Mapping a Decade of Smart Homes for the Elderly in Web of Science: A Scientometric Review in CiteSpace

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Abstract: Challenges caused by the care of the ageing population in many countries are becoming increasingly severe. However, high expenditures on healthcare services and the cost of infrastructure construction will be an unbearable burden for both the government and individuals. Due to its security, convenience, and lower prices compared with traditional medical care, smart home technology, which includes information and communication technologies (ICTs), artificial intelligence (AI), and the Internet of Things (IoT), can reduce the care burden. While smart home studies targeting older adults have increased, systematic analysis of these studies is lacking. CiteSpace enables rapid clustering and visualisation of the literature using scientific diagrams, exhibiting the results more comprehensively. This analysis of academic research published within the last decade (from 2012 to 2023) through a scientometric approach can help to understand the historical variations, the latest technologies and emerging trends, and the research clusters that have emerged related to the study of smart homes for the elderly (SHFTE). The study results showed that recent research mainly centres on IoT for home automation and home-based healthcare, including wearable device applications and information security analysis. Research trends regarding SHFTE have focused primarily on developing and updating smart technologies based on the IoT, sensors, and related home monitoring. Therefore, greater emphasis must be placed on connecting smart homes and intelligent buildings with communities and societies, developing the potential of smart communities, and investigating the application of smart integration to the home and community in cities.

Keywords: smart home; smart technology; CiteSpace; older adults; senior care

1. Introduction

In the next 50 years, the world’s proportion of people aged 60 and over will almost double from 12% to 22% according to the World Health Organization [1]. The number of people aged under 5 exceeded that of those 60 and older in 2020. As the global elderly population grows steadily, countries are dealing with the challenges of population ageing, and every country will face an ageing society. Globally, most countries face significant challenges when building medical facilities, long-term medical care, and social insurance for the elderly due to the increasing numbers of older adults [2,3].

It has been decided by the United Nations (UN) General Assembly that the United Nations Decade of Healthy Aging between 2021 and 2030 will focus on 4 areas of work: changing the perception, feelings, and actions of ageing and ageism; promoting older people’s capabilities through the development of communities; providing primary healthcare services and person-centred, integrated care to older people; and providing quality long-term care [1]. Since 1982, China has had a state policy of family planning to control the country’s total population, which means that a family can only have 1 child. Now, 30 years later, this policy has resulted in a situation where most older adults will have to face living
alone; moreover, the elderly population is increasing year by year, and the dependency burden of young people is growing gradually, with the elderly dependency ratio rising from 12.7% in 2012 to 20.8% in 2021 [4], an increase of 8.1% (Figure 1). A growing number of seniors over 65 has resulted in China having the most older adults in the world. The number of seniors over 65 has increased by 72 million over the past decade to reach 200 million [5], 14.2% of the country’s total population. It is clear from these figures that the issue of older adults has become pressing in China and one that is faced by both China and the rest of the world.

The EU’s projections for the future elderly population are not optimistic either. Survey data show that the number of people over 65 is expected to grow from 17.1% to 30.0% in 2060 (from 84.6 million in 2008 to 151 million) [6]. The same data are reflected in the United States, where the population over 65 has reached 5.58 million, accounting for 17.1% of the total population in 2021. It is predicted that by 2050 it will reach 20.2% [7]. In Japan, where the population is ageing even more severely, it is expected that in 2050 the population of people over 65 years old will reach 39.6% of the total population [8]. South Korea’s population is ageing faster than any other country, with 15% of the total population over 65 years old in 2019, which is predicted to grow continuously to 44% by 2067 [9].

The demand for healthcare services has increased as populations’ life expectancy has risen. However, proper fee-for-service care provided by caregivers or senior care centres remains out of reach for many older people due to the rising cost of healthcare services and the high price of care [10].

Over the past few decades, advances in information and communications technology (ICT), artificial intelligence (AI), the Internet of Things (IoT), and other technologies, as well as the growing popularity of smart cities and smart living, have driven the development of the smart home sector [11]. Smart home technology is an emerging solution to address the ageing population, the need for long-term medical care for older adults, and independent living [12]. When faced with the physical limitations of older adults, who may need long-term medical care and rapid emergency medical assistance, smart home technology can be a low-cost solution to safety, independence, health, and service [13].

The smart home was first introduced by the American Builders Association in 1984 and refers to a house with intelligent interactive technology [14]. Smart homes can record
users’ habits and needs and interact with users through sound, image, location, light, and other ways [15]. External devices and resources provide users with health assistance, medical care, security, education, entertainment, and many other services [16]. To accommodate this societal development, the concept of the ageing smart home has been developed. This concept focuses more on older adults’ health, independence, and security needs.

