A Bibliometric Analysis of Smart Home Acceptance by the Elderly (2004-2023)

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***Abstract*—Both academia and business firmly endorse the notion that a smart home would be the solution to easing the excessive social burden associated with demographic ageing and improving older adults' quality of life by enhancing living independence while encouraging their desire to age in place. This study uses bibliometric analysis to examine the research trends on elderly people's acceptance of smart home. The results are derived from analysis using the VOSviewer software on 257 documents in the Scopus database. The results reveal that: there is an accelerating growth rate for the smart home literature focusing on the elderly's acceptance since 2004; the majority of these studies are journal articles filed in the research area of computer science; the most commonly mentioned keywords include "smart home(s)" and "older adults"; the US has produced the highest number of related works; and the most cited articles are composed by authors across nations with tight collaborations.**

***Keywords*—Smart home; acceptance; elderly people; ageing-in-place; bibliometric analysis; VOSviewer**

I. Introduction

A report from the United Nations [1] revealed a global ageing trend by stating that the worldwide population of people aged 65 and above has grown to 771 million by 2022, and is estimated to reach 1.6 billion by 2050 with an increased proportion of 16 percent from 10 percent (in 2022) of the overall population. Demographic ageing may incur serious social problems, such as overburdened health care systems due to the increased demand for nursing facilities and care services [2],[3]. In addition, elderly people are showing significant willingness to continue living in their own homes [4], [5] for the strong desires of independent living, healthcare and social connection [6]. Meanwhile, the elderly care industry has been driven towards intelligence by the Internet technology sector's quick expansion, so the smart home-based elderly care model has come into being for the reason that smart homes would considerably ease the strain of social health care systems by integrating limited elderly care resources in the market and society to provide elderly care services with wisdom, precision and efficiency [7], and on the other hand, would satisfy the need for ageing-in-place (AIP) by the elderly [2]. Therefore, smart home research from the elderly perspective is of great significance to comprehensively learn how their intentions to accept and utilize smart home technologies are formed.

Smart homes are commonly considered as residences in which devices and appliances equipped with interconnected sensors are placed for the purpose of improving inhabitants' comfort, convenience, safety, security and quality of life [5], [8]. The increasingly expanding consumer interest has led to a rapid growth in the smart home industry. Tech giants like Google, Amazon, Apple, Huawei, Xiaomi and Samsung are racing to meet the demands for their smart home products and services by competing in this emerging market [9]. As Statista [10] estimated, from US$115.7 billion in 2022, the global smart home market's revenue is projected to soar to US$222.9 billion in 2027, a CAGR of 22%. Users can benefit from personalized smart home services through either automation or remote control [11] since data and information are automatically interchanged between devices to make corresponding responses according to changes in surrounding environment or users' customization [12]. With the aid of assistive technologies, the elderly may enjoy a higher quality of life in a "smart home" as evidence has shown that the utilization of nursing homes or care-givers leads to negative impacts on older people, such as feelings of stress, depression and change of habit [3]. In this case, the academia around the world all considered AIP through the adoption of smart home as the optimal solution for ageing societies [13], [14].

The term "smart home" is used in this study to describe homes that provide their residents with superior levels of convenience, security, and comfort, which is actualized by networked devices and appliances with processers and sensors [15]. Elderly people, following the extant research, particularly include people who are aged 60 years old and above [16], [17]. Thus, this study's overarching goal is to identify the current state of research on the topic of elderly citizens' adoption of smart homes, including its driving forces and key players, with the expectation of potentially providing suggestions for future studies in this domain.

The remainder of the study is organized as follows. Based on different research focuses on smart homes, Section II overview the recent literature mainly from the perspective of older adults. Section III describes the employed methodology. The results and findings are presented in Section IV, followed by a detailed discussion on the findings. Section V makes conclusions of the whole study.

II. Literature Review

A. From Technology Perspective

There has been a lot of research on many aspects of the smart home for the elderly. One group of researchers looked at how and whether smart home technologies helped the elderly. For example, with the use of Ambient Assisted Living technology, Blackman et al. [18] demonstrated that older individuals' autonomy and quality of life could be improved. Aramendi et al. [19] tried to detect functional health decline in the elderly using in-home behavior data collected by smart

homes, and they concluded that functional health issues are predictable from smart home data, which is important for early intervention in ageing societies. Fritz et al. [20] explored a potentially prominent use of health-monitoring smart homes to provide assistance to older adults with chronic conditions by remotely detecting a range of physical status. Results showed that smart homes helped recognize clinical changes in seniors' health and treatment and medication management. To foresee the likelihood of falls among the elderly, Kulurkar et al. [21] developed a low-cost fall detection system using wearable sensors in a smart home setting, and they ended up with a considerably high accuracy rate of 95.87%.

B. From User Perspective

Another group of researchers has been looking into smart homes from the viewpoint of the elderly since there is a dearth of literature on the attitudes of older individuals about embracing such technology [22]. According to research by Pigini et al. [23], elderly people value health monitoring systems that employ smart technology for their own protection. Yu et al. [24] clustered Korean seniors based on their residential lifestyles to examine whether or not there are distinct requirements for smart home features, and they found that there was some variation. In a focus-group-based study, Ghorayeb et al. [5] revealed that both users and non-users of smart home monitoring technology considered feasibility, customization and data security of great importance to accept the technology; while users concerned more about utility, and less about privacy intrusion and trust.

