IoT application in Smart Home: A Systematic Literature Review

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Abstract
This paper aims to develop a meaningful single-source reference for IoT and Smart Home scholars concerning Smart home intellectual structure published in journals. The bibliometric data of publications was obtained from the web of science database using combinations of keywords for IoT and smart home. The search results were limited to journal articles in English from 2010 to 2021. The systematic literature review describes and analyzes the evolution of publication structure, top contributing authors, institutions, journals, countries, and the co-relations, such as co-citation and keyword occurrences. The analysis indicates that 399 journal articles have been published by 1350 authors associated with 58 countries during the last twelve years. The number of publications per year was increasing steadily. The most research was published in 2020 with 83 articles. The top author, PAL D obtained 28 citations; the top country, the USA, published 277 articles; the top journal, SUSTAINABILITY, published 36 articles; the top institute, WASHINGTON STATE UNIV published 34 articles. The work reported is limited to only the Web of Science database. While the search methodology aimed to be as inclusive as possible, it may not have captured all scholarly research output in the IoT world. The findings of this study may help researchers understand the performance of IoT Smart homes research from across the world and suggest directions for further research. This research uses rigorous bibliometric, content, and network analytic approaches to examine the literature on the IoT smart home during the last 12 years.

Keywords: IoT, Smart homes, RFID, network analysis, Systematic Literature Review

Introduction
Smart homes are getting popular since they combine energy efficiency with a high standard of life. Many ICTs and energy technologies are widely available, allowing people to incorporate new technology and services into their homes easily. A smart home is defined as "a residential environment equipped with information and communication technology that meets the requirements of residents in terms of convenience, security, entertainment, and comfort" (Marikyan et al., 2019). The key idea of the smart home is implementing well-designed management features that enable owners to maintain their homes most efficiently. Combining current and advanced ICT and energy technologies in the housing environment provides a significant opportunity for applications and services (Shapsough & Zualkernanl, 2020). In particular, ubiquitous computing technologies, which allow all things to be linked everywhere and at any time, utilize small sensors to give information to whole network systems, thus enabling the users to become a part of a network connected to all objects. This implies that users are part of a network of linked computers that transmit and receive data without using conventional communication methods. This is the core idea of the Internet of Think (IoT).

Smart homes allow users to communicate with different gadgets and services through IoT (Neagu et al., 2017).

In their conceptualization of IoT, Wang et al. (2021) highlighted wireless sensor networks and IoT security/privacy as the mainstays of the IoT. Then, they said that the development and uses of IoT have continuously increased in smart cities, smart homes, and smart environments. IoT has continuously impacted and changed our society in areas like metropolitan areas, agricultural, transportation, housing environments, and healthcare systems. Incorporating IoT into smart home creates a new domain of smart homes with IoT that is unlike any other. IoT and smart homes have had a significant impact on our daily lives by providing services that can be accessed from almost anywhere at any time. With this development, many researchers have stated that a smart home, is described as "a network of physical devices that offer electrical, sensor, software, and network connection within a house" (Alaa et al., 2017). Many sensors and actuators are interconnected to the primary gateway of a smart home network, the main control system that users access through their digital devices like smartphones or desktop computers (Galinina et al., 2015).

According to Khalaf et al. (2019), several effective methods to apply the idea of the IoT to smart home applications were explored. The SHIoT is an example of a newly developing market and research topic that has been identified as a promising area for future studies. Many research had examined the use of IoT products and services in smart home settings, the removal of technical and associated issues limiting the spread of SHIoT and evaluated ways to enhance both the efficiency and the possibility of implementing SHIot (Park et al., 2017).

This aim of this study is to provide significant insights into future research topics by assessing the existing status and research settings. With this approach, the contributions and efforts of researchers in the SHIoT fields can be explained, a comprehensive picture of research trends can be provided, and new aspects of SHIoT can be highlighted. Based on various research topics, this study conducts a systematic literature review of SHIoT-related publications.