While smart home studies targeting older adults have increased, systematic analysis of these studies is lacking. This study uses a scientometric approach to analyse scholarly research published over the past decade in smart homes for the elderly (SHFTE). The core contribution of this study is to identify the knowledge structure of SHFTE from its large body of literature. In addition to providing a clear overview of authors, publications, countries, organisations, and publication sources, we provide a visual analysis of literature searches in the Web of Science (WoS) database for identifying the number of publications, the disciplinary distribution, the research history, highly cited articles, keyword clusters, keywords bursts, the disciplines, and the research hotspots. The study also explores the research directions and development trends of elderly smart homes based on the results of this study, which will provide researchers, policymakers, and practitioners with a better understanding of the research progress in this area, provide valuable references for future research, and solve the problem of elderly home care after population ageing [17,18].

2. Data and Methods
2.1. Data Sources

Web of Science Core Collection is the world’s leading citation database. The database contains records of articles from journals with the most significant impact worldwide, including open-access journals, conference proceedings, and books [19]. It is also a collection of the world’s most prestigious core academic publications in all fields of study, including natural sciences, engineering, biology, medicine, etc. Among the citation indexes used to ensure that the sample data are comprehensive and accurate are the Science Citation Index Expanded (SCI-Expanded), the Social Science Citation Index (SSCI), the Arts and Humanities Citation Index (1975–present), and the Emerging Sources Citation Index (ESCI). The final search term was selected after several experiments: (TS = (“elderly” OR “old people” OR “ageing” OR “elderly people” OR “old adults” OR “senior citizens” OR “older adults” OR “seniors”) AND TS = (“smart home” OR “smart technology” OR “Intelligent technology” OR “Intelligent home” OR “home automation” OR “domotics”)). The time was set from January 2012 to February 2023. This study excluded the following from the retrieved literature: (1) meeting abstracts, (2) reviews, (3) book reviews, (4) data papers, and (5) research papers with incomplete literature and irrelevant to the research topic. Finally, 1034 papers were obtained from WoS, and the studies searched were broadly consistent. The search was conducted on 11 February 2023.

2.2. Research Methodology

This study conducted a scientometric analysis of the existing literature on SHFTE to address the following research questions: 1. What are the research clusters, historical changes, latest technologies, and emerging trends in SHFTE? 2. What are the classifications of smart home technologies suitable for older adults in recent years?

To answer such questions, we used a scientometric analysis software—CiteSpace. CiteSpace is a data visualisation and analysis software developed by Prof. Chaomei Chen, aiming at scientifically analysing knowledge in the literature using an econometric approach. This program can visualise and analyse data in the research field, track the hot issues of research in the field, and identify research trends [20]. Moreover, the literature citation and co-citation networks make finding the critical literature in this research area easier. Before analysing the data with CiteSpace, duplicates were removed from the WoS
data using the software’s built-in data processing tool to ensure the study results’ accuracy.

CiteSpace was used to conduct a comprehensive analysis of the dataset, which included the annual distribution of the dataset, the co-occurrence and keywords analysis, disciplinary distribution, and the distribution of publications. While the analysis of keywords gives us an insight into the literature, popular terms, and research frontiers within the broad field of research, the analysis of the annual distribution provides us with an understanding of the current state of the field [21].

3. Analysis and Results

3.1. General Observations

As mentioned above, the literature on SHFTE comprises 1034 publications from January 2012 to February 2023 from 83 countries, including 3433 authors, 1293 organisations, and 809 publication sources (Table 1).

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covered period</td>
<td>For January 2012 to February 2023</td>
</tr>
<tr>
<td>Covered countries</td>
<td>83</td>
</tr>
<tr>
<td>Number of publications</td>
<td>1034</td>
</tr>
<tr>
<td>Number of organisations</td>
<td>1293</td>
</tr>
<tr>
<td>Number of authors (including corresponding authors, authors, and co-authors)</td>
<td>3433</td>
</tr>
<tr>
<td>Number of publishing sources</td>
<td>809</td>
</tr>
</tbody>
</table>

SHFTE publications have increased over the last decade, as shown in the statistical chart (Figure 2); the highest number of publications was in 2020, with 139. The year with the most citations was 2021, with 130 publications and 3159 citations. This trend indicates that research on SHFTE has gained significant academic interest in the last five years. Journal articles comprise 51% of publications, conference papers comprise 44%, and review articles comprise 6% (Figure 3). The United States (n = 137), China (n = 116), and Italy (n = 74) are the top 3 producers of publications, accounting for 13.25%, 11.22%, and 7.20% of total publications, respectively (Table 2). A majority (51.7%), a large percentage (42.46%), and a small percentage (14.7%) of the publications pertain to computer science, engineering, and telecommunications (Table 3). The top three authors with publications in this field are Mukhopadhyay SC; Goubran R, Knoefel F, and Yasumoto K; and Suryadevara NK and Vanus J (Table 4), and a list of the top five organisations with the most publications in this field is shown in Table 5.