C. Bibliometric and Scientometric Work

Benefit from the rapid growth of information technology and statistics tools, scholars have recently made effort to systematically analyze extant smart home literature through bibliometric data. Choi et al. [25] used a bibliometric approach and analyzed 2339 articles published between 2015 and 2019 from the Scopus database in smart home and Internet of Things (IoT) domain in order to indicate key research trends and knowledge mapping for future studies. Li et al. [26] applied a scientometric analysis with smart home research published from 2000-2021 in the Scopus database to illustrate historical changes, emerging trends, and research clusters. Ohlan and Ohlan [27] comprehensively analyzed bibliometric data published in the Web of Science from 2001 to 2021, and suggested indispensable trends and patterns of smart home research. Another study by Hong et al. [28] applied bibliometric and scientometric analyses with 1408 related articles acquired from the Web of Science database to thoroughly overview smart home features for the elderly.

However, in the existing review studies on smart homes, bibliographic approach was seldom applied, and none of the authors made older adults the central focus of their work. Besides, taking the competence of smart homes in helping ease social stress into consideration in the context of demographic ageing, there is a need for systematic research to comprehensively analyze the research trends on the smart home acceptance literature particularly for the elderly. As far as the authors are aware, no research has been done in the area of Smart Home Acceptance by the Elderly (SHAE). Given that it contributes to substantial insights via bibliometric analysis on a specific subject, structurally reviewing earlier studies to tease out key research trends becomes crucial for scholars. Therefore, this study aims to investigate current research trends of smart home studies, especially those related to the acceptance by the elderly, applying a bibliometric approach to summarize current directions in this field, prominent venues and authors, research clusters, as well as to identify and suggest prospective research directions. Findings of this study will present relevant stakeholders, such as academics, policymakers, and businesses, with research and working directions for the near future.

III. Methodology

A. Bibliometric Analysis

In the study, published articles in the Scopus database on the global trend of SHAE from 2004 through 2023 (by 25 July) are analyzed using bibliometric analysis. Bibliometric analysis was firstly introduced by Pritchard [29], and has been commonly described as a technique using mathematics to statistically analyze published books, articles, and other communication media so as to provide a broad overview of certain knowledge field [25], [30]. By conducting this technique, academics will gain insight into selected research domains in terms of research trends, significant authors, institutions, publishers, nations, as well as potential research gaps [31].

B. Data Collection

The Elsevier Scopus database was utilized to collect bibliographic data for this study, which has been recognized as a leading multidisciplinary repository of influential peer-reviewed research in social science fields [25], [32] for the reason that it contains a considerable number of high-quality materials, e.g., 75.5 million files, 24.6 thousand titles, and 194 thousand books [26]. Compared to other commonly used databases for bibliometric analyses (i.e., PubMed and Web of Science), Scopus is advantageous for the reasons that it is the largest database containing multidisciplinary publications, and publications are classified into multiple research areas accordingly [33], which makes it more suitable for mapping based on research areas. And the appropriateness of adopting Scopus database has been particularly acknowledged by scholars in the smart home domain [25], [26]. Thus, from the time the first publication on SHAE appeared in the Scopus database until this study was composed, all publications on the subject of the smart home acceptance by the elderly were included (25 July, 2023).

The objective of this research is to examine, from a user's point of view, the relationships between and clusters of related studies on smart homes. Therefore, the query (TITLE-ABS-KEY (smart AND home) AND (adoption OR acceptance)) was set as the search task, which produced a number of 1421 documents. Based on the search results, the query was then refined as (TITLE-ABS-KEY (smart AND home) AND (adoption OR acceptance) AND (elderly OR older)) to focus on the predetermined target age-group, and this resulted in a reduced number of 257 documents. All of the generated documents from the refined searching are retained for a thorough analysis and understanding of the research trends.

The data was collected on 25 July, 2023. The search result includes conference papers, articles, book chapters, reviews, conference reviews, books, notes, letters, and short survey. Data were exported in "CSV" format to be compatible with VOSviewer, the software employed for data analysis.

IV. Results

A. Publication Trend

Table I summarized the publication trend by year since the first article on the elderly acceptance in smart home industry published in 2004. It is clear that not all research articles have been cited. Except for the first six years (2004 – 2009), the proportions of cited publications over total yearly publications never reached 100% for the following years onwards. Overall, the average proportion was 77.14% with a standard deviation of 13.10 from 2010 to 2023. The number of citations received also varied a lot. Documents published in 2018 seem to be most influential since they gained the highest number of citations of 855. Besides, publications in the years of 2008, 2014, 2016 and 2019 also had significant impact for the academia with citations over 460, respectively.

TABLE I. Publication Trend

Year	Number of Publications	Cited Publications	Proportion	Total Citations
2004	2	2	100%	67
2005	0	0	-	0
2006	1	1	100%	1
2007	2	2	100%	50
2008	5	5	100%	503
2009	3	3	100%	40
2010	6	5	83%	69
2011	10	8	80%	256
2012	13	11	85%	204
2013	9	6	67%	339
2014	13	10	77%	520
2015	10	9	90%	202
2016	13	12	92%	505
2017	17	13	76%	341
2018	22	15	68%	874
2019	20	16	80%	480
2020	23	21	91%	285
2021	30	26	87%	359
2022	41	26	63%	92
2023	17	6	35%	17
Total	**257**	**197**		**5204**