Literature Review

The Internet of Things (IoT) is the "digitalization of machinery, automobiles, and other physical world components" (Manyika et al., 2015). Over the last decade, IoT is received much interest from academics and industries. It expands exponentially as the internet engages people with different technologies embedded in smart gadgets. The IoT brings significant changes in the developing worlds' economic, environmental, healthcare, social, and political realms (Kshetri, 2017). The term "IoT" was created in 1999, and Ashton (2009) describes IoT as "globally developing Internet-based information service architecture" (p. 98). If all items in everyday life were provided with identifiers and wireless connections, Ashton believed that these items could interact with one another and be managed by machines without the need for human intervention. It is not just electronic devices and highly technological things, such as equipment and gadgets, that are included in this category; it is also "things" that are not usually considered electronic in any way. There are no restrictions on what can be included in this category. It consists of real-world objects like food products, furniture, clothing, materials, supplies and components, warehousing and specialized items, landmarks, monuments, works of art, and everything associated with commerce, culture, and sophistication (Kosmatos et al., 2011).

Radio Frequency Identification (RFID) tags for object tracking, low-power actuators that can turn anything on and off – things like lights, heating, and air conditioning systems, video

cameras, and low-power sensor systems for collecting information on everything from temperature and air quality to path and motion identification– are the technologies required for this to be possible (Zaslavsky et al., 2012). For long-range communication, the IoT is utilized within a network using a variety of protocol configurations to enhance the efficacy of user requests, excellent response, effectiveness, and low energy consumption. One of the main objectives of the IoT is to make it possible for everyone to be linked to everything and everyone, utilizing any route or network and any service, and help prevent issues by simplifying, smartening, and integrating peoples' life wherever possible (Manyika et al., 2015).

A Smart Home includes actuators, sensors, networks, middleware, and two interrelated parts: a smart network and a smart load (Saad al-sumaiti et al., 2014). A smart homes' primary goals are to enhance home automation, simplify power efficiency, and decrease the environmental pollution. The communication network for home automation may be enhanced by using twisted radio signals, pair power lines, fiber optics in a bus-based network, or an internet protocol as a standard for communication. Users may enhance their expertise and knowledge with home power management, engage in demand-side management (DSM) programs, and implement an energy-management system(EMS) to control smart home energy.

In the last few years, "smart" has become a general term for new technology with some artificial intelligence level. The main characteristics of smart technology are that it can get information from the environment and proceed appropriately (Balta-Ozkan et al., 2014; Chan et al., 2008). Smart technology has become the foundation for new ideas like the "smart home," which is an innovative type of home to improve the well-being of people (Dawid et al., 2017). The worldwide expansion of smart home technology turnover has been pushed by the wave of product and service transformations into smart ones, which has encouraged the rise of device compatibility (Khalaf et al., 2019). The advantages made possible by smart technology have stimulated the attention of both academics and professionals. Significant attention has been dedicated to home appliances, where smart technology has been properly researched and practically implemented (Balta-Ozkan et al., 2014).

Research Methodology

The systematic literature review is one of the most effective instruments for assessing publication output and research trends across all disciplines (Erfanmanesh & Abrizah, 2018). It successfully identifies, classifies, and analyzes articles, resulting in useful results (Merigó & Yang, 2017). The systematic literature review is a methodologically rigorous, methodical, and novel approach to assessing conventional literature. It employs statistical approaches that enable the identification of qualitative and quantitative changes in an academic research topic; it also aids in the development of a topics' profile and identifies significant opportunities within a field (Misra et al., 2016).

Data collection

The advanced search option in the Web of Science database was used to search relevant literature on IoT applications in Smart homes. The Web of Science database was chosen because of its extensive coverage of the literature (Baas et al., 2020) and widespread usage in bibliometric research (Rawat & Sood, 2021). ("Smart home") OR ("Smart house") OR ("Intelligent home") OR (Digital home") OR ("Ubiquitous home") OR ("Knowledge based home") were the keyword combinations used to search the articles from the Web of Science database. The publishing period lasted from 2000 to 2021. Only English-language publications were gathered. A preliminary search yielded 494 Web of Science results. The bibliometric

data from the search results were extracted from the databases to be checked further. Duplicate items were eliminated, as were those unrelated to IoT Smart home. This exclusion has been used in many other research to minimize noise from the data (Song et al., 2020). After data purification, the systematic literature review was performed on 399 articles with 5782 cited references.

Initially, we searched in the database for research articles using the keywords: "Smart home, Smart house, Intelligent home, Digital home, Ubiquitous home, Knowledge-based home", as indicated in Table I. Nearly 494 research publications were found in the database. Next, we apply exclusion criteria by research type: Articles and Languages: English. It was observed that the final number of papers dropped to 417. The findings were further filtered to remove the years before 2009. We narrowed our search on Web of Science to journal articles. Finally, 399 research papers from the Web of Science database were obtained.