<table>
<thead>
<tr>
<th>Countries/Regions</th>
<th>Record Count</th>
<th>% of 1034</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>137</td>
<td>13.25%</td>
</tr>
<tr>
<td>China</td>
<td>116</td>
<td>11.22%</td>
</tr>
<tr>
<td>Italy</td>
<td>74</td>
<td>7.16%</td>
</tr>
<tr>
<td>Canada</td>
<td>71</td>
<td>6.87%</td>
</tr>
<tr>
<td>South Korea</td>
<td>63</td>
<td>6.10%</td>
</tr>
</tbody>
</table>
Figure 2. Annual distribution of the studies on smart homes for the elderly from WoS.

Figure 3. Document types of the SHFTE literature.

Table 3. The subject area of the SHFTE literature.

<table>
<thead>
<tr>
<th>Subject Areas</th>
<th>Record Count</th>
<th>% of 1034</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Science</td>
<td>535</td>
<td>51.741%</td>
</tr>
<tr>
<td>Engineering</td>
<td>439</td>
<td>42.456%</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>152</td>
<td>14.700%</td>
</tr>
</tbody>
</table>

Table 4. Top 3 most productive authors (first author).

<table>
<thead>
<tr>
<th>Rank</th>
<th>Author</th>
<th>Record Count</th>
<th>% of 1034</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mukhopadhyay SC</td>
<td>13</td>
<td>1.257%</td>
</tr>
<tr>
<td>2</td>
<td>Goubran R</td>
<td>10</td>
<td>0.967%</td>
</tr>
<tr>
<td>=2</td>
<td>Knoefel F</td>
<td>10</td>
<td>0.967%</td>
</tr>
<tr>
<td>=2</td>
<td>Yasumoto K</td>
<td>10</td>
<td>0.967%</td>
</tr>
<tr>
<td>3</td>
<td>Suryadevare NK</td>
<td>9</td>
<td>0.870%</td>
</tr>
<tr>
<td>=3</td>
<td>Vanus J</td>
<td>9</td>
<td>0.870%</td>
</tr>
</tbody>
</table>
The top ten most-cited articles related to senior smart homes are listed in Table 6. These ten articles focus on three main areas: healthcare, Internet technology, and assisted living. These three areas reflect the need for smart technology and the Internet to improve seniors’ home living adaptability. In addition, monitoring older adults’ health data and the Internet’s application for data collection and exchange is another important research topic. Using the Internet can improve the safety of living and the living experience of older adults.

Table 5. Top 5 most productive affiliations.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Affiliation</th>
<th>Record Count</th>
<th>% of 1034</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Centre National De La Recherche Scientifique Crns</td>
<td>27</td>
<td>2.61%</td>
</tr>
<tr>
<td>=1</td>
<td>Udice French Research Universities</td>
<td>27</td>
<td>2.61%</td>
</tr>
<tr>
<td>2</td>
<td>Massey University</td>
<td>20</td>
<td>1.93%</td>
</tr>
<tr>
<td>3</td>
<td>Washington State University</td>
<td>15</td>
<td>1.45%</td>
</tr>
<tr>
<td>4</td>
<td>Marche Polytechnic University</td>
<td>13</td>
<td>1.31%</td>
</tr>
<tr>
<td>=4</td>
<td>University of Ottawa</td>
<td>13</td>
<td>1.31%</td>
</tr>
<tr>
<td>=4</td>
<td>University of Quebec</td>
<td>13</td>
<td>1.31%</td>
</tr>
<tr>
<td>=4</td>
<td>Carleton University</td>
<td>13</td>
<td>1.31%</td>
</tr>
<tr>
<td>=4</td>
<td>Communauve Universite Grenoble Alpes</td>
<td>13</td>
<td>1.31%</td>
</tr>
<tr>
<td>5</td>
<td>Institut National Polytechnique De Grenoble</td>
<td>12</td>
<td>0.97%</td>
</tr>
<tr>
<td>=5</td>
<td>Nara Institute of Science Technology</td>
<td>12</td>
<td>0.97%</td>
</tr>
<tr>
<td>=5</td>
<td>University of Toronto</td>
<td>12</td>
<td>0.97%</td>
</tr>
<tr>
<td>=5</td>
<td>University of Washington</td>
<td>12</td>
<td>0.97%</td>
</tr>
<tr>
<td>=5</td>
<td>University of Washington Seattle</td>
<td>12</td>
<td>0.97%</td>
</tr>
</tbody>
</table>

Table 6. Top 10 most-cited publications in WOS.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Publication Title</th>
<th>Authors and Years</th>
<th>Research Focus</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Portet, F. (2013)</td>
<td>Personal and Ubiquitous Computing</td>
<td>208</td>
<td></td>
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</table>
Older Adults’ Reasons for Using Technology while Aging in Place
A systematic review of the smart home literature: A user perspective
Smart Homes for Elderly
Healthcare-Recent Advances and Research Challenges
The Smart Grid-State-of-the-art and Future Trends