The publication trend can be seen in three stages in terms of research productivity, which is shown in Fig. 1. The first publication appeared in 2004, and was composed by Barlow and Venables [34], entitled "Will technological innovation create the true lifetime home". For the first stage (2004-2009), no more than five documents were published each year. With an average of 2.2 publications per year, 13 publications (5.06%) in total were produced throughout this time period. In the second stage (2010-2017), a steady growth emerged, and yearly publications ranged from 6 to 17. Overall, 91 publications (35.41%) were produced with an annual average of 11.4. Starting from 2011, a threshold of minimum ten articles (except for 2013, 9 articles) were achieved every year. The third stage extends throughout the most recent six years (2018-2023). Productivity increased considerably as researchers shifted their focus to the positive or negative effects of smart homes on the elderly. The lower bound for annual publications in this phase increased to 20 from the previous level of 6 with an exception of 17 publications in 2023, which is just the middle of the year. Notably, scholars made the most publications of 41 solely in 2022, and the total publications since 2020 (111) has way exceeded the sum of the entire second stage (91).

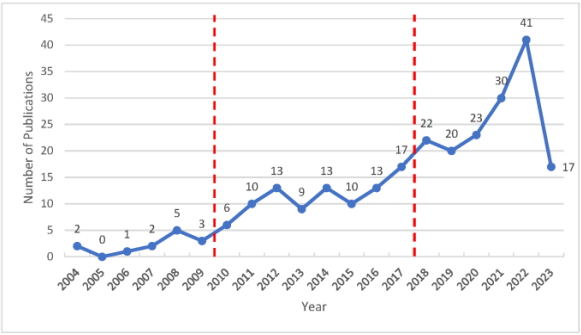

Fig. 1. Publication trend.

B. Types of Documents & Sources

By analyzing the data obtained from the Scopus database, seven types of documents were identified, i.e., article, conference paper, conference review, review, book chapter, book, and note. As displayed in Table II, the proportion of "article" (43.58%) is the highest, followed by "conference paper" (34.24%). While other document types account for less than 10% respectively, and there are only one "book" and one "note" published only within the investigated time range.

TABLE II. Summary of Document Types

Document Types	Number of Publications	Proportion
Article	112	43.58%
Conference Paper	88	34.24%
Conference Review	22	8.56%
Review	20	7.78%
Book Chapter	13	5.06%
Book	1	0.39%
Note	1	0.39%
Total	**257**	**100%**

From Table III, all publications related to the elderly people's openness to smart homes fall into four source types. More than half of the total documents were published in "journal" (52.14%). Not much differences were found between "conference proceeding" (24.12%) and "book series" (19.07%), while "book" seems to be the least interested by researchers since only 12 have been published throughout 19 years since 2004.

TABLE III. Summary of Source Types

Source Types	Number of Publications	Proportion
Journal	134	52.14%
Conference Proceeding	62	24.12%
Book Series	49	19.07%
Book	12	4.67%
Total	**257**	**100%**

C. Subject Areas

In all, 21 research areas were addressed by the 257 documents. The distribution of the top ten subject areas related to older adults' adoption of smart homes over a five-year period is shown in Table IV. The density of publications is shown by the red backdrop. The more papers that emerged within a certain year period, the deeper is the shade of red. "Computer Science" (140 publications) has the highest number of articles that are relevant; it is followed in relevance by "Medicine" (80 publications), "Engineering" (70 publications), "Mathematics" (46 publications), and "Social Sciences" (40 publications). It seems that the majority of the studies examining the benefits of smart homes for the elderly focus on their technical and medical applications. In contrast to recent increase in "Biochemistry", "Genetics", and "Molecular Biology", subject areas such as "Engineering", "Social Sciences", and "Physics and Astronomy" exhibit constant growth. "Health Professions" shows a brief decline followed by a minor recent rise.

TABLE IV. DISTRIBUTION OF TOP TEN SUBJECT AREAS IN FIVE-YEAR PERIOD

Research Area	2004-2008	2009-2013	2014-2018	2019-2023	Total
Computer Science	4	26	43	67	**140**
Medicine	5	11	24	40	**80**
Engineering	1	9	30	30	**70**
Mathematics	3	13	13	17	**46**
Social Sciences	2	3	10	25	**40**
Nursing	3	0	8	16	**27**
Biochemistry, Genetics and Molecular Biology	1	1	6	8	**16**
Health Professions	2	5	1	5	**13**
Physics and Astronomy	0	1	3	8	**12**
Business, Management and Accounting	0	2	2	7	**11**

D. Source Title

Research on the SHAE is covered by 160 publication sources. With a minimum of three publications, Table V lists the publications sources with the most activity. The greatest numbers of studies relating to computer science fields are presented in the form of conference proceedings, which are included in the source of "Lecture Notes in Computer Science" (31, 12.1%). When it comes to producing high-quality conference materials, "ACM International Conference Proceeding Series" is another top pick, coming in at number four on the list of all source titles. "Gerontechnology", "Communications In Computer And Information Science" and "Jmir Aging" are the three most prolific journals, with 7, 6, and 5 publications, respectively. Each of the remaining sources contributes less than 2%.