Levels	Keywords	No.of articles
1	("Smart home") OR ("Smart house") OR ("Intelligent home") OR (Digital home") OR ("Ubiquitous home") OR (Knowledge based home")	494
2	Applying exclusions criteria and manual filtering- Refined by: Document Types: Articles Languages: English	417
3	Applying exclusions criteria and manual filtering- Refined by: NOT Publication Years: 2009 or 2008 or 2007 or 2006 or 2005 or 2004 or 2002 or 1997	399

Table 1 Levels of data filtering

Analysis

Year of publications

After obtaining data from the Web of Science database, current patterns in research article publishing during the past twelve years were observed. Every year, the number of research papers published increases. Figure 1 shows the growth in research publishing, which shows the popularity of research. According to the data, five papers were published in the year 2010. Ten research papers were published in 2011 and 2012. Thirteen research papers were published in 2013. In addition, in the year 2014, Twelve research papers were published. In the later part of 2015, Seventeen articles were published. In 2016, Eighteen research were published, forty-one studies were published in 2017, Fifty-Seven researches were published in 2018, Sixty-one studies were published in 2019, Eighty-three studies were published in 2020, and Sixty researches were published in 2021. We looked at recent research articles because the analysis revealed few smart home domain publications before 2010. In 2010, for example, there were just five publications in this field of study. Therefore, we looked at research publications between 2010 to 2021.

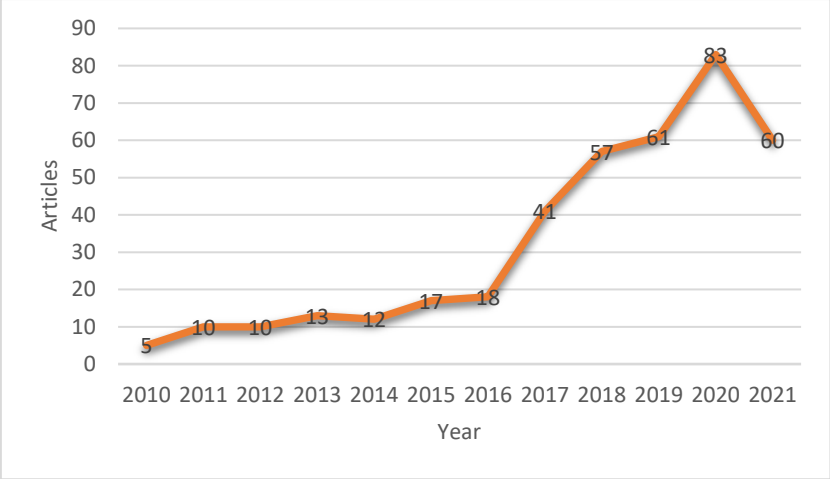

Figure 1 Year of publication

Top authors

This analytics also reveals other information about the research work, such as highlighting the top authors who gave a maximum contribution in terms of several publications to this research domain – the contribution of top authors is shown in Table 2. This table gives information about the authors' names and the number of research papers they published. The research on smart cities is in a growing phase. Therefore, there is no clear leader among these authors. We marked the top authors for their impeccable contributions and followed the trajectory of their future work in this domain.