<table>
<thead>
<tr>
<th></th>
<th>Title</th>
<th>Author</th>
<th>Journal/Conference</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Older Adults’ Reasons for Using Technology while Aging in Place</td>
<td>Peek, STM. (2016)</td>
<td>Gerontology</td>
<td>202</td>
</tr>
<tr>
<td>9</td>
<td>Smart Homes for Elderly</td>
<td>Majumder, S. (2017)</td>
<td>Sensors</td>
<td>197</td>
</tr>
</tbody>
</table>

3.2. Keyword Analysis

3.2.1. Distribution of Publications by Keywords

Keywords are one of the essential information factors about articles that reflect research trends in CiteSpace; the co-occurrence network graph of keywords analyses the descriptor (DE) and identifier (ID) fields in a document and generates a network view of these variables. In the visual graph, circles and size subscales represent keywords and their frequency of occurrence. The line between each circle represents the academic relevance between the keywords; the distance between the circles represents whether the theoretical relevance is closer. The colour of the circles represents the chronological order, with the average year of publication of the keywords in demand from early (light colour) to recent (dark colour). Red circles represent the emergence (first occurrence) of the keywords. CiteSpace automatically generates clusters based on keywords in the literature, and larger clusters represent more relevant literature for that cluster, indicating a hot area of interest for researchers.

The keyword cluster network diagram (Figure 4) aims to cluster these 1034 documents according to the keywords in the abstract, title, and topic, with the colour overlays representing the intersection of the documents between the different clusters. Time is reflected in each dot; the size of the dot reflects the number of relevant documents, and the publication time of the literature ranges from early (yellow) to recent (green). The largest cluster is #0# smart home (CiteSpace is sorted by cluster size starting from 0). The clusters with high academic relevance to this cluster are #9 smart home care, #10 research agenda, #2 visual sensor, and #1 daily living. Moreover, “ambient intelligence” is represented by a large red circle, which means that this keyword has emerged in recent years and has attracted much interest from researchers. In addition, keywords closely related to smart homes are “home automation”, “recognition”, “machine learning”, “Privacy”, and “assistive technology”. This shows that, with the combination of IoT and smart homes, researchers are not only concerned with technological advances but also with the security and privacy issues associated with these emerging technologies. Wearable technology embedded with IoT offers a direct link between the smart home and smart city for older adults, which may be an emerging research direction with broad application prospects.
Clusters #4 and #5 contain “fall detection”, “activity recognition”, “detection system”, and other keywords with larger circles, which means that these two clusters are newer research directions for smart homes. In addition, more contemporary research topics have emerged in recent years, such as a sensing infrastructure survey in cluster #7, a visual sensor in cluster #2, and deep learning, all of which are directly related to IoT; this implies that the emergence of the IoT is closely associated with the development of SHFTE. Therefore, the IoT has the potential to establish a link with each cluster and thus become a new hub.

The timeline (Figure 5) also shows that cluster #0, which has been ongoing since 2012, is closely linked to all clusters, especially to clusters #1 and #2, mainly in terms of “care”, “adoption”, “recognition”, “deep learning”, and other keywords. It can also be seen that many of the keywords that first appeared in 2012 have continued to be studied until this year, indicating that 2012 was a more active year for research.
According to the time zone diagram (Figure 6), the keywords that frequently appear in 2022 and 2023 are “health technology”, “community”, “life space”, “smart home systems”, “freezing of gait”, and other topics related to medicine and health, smart technology, Internet technology, etc., indicating that these topics have continued to receive attention from researchers this year.

Figure 6. SHFTE Research Keyword Time Zone Diagram.

3.2.2. Keyword Bursts

Keyword bursts can reflect changes in research topics and hotspots. The top 30 most-cited keywords from 2012 to 2023 are shown in Figure 7, with the Strength value indicating the intensity of the keyword cited and representing the number of studies related to the keyword. Strength is the most significant keyword for smart homes (7.83), which first appeared in 2012 and lasted until the end of 2014. It is worth noting that “privacy” (3.99) is the most recent keyword in 2021. Digital health (3.59) continues until 2023, indicating that with the development of smart technology, the security of information in the Internet of Things is recently receiving attention from researchers. Digital healthcare is also a recent research hotspot. Additionally, deep learning, mobility, and gait analysis are all research hotspots related to smart technologies, indicating that the upgrading and development of smart technologies also continue to grow.
3.3. Co-citation Analysis of the Literature

Co-citation in the literature is a situation in which two papers co-cite the same literature. In this way, a co-citation relationship is formed between the two papers, which can be used to chart the study’s development and evolution. A co-citation analysis can reveal a research field’s main trends, directions, and terminology by exploring the knowledge structure. In CiteSpace, clustering by subject keywords shows the co-citation relationships between the literature and research fields; a circle’s size indicates the frequency with which the literature is cited. The larger the node, the more frequently the literature is cited, and the greater the connection between the lines. The larger the circle, the more regularly the literature is cited; the more significant the lines, the more critical a paper is. In a certain period, the red circles indicate that the article was frequently cited, which indicates that the report had a significant impact on its field (Figure 8).