E. Author Keywords

Understanding the distribution and links between the primary research themes on the SHAE was facilitated by the use of co-occurrence analysis, which may probe the internal relationships of a given academic subject [35]. Based on "keywords" of bibliographic data, a map is produced using the VOSviewer software co-occurrence analysis. Setting the minimum occurrence number to five resulted in a clear keyword network visualization after a number of optimization processes that varied the minimum number of keyword occurrences. The results created a graph with 32 keywords based on five clusters, each with a different focus (see Fig. 2). Cluster 1 (red) focuses on assistive technology for older adults, Cluster 2 (green) emphasizes smart home functionality, Cluster 3 (blue) highlights the Internet of Things and healthcare, Cluster 4 (olive) emphasizes the acceptance of smart home technology, and Cluster 5 (purple) focuses on older people and gerontechnology. Generally, the most common keywords related to older adults and smart homes are included in Cluster 1, while Cluster 4 is mainly about aging and disease.

TABLE V. PRODUCTIVE PUBLICATION SOURCES

Source Title	Publications	Proportion
Lecture Notes In Computer Science	31	12.1%
Gerontechnology	7	2.7%
Communications In Computer And Information Science	6	2.3%
ACM International Conference Proceeding Series	6	2.3%
IEEE Access	5	1.9%
Jmir Aging	5	1.9%
International Journal Of Environmental Research And Public Health	4	1.6%
Gerontology	3	1.2%
Handbook Of Smart Homes Health Care And Well Being	3	1.2%
International Journal Of Medical Informatics	3	1.2%
Journal Of Medical Internet Research	3	1.2%
Personal And Ubiquitous Computing	3	1.2%
Procedia Computer Science	3	1.2%
Proceedings Of The ACM On Human Computer Interaction	3	1.2%
Sensors	3	1.2%
Universal Access In The Information Society	3	1.2%
Others	166	64.6%

In particular, regarding the topic of ageing-in-place and the use of smart technology by the elderly, the most often occurring terms are concentrated in Cluster 1, which has a total link strength of 168. The keyword "smart home" dominates Cluster 2 and has the greatest frequency of occurrence and total link strength of any other term generated. Cluster 3 is somewhat related to Cluster 2 and focuses on the application of IoT technology in the field of geriatric care due to the tight relationship between the technical features of smart homes and IoT. Ageing and the acceptance of smart home technologies are the two topics majorly covered under Cluster 4. With the lowest total link strength of 84 among all five clusters, Cluster 5 focuses primarily on investigating elderly-oriented technologies.

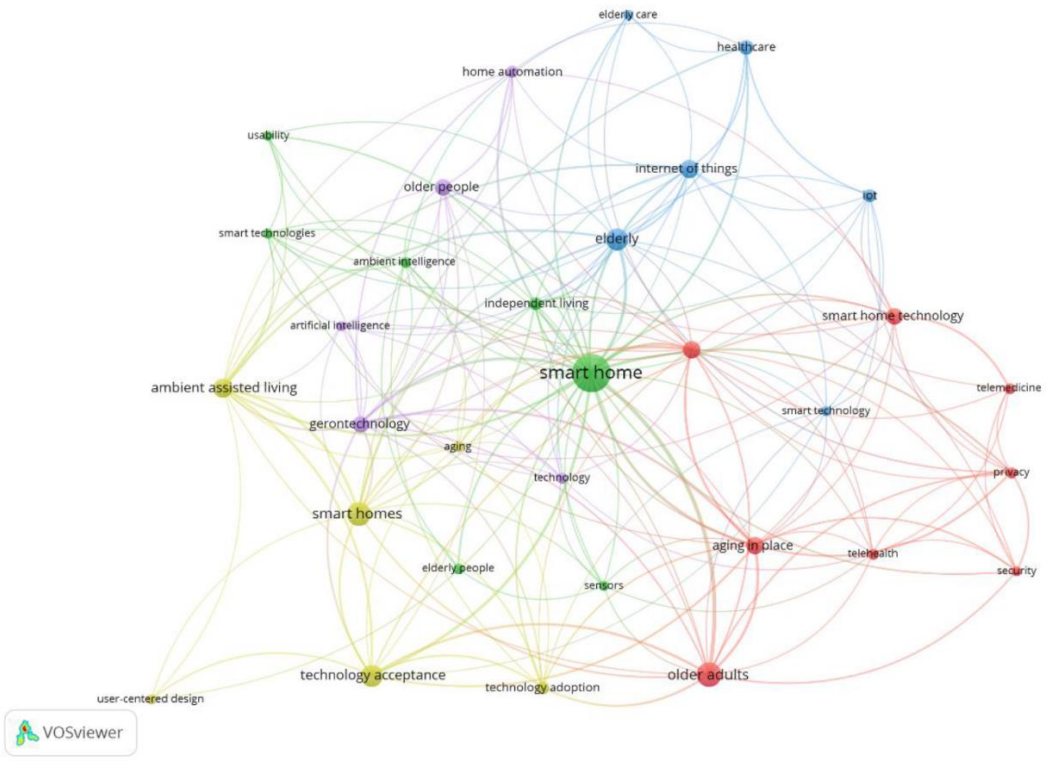

Fig. 2. Co-occurrence network by author keywords.

Table VI lists all keywords generated from related publications in a cluster view. All clusters contain keywords relating to both the elderly (e.g., "older adults", "elderly people", "elderly", "ageing", "older people") and technological concepts (e.g., "assistive technology", "ambient intelligence", "internet of things", "ambient assisted living", "gerontechnology"). However, only the fourth cluster specifically concerns about individuals' willingness to accept or adopt smart home technology. This is consistent with the viewpoint that there is a lack of studies regarding smart homes from the perspective of users' perceptions of embracing smart home technologies [12], especially for the elderly people [5].