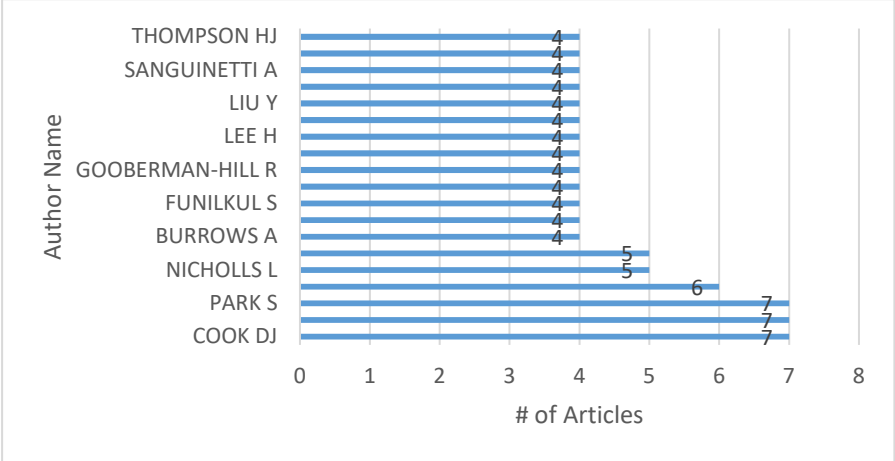

Figure 2 Top Authors

Authors with the most local citations

The top 15 most local cited authors are shown in Table 4. PAL D articles were cited 28 times, NICHOLLS L and STRENGERS Y were cited 26 times each, while FUNILKUL S, LEE H, YANG H, and ZO H work were cited 24 times each.

Author	Citations
PAL D	28
NICHOLLS L	26
STRENGERS Y	26
FUNILKUL S	24

LEE H	24
YANG H	24
ZO H	24
DARBY SJ	20
GRAM-HANSSEN K	20
SANGUINETTI A	19
FORD R	18
KARLIN B	18
BALTA-OZKAN N	12
BICKET L	12
DAVIDSON R	12

Table 2 Authors with the most local citations

Top 10 cited authors in frequency

The most cited authors are listed in Table 3. The most influential and contributory authors are in the front rank and they are FARAHANI B (frequency = 269), BALTA-OZKAN N (frequency = 200), WILSON C (frequency = 161), PEEK STM (frequency = 135), WILSON C (2017) (frequency = 132), ZWIJSEN SA (frequency = 113), LUJANO-ROJAS JM (frequency = 111), DI GIORGIO A (frequency = 110), HEINZ M (frequency = 99), and DEEN MJ (frequency = 94).

Author and Paper	Total Citations
FARAHANI B, 2018, FUTUR GENER COMP SYST	269
BALTA-OZKAN N, 2013, ENERGY POLICY	200
WILSON C, 2015, PERS UBIQUITOUS COMPUT	161
PEEK STM, 2016, GERONTOLOGY	135
WILSON C, 2017, ENERGY POLICY	132
ZWIJSEN SA, 2011, AGING MENT HEALTH	113
LUJANO-ROJAS JM, 2012, ENERGY POLICY	111
DI GIORGIO A, 2012, APPL ENERGY	110
HEINZ M, 2013, J GERONTOL NURS	99
DEEN MJ, 2015, PERS UBIQUITOUS COMPUT	94

Table 3 Top 10 cited authors in frequency

Top contributing countries

The contribution of several nations to this study topic is also highlighted in this analytics effort. Table 4 shows the involvement of numerous nations. The ranking of various nations that contribute to this research area is shown in this table. The names of countries and the number of research articles are included in this table. In terms of the research contribution, the USA is first, followed by the UK and South Korea, with Germany in fifth place. The fact that the USA is in the first place implies that emerging countries are more interested in smart home development for their future.

Region	Frequency
USA	277
UK	168
SOUTH KOREA	140

CHINA	136
GERMANY	73
AUSTRALIA	58
NETHERLANDS	44
CANADA	43
ITALY	41
FRANCE	37
JAPAN	36
SPAIN	23
GREECE	22
BRAZIL	21
DENMARK	21
IRELAND	20
THAILAND	19
SAUDI ARABIA	18
FINLAND	17
SWEDEN	15

Table 4 Top contributing countries

The 10 most often published journals

This research analysis generated data on the contribution of research journals – the contribution of the top journals is presented in Table 5. This table summarizes the titles of journals that have published research articles on this subject and the number of papers published in each publication. Sustainability is the publication that publishes the most research articles in this field. The publications are well-known for covering the technical elements of electronic devices and technology research. This demonstrates the critical nature of these technical issues in developing smart cities.

Sources	**Articles**
SUSTAINABILITY	36
ENERGY RESEARCH \& SOCIAL SCIENCE	16
SENSORS	10
IEEE ACCESS	9
PERSONAL AND UBIQUITOUS COMPUTING	9
ENERGY POLICY	8
APPLIED ENERGY	6
ENERGIES	6
BEHAVIOUR \& INFORMATION TECHNOLOGY	5
INTERNATIONAL JOURNAL OF DESIGN	5

Table 5 The 10 most often published journals

Top 10 important institutions in frequency

The indicator of institutions in frequency, as shown in Table 6, was used to investigate the most significant institutions. WASHINGTON STATE UNIV, KING MONGKUTS UNIV TECHNOL THONBURI, and UNIV BRISTOL were the top three institutions. These three institutions are prominent, implying that the level of smart home research at these three

universities is very advanced. Furthermore, CHUNG ANG UNIV, HONG KONG POLYTECH UNIV, UNIV WASHINGTON, HANYANG UNIV, HANYANG UNIV, AALBORG UNIV, and YONSEI UNIV are among the top 4-10 institutions.