Figure 7. Top 30 Keywords with the Strongest Citation Bursts.
As can be seen in the figure, the number of articles cited gradually increases from 2012 (purple node) to 2023 (yellow node); the high citation bursts of the articles cited are marked with red nodes, the duration set by the authors is at least 4 years, and the results obtained include 21 articles, indicating that 21 articles have been cited highly frequently and for at least 4 years in the last decade (Figure 9). The author names marked in the figure represent the authors of the most-cited papers.

The obtained citation network graph was re-clustered by topic to obtain the citation network graph classified by clusters (Figure 10). The chart also reflects the temporal
relationship, with lighter colours representing more recent times. The most-cited article in the #0 smart home technology cluster is by Li et al., “Motivations, barriers, and risks of smart home adoption: from systematic literature review to conceptual framework” [22]. Table 7 shows the top 10 most-cited articles in cluster #3 by the highest coverage. Coverage means that an article cites the percentage of coverage of all articles that are classified into this cluster. Higher coverage indicates that the literature is more relevant to that cluster and reflects the cutting-edge topics of research in that area. The articles listed in Table 6 reflect the level of contribution of the literature in this field, while the articles listed in Table 7 reflect the research trends in this field.

![Figure 10. Clustering network diagram of cited literature.](Image)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Coverage</th>
<th>Title</th>
<th>Author, Year</th>
<th>Research Focus, Vol, Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24</td>
<td>Motivations, barriers and risks of smart home adoption: from systematic literature review to conceptual framework.</td>
<td>Li, W (2021)</td>
<td>Energy Research &amp; Social Science, V80, P29</td>
</tr>
<tr>
<td>2</td>
<td>21</td>
<td>Smart homes: how much will they support us? a research on recent trends and advances</td>
<td>Zielonka, A (2021)</td>
<td>IEEE Access</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
<td>Internet-of-things and smart homes for elderly healthcare: an end user perspective Review of applications and user perceptions of smart home technology for health and environmental monitoring</td>
<td>Pal, D (2018)</td>
<td>IEEE Access</td>
</tr>
<tr>
<td>4</td>
<td>19</td>
<td>Ethics and acceptance of smart homes for older adults Prohibitive factors to the acceptance of internet of things (iot) technology in society: a smart-home context using a resistive modelling approach</td>
<td>Rhee, JH (2022)</td>
<td>Journal of Computational Design and Engineering</td>
</tr>
<tr>
<td>5</td>
<td>18</td>
<td>Prohibitive factors to the acceptance of internet of things (iot) technology in society: a smart-home context using a resistive modelling approach</td>
<td>Pirzada, P (2021)</td>
<td>Informatics for Health and Social Care, V47, P28</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>Research Focus</td>
<td>Pal, D (2021)</td>
<td>Technology in Society, V66, P16</td>
</tr>
</tbody>
</table>
Li et al. [22] discuss the motivation, barriers, and risks users face when using smart homes. Smart homes can provide efficient energy management, better home healthcare services, potential financial savings and benefits, and improved quality of life. At the same time, the development of smart homes presents some barriers: mistrust and resistance from the user population, limited knowledge of smart homes, cost of use, security concerns about privacy breaches, technology anxiety, and negative social impacts. Pirzada et al. [23] discussed the acceptance of smart home technology among older adults from an ethical perspective. From 2006 to 2020, many researchers conducted research experiments on assistive technology for older adults, and the results of the studies showed that the impact of smart technology on older adults was positive and optimistic and that family members were more eager to adopt the technology than older adults themselves [24].

Pal et al. [25] demonstrated experimentally that privacy concerns are a crucial reason why home IoT and smart home solutions have yet to be widely adopted. In addition to information leaks, privacy violations occur when physical private space is destroyed, and users fear they may lose control over the space they use for privacy. Schomakers et al. [26] also investigated users’ perceptions of privacy issues with smart home automation. The results showed that semi-automated systems were more popular than fully automated smart homes. On average, the most popular smart home systems were those for energy management with the highest reliability; the least accepted were those for elderly health, due to excessive collection of personal information and reliance on data stored in the public agency’s cloud.

Another area of smart home technology that has received attention from researchers is smart assistive monitoring. To determine how users perceive wearable and non-wearable health and environmental monitoring devices from a utility, ease-of-use, and privacy perspective, Rhee et al. [27] compared different user perceptions of these technologies. Some older people disagreed with the usefulness of the health devices because they did not want to acknowledge their vulnerability. In contrast, others felt that wearable devices were more helpful for health monitoring. Ijaz et al. [28] presented and discussed how smart IoT and cloud computing technologies could effectively improve patient care. During the COVID-19 period, IoT-based systems were widely used. Patients can receive accurate health monitoring by accessing data at home, and medical staff can be in hospitals and clinics to diagnose patients via the Internet. This approach is seen as promising for use in medical centres.