TABLE VI. KEYWORDS BY CLUSTERS

Cluster	Keyword	Occurrence	Total Link Strength
Cluster 1 (red)	older adults	26	39
	aging in place	14	37
	assistive technology	14	29
	smart home technology	12	16
	privacy	6	17
	telehealth	6	10
	telemedicine	6	8
	security	5	12
Cluster 2 (green)	smart home	58	86
	independent living	8	17
	ambient intelligence	6	13
	elderly people	6	5
	smart technologies	5	10
	sensors	5	9
	usability	5	7
Cluster 3	elderly	21	35
Cluster (blue)	internet of things	15	24
	healthcare	10	13
	iot	8	10
	smart technology	5	8
	elderly care	5	7
Cluster 4 (olive)	smart homes	24	33
	technology acceptance	21	33
	ambient assisted living	16	33
	technology adoption	8	18
	ageing	5	12
Cluster 5 (purple)	user-centered design	5	5
	gerontechnology	12	34
	older people	13	15
	home automation	7	14
	technology	6	10
	artificial intelligence	5	11

F. Citation Analysis

The top ten most influential papers in the field of SHAE as determined by citation analysis are listed in Table VII of the findings. The article with the highest total citations addressed elderly people's adoption of voice-activated smart homes and proposed corresponding benefits and concerns [36]. After this article appeared in 2013, it has attracted 305 citations. The second-highest cited work developed a conceptual model to describe the influencing elements of older individuals' usage of technology that support ageing-in-place [37]. A total of 276 citations have been made to this article since its publication in 2016. Even though over 42% of the publications were merely from the top five most prolific countries, it is worth noting that

leading studies in the field of SHAE were authored by researchers from a variety of nations.

TABLE VII. TOP TEN CITED ARTICLES

Author(s)	Article Title	Year	Source Title	Citations
Portet, F., Vacher, M., Golanski, C., Roux, C., Meillon, B.	Design and evaluation of a smart home voice interface for the elderly: acceptability and objection aspects [36]	2013	Personal and Ubiquitous Computing	305
Peek, S. T. M., Luijkx, K. G., Rijnaard, M. D., Nieboer, M. E., van der Voort, C. S., Aarts, S., van Hoof, J., Vrijhoef, H. J. M., Wouters, E. J. M.	Older Adults' Reasons for Using Technology while Aging in Place [37]	2016	Gerontology	276
Robinson, H., MacDonald, B., Broadbent, E.	The Role of Healthcare Robots for Older People at Home: A Review [38]	2014	International Journal of Social Robotics	261
Pal, D., Funilkul, S., Charoenkitkarn, N., Kanthamanon, P.	Internet-of-Things and Smart Homes for Elderly Healthcare: An End User Perspective [39]	2018	IEEE Access	185
Bansal, P., Kockelman, K. M.	Are we ready to embrace connected and self-driving vehicles? A case study of Texans [40]	2016	Transportation	162
Mital, M., Chang, V., Choudhary, P., Papa, A., Pani, A. K.	Adoption of Internet of Things in India: A test of competing models using a structured equation modelling approach [41]	2018	Technological Forecasting and Social Change	157
Shin, J., Park, Y., Lee, D.	Who will be smart home users? An analysis of adoption and diffusion of smart homes [15]	2018	Technological Forecasting and Social Change	152
Courtney, K., Demiris, G., Rantz, M., Skubic, M.	Needing smart home technologies: the perspectives of older adults in continuing care retirement communities [42]	2008	Journal of Innovation in Health Informatics	144
Demiris, G., Oliver, D. P.,	Findings from a participatory	2008	Technology and Health	134
Dickey, G., Skubic, M., Rantz, M.	evaluation of a smart home application for older adults [43]		Care	
Courtney, K.L.	Privacy and Senior Willingness to Adopt Smart Home Information Technology in Residential Care Facilities [44]	2008	Methods of Information in Medicine	126

G. Co-Authorship Analysis by Countries

The analysis of international co-authorship networks covered only nations with at least five total publications. Only 18 of the 43 countries satisfied the criteria. There are six European countries, two American, one Asian, and one Oceanian among the top ten most productive countries listed in Table VIII. The US, Germany, and the UK are the top three nations. In terms of publications, the US is well ahead of any other country in the SHAE field. C/P value, which measures the average citation count in a single publication, places the Netherlands, France, and Austria among the leaders in this field despite their relatively low total number of publications.

TABLE VIII. TOP TEN PRODUCTIVE COUNTRIES

Country	Number of Publications (P)	Citations (C)	C/P	Total Link Strength
US	46	1308	28.43	7
Germany	27	434	16.07	11
UK	27	538	19.93	9
Italy	22	555	25.23	12
Canada	19	213	11.21	7
China	15	198	13.20	7
Netherlands	15	680	45.33	11
Australia	13	158	12.15	3
France	11	418	38.00	6
Austria	8	300	37.50	7

Fig. 3 show the national network. The size of the node expands as more articles are published in a single country, and the connecting lines between nodes represent the closeness of the collaboration between the two nations; a thicker line indicates greater cooperation. This network consists of 35 links and 4 clusters. Within each of their different clusters, the US, Germany, UK, and China all contribute significantly to publications, and with the exception of Germany, they are all tightly connected. Since Italy, Germany, and Netherlands have the top three total link strengths (12 for Italy, 11 for Germany, and 11 for Netherlands) among the 18 countries, there are strong lines connecting them, showing tight collaborations. And, in terms of publications, they also ranked highly.