Affiliations	Articles
WASHINGTON STATE UNIV	34
KING MONGKUTS UNIV TECHNOL THONBURI	19
UNIV BRISTOL	18
CHUNG ANG UNIV	15
HONG KONG POLYTECH UNIV	15
UNIV WASHINGTON	15
HANYANG UNIV	14
AALBORG UNIV	13
UNIV NOTTINGHAM	13
YONSEI UNIV	12

Table 6 Top 20 important institutions in frequency

Keyword analysis

Figure 3 illustrates the clustering network. It was discovered that the most important group in a smart home. These clusters are linked together and provide technical language for smart homes, big data, deep learning, and IoT. Figures 3 and 4 present the keyword analysis and the treemap of Smart home literature and show smart home literatures' dynamics and evolution.

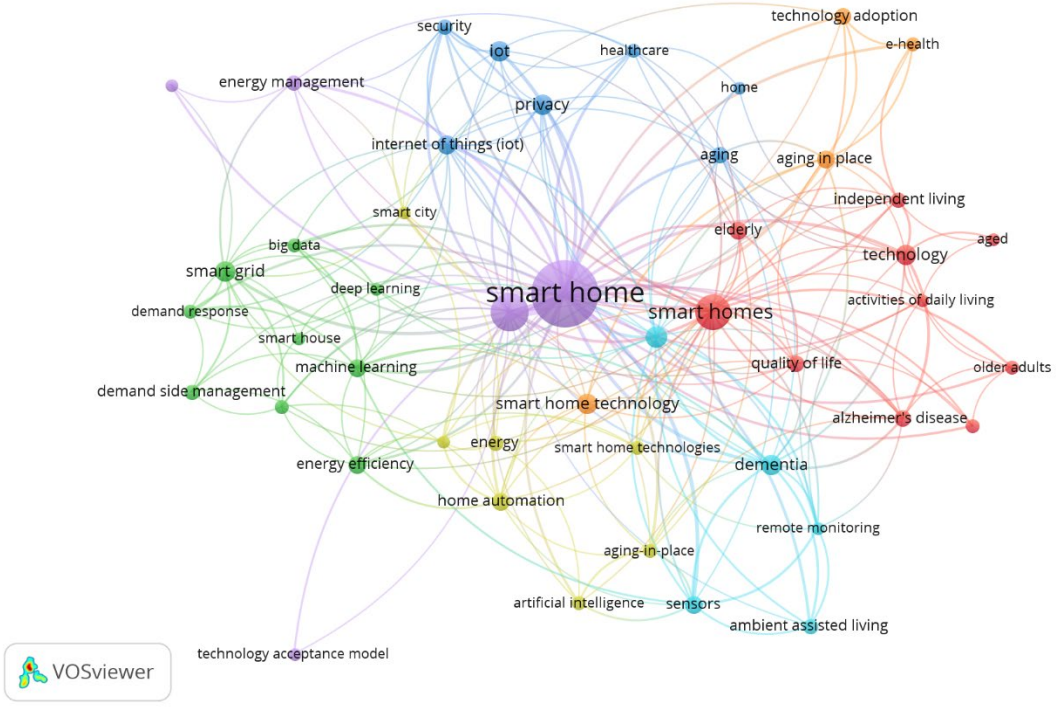

Figure 3 Keyword Occurrence

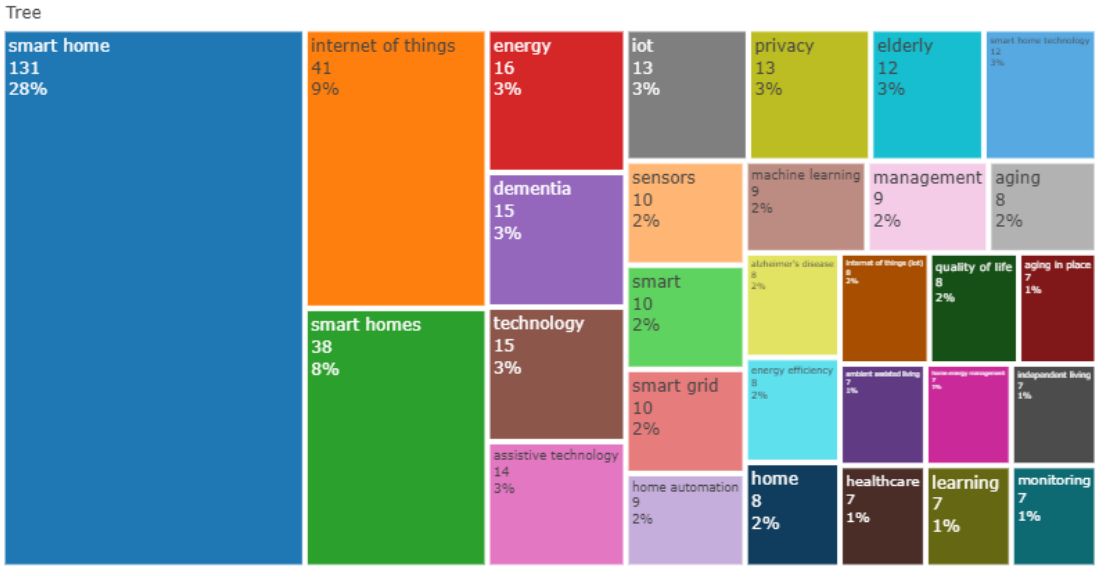

Figure 4 Treemap for keywords used by authors

Co-citation of countries

A measure of citation connections is co-citation. The country, institution, document, and authorship network shows the semantic grouping among the referenced and citing articles (Small, 1999). This test is carried out with the help of VOSviewer