Ma et al. [29] summarised the design strategies for smart home retrofitting, which can be achieved by adapting existing houses to suit older adults. Assistive technologies (ATs) ranging from home automation to wearable monitoring devices are designed to compensate for the decline in the basic life skills of older adults and for the gradual loss of control over their living environment, which can be enhanced with the help of ATs to improve the daily safety of their daily activities. Moreover, a smart home transformation process and a technology classification of smart home environments are proposed. In [30],
Zielonka et al. presents a comparative study that examines the recent advances in home technology in the context of the Internet of Things (IoT). Through research reports and patent analysis, the study identifies the key directions and trends of research in this field. Furthermore, the paper provides an overview of the proposed solutions and highlights the leading publishers and innovators in the smart home industry.

These studies show that the emerging keywords of SHFTE are privacy, digital health, deep learning, mobility, and gait analysis. This shows that the recent main topics of interest for researchers are mainly in the healthcare field.

3.4. Distribution of Publications by Country

In the literature related to SHFTE, the results obtained from the co-occurrence network according to the country of publication and the topic of the article are consistent with Table 2; the United States is the country with the most published articles (n = 138), followed by China (n = 119), and then Italy. As can be seen from the figure, China, the United States, Korea, Spain, and Australia are more closely linked in the published literature, indicating that the keywords reflected are routine variability, wellness model, smart nursing home, reminder care system, complex activities, etc. (Figure 11).

![Figure 11. SHFTE Research of Publications by Country.](image)

In addition, Japan, France, Canada, Germany, and India also show a high level of interest in this field, with France being more closely linked to Canada, and Germany being more relevant to India.

4. Discussion

By collecting and classifying these 1034 articles on SHFTE in the WoS database and performing a scientometric analysis of the results, we analysed the current research status, development history, and future trends of SHFTE. Based on our data, we reclassified the smart homes by technology type (Figure 12). Using CiteSpace’s keyword clustering results, these 1034 articles were reclassified according to smart technology type to integrate current smart home technologies in a comprehensive perspective. Based on the usage
scenarios and purposes of the seniors, the smart home technologies were classified into daily living environment and quality of life, energy management and sustainability, healthcare and life security, and social and entertainment.

The first category, daily living environment and quality of life, includes residential security and environmental renovation. Technologies related to residential security include activity monitoring, door and window intrusion alarm monitoring, carbon monoxide alarms, water flooding alarms, intelligent electronic door locks, and GPS location devices, etc. Another aspect of improving the quality of life is the renovation of the indoor space environment such as the workspace, kitchen, bathroom, bedroom, and other spaces designed for seniors to improve their quality of life and work, such as smart appliances, smart toilets, barrier-free handrails, sensor lights, etc.

The second category is energy management and sustainability. This category covers all technologies of home automation control. All appliances in the home are linked through the Internet of Things (IoT), including environmental monitoring automation. As an automatic feature, lights will automatically be on when someone passes by, curtains will automatically open in the morning, and air conditioning or heating equipment will automatically turn on when the room temperature is too high or too low. The automatic control system of the equipment is to achieve the purpose of energy saving by automatic control of the switch of the electrical equipment. Moreover, the energy consumption in the home can be visualized through smart phones or monitored with monitors. The third category, “Healthcare and Life Safety”, includes wearable and non-wearable devices (sensors) through which many medical monitoring concepts are implemented. These include fall monitoring, gait analysis, vital sign monitoring, activity monitoring, etc. The fourth category is social and entertainment, which consists of various smart technologies that enhance the living experience. It is worth mentioning that emotion perception, a concept that has only been introduced in recent years, is used to monitor and analyse the activities of target objects and determine the current emotional activity through sensors and AI recognition.

It is worth noting that while smart technology is beneficial for seniors to improve the convenience and security of their lives [31], the operation of smart devices has a certain complexity, and the need to learn how to use new technologies has led some seniors to object because they consider themselves incapable of operating them [23].
Figure 12. Classification of smart home technology.
4.1. Daily living Environment and Quality of Life

Smart home technology aims to improve the daily living environment and the quality of life of users, including residential security and environmental improvement. Intelligent security of a residence is achieved by installing monitoring devices and sensors in the residence. Monitoring devices can provide timely warning to family members or caregivers in response to possible high-risk events, such as when a stranger breaks in or an emergency occurs [32,33]. However, the use of cameras increases the risk of privacy leakage; in order to improve the privacy of cameras, researchers have improved data security through techniques such as information network security, security protocols, and security threat models to protect privacy while also guaranteeing the security of data transmission [34]. In addition, due to memory loss in the elderly and the possible impairment of vision and hearing, smart home devices can monitor fire, gas leakage, flooding, and other safety hazards in the room and issue alerts in time to remind older adults to take appropriate measures to ensure the safety of their lives. At the same time, smart home devices can provide emergency rescue services, such as the emergency call button and positioning function. Older adults can send distress signals and location information to family members or medical personnel through smart home devices to get immediate help in case of an emergency [35].

