highlight the importance of involving people with disabilities and older individuals in the decision-making process regarding integrating these technologies into their living spaces, as well as in the design and operation of these systems. **Participatory design** was applied in the prototype of a threat detection system (Hussein, Adda, Atieh, & Fahs, 2014), with thirty participants with various types of disabilities being interviewed to achieve better outcomes. Participation was not mentioned in the other studies describing prototypes as part of the design process.

CONCLUSIONS

Smart home technologies hold great potential for improving the quality of life for older adults and people with disabilities. While reviews of smart homes as assistive technologies have been conducted, this paper introduces a new perspective by examining aspects relevant to architects: impact on users and systematisation of technology which can be used in project. The aim of this study is to bring the topic closer to architects by systematising current technologies that can be applied and identifying

the necessary collaborators for a successful project. Further research should place additional emphasis on social and economic aspects, considering the interconnection between the economic and social vulnerability of older adults and people with disabilities and their physical condition. These technologies are often inaccessible to the most socially and economically vulnerable individuals who need them, highlighting the necessity of involving social services and insurance systems to ensure their effective implementation. The topic researched in this paper is relevant to at-risk groups, for whom it enables independent control over their environment, and to their caregivers, nurses, and families, as these technologies reduce their burden. On the other hand, ethical concerns regarding the balance between monitoring and privacy remain crucial and should be discussed in more detail. Considering all these factors, the most significant conclusion is that the primary goal should be participatory design, involving a broader range of stakeholders in designing these technologies and spaces. The lack of **participatory design** and inclusion of **architects** and **social sciences** in theory and practice is evident and is a possible guideline which can lead the future research and improvement of these systems and their implementation in homes.

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