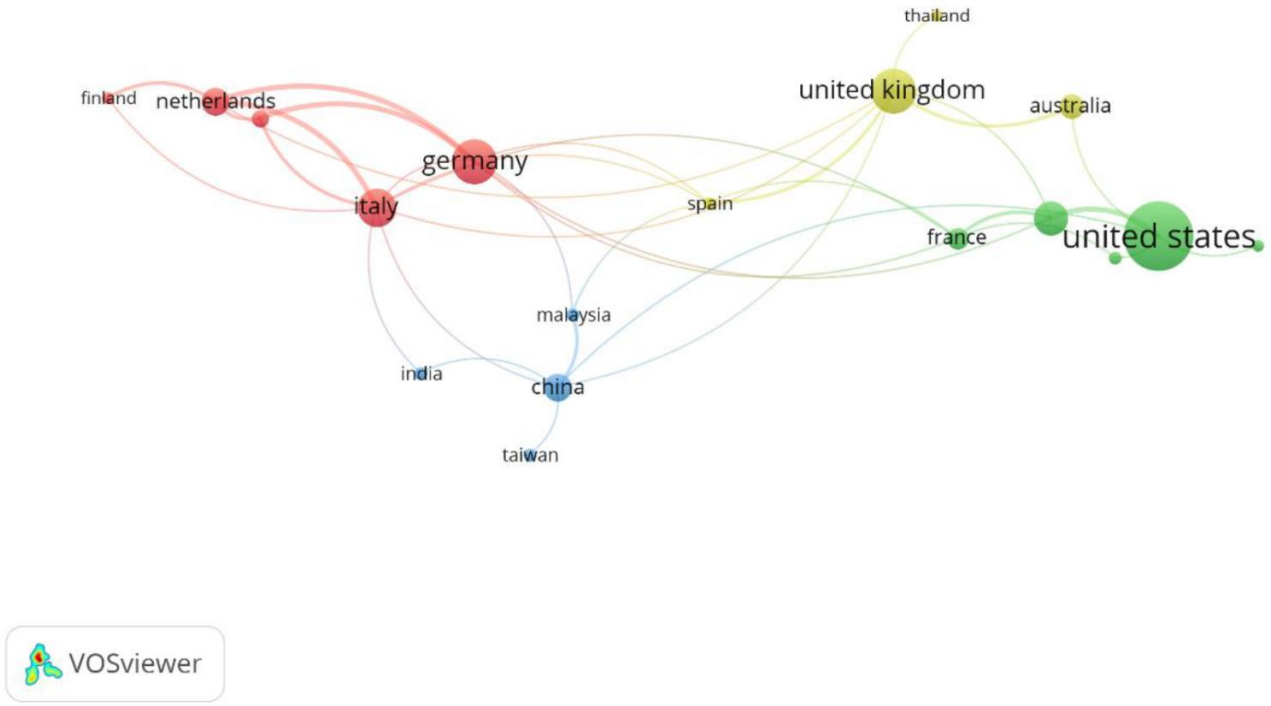

Fig. 3. Co-authorship network by countries.

H. Co-Authorship Analysis by Authors

Modern research has entered the age of big science, which emphasizes the need of scientific cooperation due to increased comprehensiveness and complexity [45], [46]. As a result of the complementarity in knowledge and intelligence, academics tend to form solid connections and network blocks [47], and sustain persistent collaborations [48]. Table IX provides a summary of the top ten prolific writers on the SHAE by concentrating on writers who have coauthored at least two papers and been referenced in no less than four other works. Demiris, G. has published the most articles with the highest citations collected; however, his C/P figure only ranked the 8th. Aarts, S., Peek, S.T.M. and Wouters, E.J.M. are closely collaborating with the same publications of 3, and citations of 325. The same pattern has been detected between Portet, F. and Vacher, M.

The scholars who have co-authored with the most other authors is analyzed by the co-authorship network analysis. Co-authorship relationships revealed in research on seniors' acceptance of smart homes are shown in Fig. 4. The constructed network has 63 authors that satisfy the aforementioned criteria with 109 links and a total link strength of 197. The authors are divided into 21 groups, each of which is indicated by a distinct color. The size of each node in the network, which represents an individual author, reflects its relative importance in the network. The findings reveal that Aarts S., Peek S.T.M., and Wouters E.J.M. are top three biggest author nodes and that they are all members of the same cluster (green), which has the greatest total link strength of 134. And academics from the Netherlands predominate, with many members having ties to the same institution, such as Maastricht University and Tilburg University. The interest areas of this group include older adults' technology acceptance, ageing-in-place and healthcare. For example, Peek S.T.M. "Older Adults' Reasons for Using Technology while Aging in Place" [37] in 2016, the most highly collaborative article (9 authors), and "Factors influencing acceptance of technology for aging in place: a systematic review" [49] in 2014, the most cited article (1044 times). In another group (red), scholars are from various countries (e.g., Austria, UK, Netherlands and US), and this group specializes in social applications of intelligent technology.