As the memory of the elderly gradually decreases with age, and some may have Alzheimer’s disease or dementia, they are often unable to find their way home after going out, resulting in serious consequences of getting lost and going missing [36,37]. When the GPS positioning system is used with a smart home, it can identify the location of the older adults and inform the family before an accident occurs, reducing the risk of older adults getting lost.

A second type of modification is to the home environment. Older adults’ physical conditions and living habits differ from those of young people. The indoor environment has become increasingly unsuitable for older adults as they age. Therefore, to improve the safety of the elderly, the indoor environment needs to be modified.

Bathrooms are places that are more frequently used by older adults and are prone to safety accidents. Due to changes in their physical conditions, sight lines, lighting, antislip, and handrails are essential aspects that need reconsidering for older adults. Therefore, Liu et al. [38] proposed retrofitting for bathrooms and toilets. Additionally, the bedroom is frequently used by older adults, and the modification of the bedroom is also related to the behaviour patterns of older adults. Lee et al. [39] proposed three behaviour patterns for the smart bedroom. Moreover, with the gradual development of technology, older people are more adept at using smart technologies, such as the Internet or social networks and smartphones, and have the desire and need to use home workspaces. Therefore, Cho et al. [40] proposed the design direction of smart workspaces for the elderly.

4.2. Energy Management and Sustainability

Smart energy management in the home is intended to reduce the cost of living and improve energy use based on the operation of energy-efficient buildings to achieve better indoor conditions. In this direction, artificial intelligence and advanced smart metering can be used in energy management, as well as the proposed combination of heating, ventilation, and air-conditioning units (HVAC); renewable energy sources (RES); and battery energy storage systems (BESS), in addition to advanced control technologies for building energy systems, such as model predictive control [41], reinforcement learning [42], and optimal control [43]. All these technologies provide suitable solutions and optimisation for energy management in smart homes. Furthermore, various advanced intelligent lighting systems have been developed to create an energy-efficient system that combines electricity and natural light [44].

Optimising energy consumption while maintaining resident convenience is one of the most important intentions of the smart home. The smart home is a combination of
automation (non-smart) and intelligent (smart) systems. Devices such as sensors and appliances (automation) are used to monitor and collect information about the environment [45], while intelligent systems manage these automated devices and energy losses are monitored in real time and controlled through intelligent systems [46]. Thus, indoor air quality, temperature, humidity, ventilation, light, and heating in the home environment can be monitored. When the house is unoccupied, the automated system will turn off or dim all artificial lighting, reduce the ventilation rate, and lower the heating. It also anticipates and provides heating and hot water in advance based on daily activities and triggers the heating of equipment in advance. For many years, researchers have been investigating the use of information and communication technologies to automatically and intelligently control heating systems and intelligent air-conditioning systems [47–49], as well as to visualise energy use. The home’s automated energy control system can help seniors automate the management of electrical devices in their homes, greatly improving convenience, achieving energy savings, and reducing the cost of living.

4.3. Healthcare and Life Security

Healthcare is the most researched and widely used area in SHFTE. Sensing technology is used to monitor the medical health of older adults for their home-based care needs. Physiological sensors are used to measure physical health indicators such as respiration and heart rate for assessing older adults, and there are many wearable or non-wearable devices on the market today for sensing respiration and heart rate, assessing sleep patterns [50], for pressure management [51], and for predicting respiratory-related diseases. For example, pressure sensors can be installed on mattresses in older adults’ rooms to monitor their sleep status and living conditions and detect abnormal physical conditions promptly. Wearable devices can be used not only to monitor primary vital signs data, such as heart rate, blood pressure, body temperature, and blood glucose, but also to capture human movement data, monitor activity and gait, and monitor abnormal behaviours such as falls and comas [52–54]. In addition, these data can be transmitted to medical institutions in real time, and doctors can make timely diagnoses and treatments based on this data [55].

The elderly can use smart home devices for remote consultation, remote diagnosis, remote monitoring, and other services to facilitate their access to medical services at home and reduce the time and cost of travelling to and from the hospital. At the same time, smart home devices also allow doctors to keep track of the health status of older adults and make timely adjustments and treatments [56].

Fall monitoring in SHFTE is an area that has been studied more this year [53]. Various technical means are usually used, including visual recognition, accelerometers, and sensors. Among them, optical recognition technology can monitor the activity status of the elderly by installing cameras to detect if they fall and then analysing the images in the cameras through intelligent algorithms to quickly identify the fall events of older adults and issue alerts promptly [57]. In addition, accelerometers and sensor technologies can monitor body posture and action trajectory in real time via sensors on older adults or furnishings. When older adults fall, the sensors automatically identify and trigger the fall alarm system [58]. To improve the accuracy and reliability of fall monitoring for older adults, smart home fall monitoring can also combine other intelligent technologies, such as artificial intelligence, machine learning [59], and cloud computing, to analyse and process a large amount of fall monitoring data, improve the accuracy and timeliness of fall monitoring, and help older adults prevent fall events [58–60].

Another use in the field of healthcare for seniors is emotion recognition. With an emphasis on automation and support, smart home technology has seen a rise in popularity in recent years. Examples include Alexa, Google Home, Apple HomePod, and several low-cost IoT gadgets. Using smart home technologies to help older persons stay in their homes is a primary target application. However, most current geriatric smart home
solutions need to be created with people’s emotional objectives in mind, which results in low acceptance, low engagement, and the failure of the technology [61].

In [62], Hossain et al. suggest creating a robust emotion detection module for an emotionally intelligent linked healthcare system. Several IoT devices are used in a smart home scenario to record audio and visual information from a patient. These impulses are input to the emotion-detecting module. Speech and image inputs are processed separately to provide classification scores, which are then merged to produce a final score that may be used to identify the mood. Caregivers may visit the patient if it is established that the emotion is pain. In comparison, another study focuses on the emotional state of specific groups of individuals, such as older adults, especially under COVID-19. In [63], they propose an IoMT healthcare monitoring system that is based on brainwaves and sensitive to emotions. Modern headsets and other gadgets now incorporate electroencephalography (EEG) sensors, which can recognise emotions based on brainwaves. Most IoT-based emotional assistance for older adults is based on various sensors for emotional monitoring and elderly recognition, including wearable technology or speech recognition [64,65].

4.4. Social and Entertainment

For seniors, it is also important that smart homes provide socialisation and entertainment. Seniors who live alone have familiar friends and neighbours who visit and participate in various social and recreational activities in the community. Social companion robots (SCRs) incorporating various sensing technologies, including vision, voice, and haptic feedback, can communicate with other intelligent devices in the environment. This integration enables the creation of advanced AI solutions that promote an age-friendly, assistive smart space [60].

Lazic et al. [66] introduced the concept of social communication service in their article. It addresses the issue of older individuals’ social isolation and loneliness by facilitating interactions between them and family members, caregivers, friends, and even strangers through social communication services. With the help of the service, senior citizens can stay in touch with friends and family while participating in regular activities such as eating together, sketching with their grandchildren, crocheting, and much more. The program includes a side feature called “Meet Others” in addition to making video calls. By pressing a virtual button, this capability enables primary users to initiate video chats with other GUIDed primary users randomly. The remote user is chosen at random by the GUIDed system and is a member of the GUIDed community; it is also possible to communicate with a GUIDed user if the remote user has consented to the call and the preferred languages of both users are the same.

Social robots are the principal embodiment of smart technology for senior socialising. Robots have been suggested as an intelligent technology that might enhance older individuals’ independence and health. While there have been tremendous advancements in hardware and sophisticated software to allow autonomous robot activities, there needs to be more focus on developing robot behaviour that is understandable and enjoyable for older persons [67–69].

5. Conclusions

To better understand research trends, publishing authors and organisations, literature citations, keyword-based clusters of existing research, and developing trends, this study conducted a scientometric analysis of smart homes for older individuals. A total of 1034 papers for the analysis were found through a search of the WoS database. It was discovered that healthcare, energy management, and home help (home automation) are the most extensively studied topics in the use of SHFTE.

The study’s findings indicate that (a) there has been a steady increase in the literature on SHFTE over the past ten years. (b) The United States, China, Italy, and Canada are the nations with the most research in this field, and there is a need to foster cross-national and cross-organisational communication and collaboration. (c) The majority of the research
currently carried out on SHFTE is concentrated on home assistance (automation), energy management, healthcare, and deep learning. The most investigated fields in healthcare are mostly sensors and wearable devices for health monitoring, fall detection, IoT-based telemedicine, deep learning, artificial intelligence, IoT for home information management, and IoT applications for home automation. (d) The emerging keywords of SHFTE are privacy, digital health, deep learning, mobility, and gait analysis. These keywords indicate a steady growth of research in the direction of healthcare. (e) There needs to be more research in the humanities, social sciences, and design fields, which highlights the need to diversify future research by including viewpoints from these fields. The majority of publications are in the technical fields of computer science, engineering, communication, etc. (f) As smart home technology advances, there is a growing need for data collection and transmission, and concerns about geriatric data security and privacy leaks should be handled carefully. (g) While smart home technology can help the elderly, the operating procedure needs to be simplified for older adults to use.

Finally, not only does this study provide a retrospective analysis of the smart home for seniors sector as well as a comprehensive and systematic summary of research trends in smart homes for seniors, but the findings also provide quantitative data to inform researchers, policymakers, the government, and the public sector and contribute to the future globalisation of the smart home industry. However, as part of the smart city issue, the present research focuses more on creating and upgrading in-home technology than on community and social aspects. As a result, greater emphasis must be placed on connecting smart homes, intelligent building with communities and societies, developing the potential of smart communities, and investigating the application of smart integration to the home and community in cities.

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