TABLE IX. TOP TEN PROLIFIC AUTHORS

Author	Publications (P)	Citations (C)	C/P	Total Link Strength
Demiris, G.	9	489	54.33	15
Ziefle, M.	9	174	19.33	10
Brauner, P.	4	42	10.5	7
Funilkul, S.	4	310	77.5	8
Pal, D.	4	310	77.5	8
Aarts, S.	3	325	108.33	17
Peek, S.T.M.	3	325	108.33	17
Portet, F.	3	324	108	9
Vacher, M.	3	324	108	9
Wouters, E.J.M.	3	325	108.33	17

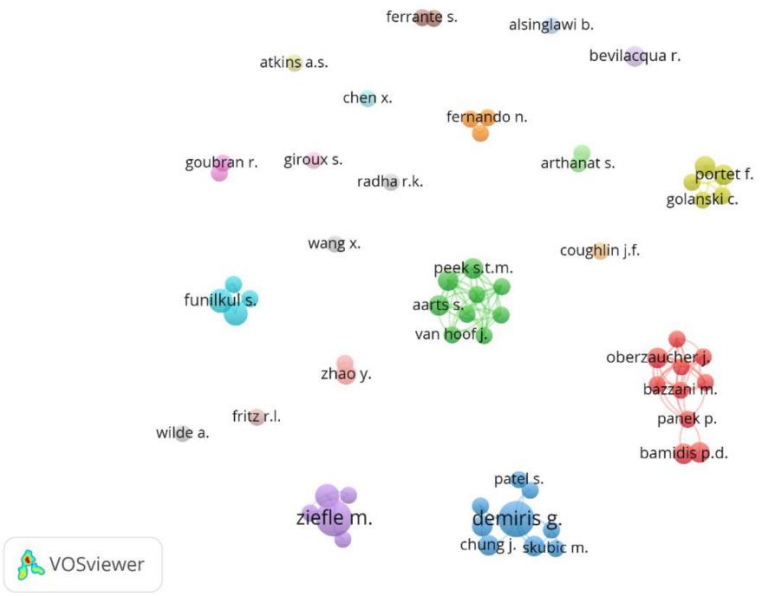

Fig. 4. Co-authorship network by authors.

I. *Bibliographic Coupling*

Bibliographic coupling happens when a third source is often cited in two distinct research publications. A visualized bibliographic coupling map at the country level (except for Taiwan) is shown in Fig. 5 with five clusters denoted by different colors, 100 linkages, and a total link strength of 3188. Totally, 18 countries and district that contributed at least five documents are covered.

In terms of published documents, the US, UK, Germany, and Italy are the most substantial nodes. The linking lines indicate the coupling relationship between countries/district and suggest that nations from various parts of the world are linked by similar patterns of citing reference in their research articles. There are a number of thick lines between countries/district from the same or different clusters, for example, China and Malaysia (the highest link strength of 265), UK and Netherlands (link strength of 199), Germany and Malaysia (link strength of 168), which reveal that there exist collaborations between these connected countries/district. In sum, the investigated data set shows a significant bibliographic connection between the countries and district in different parts of the world.

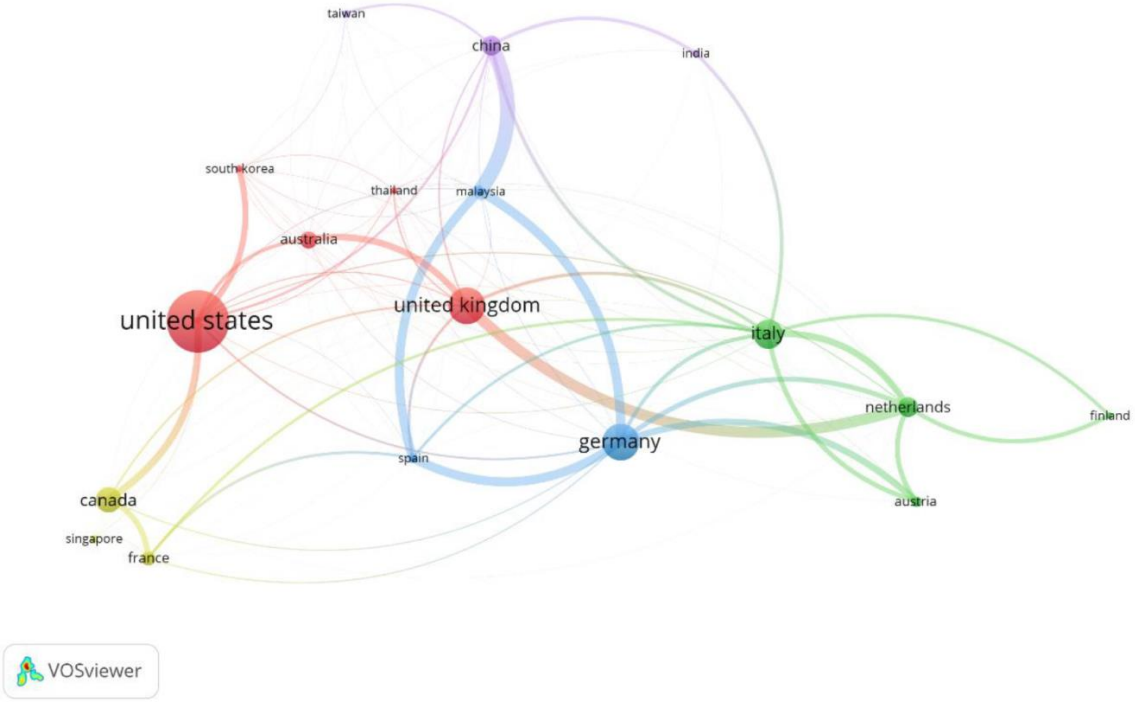

Fig. 5. Bibliographic coupling of countries/district.

V. Discussion

Due to the worldwide increasingly growing number of ageing population and the associated social issues, research about smart home focusing on the elderly population has been rapidly expanding. However, it has become challenging for academics and practitioners to have a thorough understanding of SHAE due to the enormous rise in the number of related publications. Thus, based on a number of research facets, this study offers a bibliometric analysis of studies on SHAE. The results are discussed in this section regarding each of these facets.

A. Growing Publication Trend

Since its first presentation, SHAE literature has seen a rising tide of publications, indicating growing interest in the field. Rapid development of the Internet of Things (IoT) has spawned growing practical applications across a wide range of industries, which may account for the uptick in research activity [50]. Additionally, in response to the worldwide challenges (e.g., ageing progress, resources shortage, COVID-19 pandemic), many in academia, business, and government see smart homes as a way to help solve these societal problems [26].

B. Lack of Interdisciplinary Collaboration

Over half of the current SHAE research may be categorized within the domains of "Computer Science," "Medicine," and "Engineering," according to a breakdown of the most important research topics based on the categories offered by Scopus. Moreover, the majority (13) of the 15 cited published sources focused on either computer-related topics or medically-related applications. Even though knowledge from some cross-disciplinary domains (e.g., psychology, arts and humanities, biology) were referred to, the frequencies were fairly low. Thus, researchers commonly made suggestions and appeal for more attempt at conducting interdisciplinary work [26], [51],[52]. Possible reasons for the currently less convergent research pattern might be a consequence of the competition between tech giants and with other industries [53], which limits the access of specialized knowledge, labor and services [54], then in turn hindered the interdisciplinary collaborations.

C. Little Emphasis on Elderly Users

As the rising proportion of the ageing population and the trend of AIP while applying smart home technologies [2], More studies on how well smart homes are accepted by the elderly are urgently needed. The results of keywords analysis show that technology-related terms appeared in all keyword clusters, such as “assistive technology”, “ambient intelligence”, “internet of things”, “ambient assisted living”, and “gerontechnology”. This indicates that the main topics covered in SHAE research are centered on technology attributes and advances, which has been presented in extant research [26].

Conversely, user-oriented keywords such as “technology acceptance”, “technology adoption” and “user-centered design” appeared 19, 8 and 5 times respectively, accounting for only 9 percent totally, which agrees with the argument that few research has considered the special needs and using experience of older people in the development and utilization of smart home technologies [55], [56]. Concerns about home and personal network security have been heightened as a consequence of the intensive adoption of work-from-home strategies due to the COVID-19 pandemic [57], and thus, smart home research extensively put focus on enhancing technological features to ease the concerns relating to possible risks [58]. So, technological advance is currently dominating the research interest and prevalence of existing smart home studies with little emphasis on users' perceptions of the challenges and benefits while using smart home technologies [12], [28]. Furthermore, the ways in which technology is changing the life of the elderly has been surprisingly neglected in research on AIP in smart home settings [59]. Therefore, more elderly user-oriented research on SHAE is needed in order to offer more precise insights into this industry from the demand perspective.

VI. Conclusion

In order to comprehend research publishing trends, document and source types, subject areas, popular source titles, research keyword clusters, notable authors, co-authorship networks, and bibliographic coupling patterns, this study performed bibliometric analyses on the SHAE research since 2004 till 25 July, 2023. By scanning the Scopus database for keywords related to the smart home acceptance by the elderly, the study conducted all analyses with a dataset including 249 documents using the VOSviewer software. Based on the results, this study draws conclusions that the elderly-friendly smart home has dramatically gained academic interest on a global scale in terms of the rapid rise in publications during the last five years; collaborations across disciplines is needed for further research progress in SHAE; the “Lecture Notes In Computer Science” appears to be the most common research venue; technology and health related keywords are all crucial terms other than “smart home(s)” and “older adults”; there exists some global scientific collaboration; and the coincidence of citing preferences at the country level is proved; while the co-authorship network between individual authors is not yet well-established. Thus, researchers should put more attention on learning elderly users’ acceptance toward smart homes that are considered promising solution to ageing issues.

Implications of the study are as followed. Firstly, this is the first study, to the authors’ knowledge, that employs a comprehensive bibliometric approach to analyze the global trends in research on the acceptance of smart homes by the elderly population. Quantitative information on essential knowledge is provided by the results of the study, which may be utilized to identify research gaps and to plan for future research. Secondly, for policymakers relating to smart homes, more evidence-driven decisions on resource allocation and investment priority could be made according to the findings of this study. Thirdly, insights gained from this study will help develop both national and international strategies for the smart home market.

The results should not be taken as definitive because of the study's limitations. Firstly, the scope of the study could be expanded by including more research databases (e.g., Web of Science) that index additional significant research publications. Secondly, clusters presented in the study are not absolute since the numbers are specified by the criteria determined by the

authors. Thirdly, the VOSviewer software may incur imprecise and complex results due to the issue of regarding single and plural forms of the same term as different words (e.g., “smart home” and “smart homes”).

Therefore, future research would benefit greatly from either an improved version of the VOSviewer software or the inclusion of additional tools for network analysis and visualization. Moreover, as a consequence of the COVID-19 pandemic and the accompanying restrictions on working and living at homes, people have been forced to engage in substantial and mandatory technological learning behaviors [60]. Thus, possible future study directions include accounting for the pandemic's impact on the adoption of smart home technologies among the elderly.

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