software. Paltrinieri et al. (2019) and Alshater et al. (2020) explain the significance of a node by its density and size, whereas interlinking lines illustrate the depth of the interaction between all nodes.

Co-citation between nations is seen in Figure 5. The United States has been discovered to be the hub of smart home literature, with strong ties to China, Japan, Thailand, Taiwan, and Turkey.

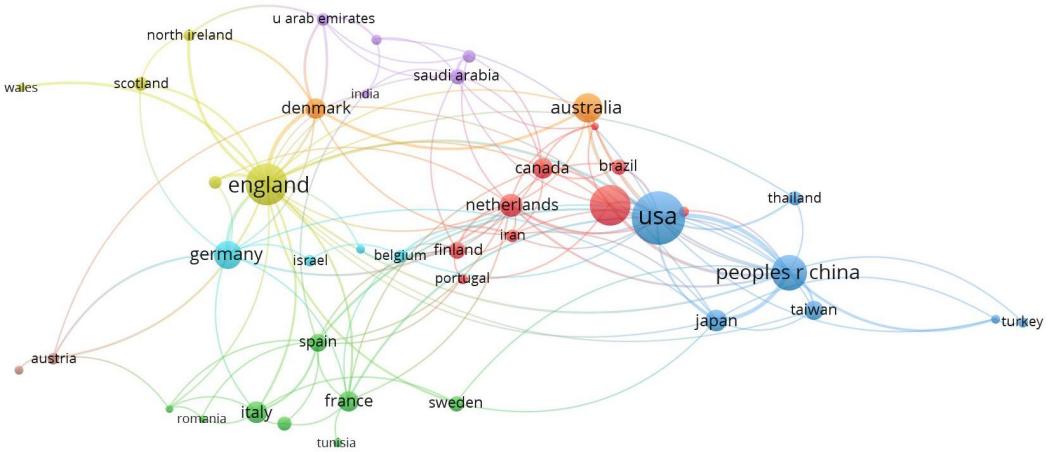

Figure 5 Co-citation of countries

Network of commonly most occurring keywords by year

Figure 6 below presents the links of the co-occurrences of author keywords and their interconnectedness—the bigger the label and circle, the more frequent the occurrence of a keyword. The colors of the circles indicate the average publication year of the keywords of the

articles. This study found that the trend of research is shifting from Smart grid, smart house, energy efficiency, smart home, smart homes, smart home technology, quality of life, smart city, big data, deep learning, machine learning, security, IoT, privacy and remote monitoring (from blue to yellow).

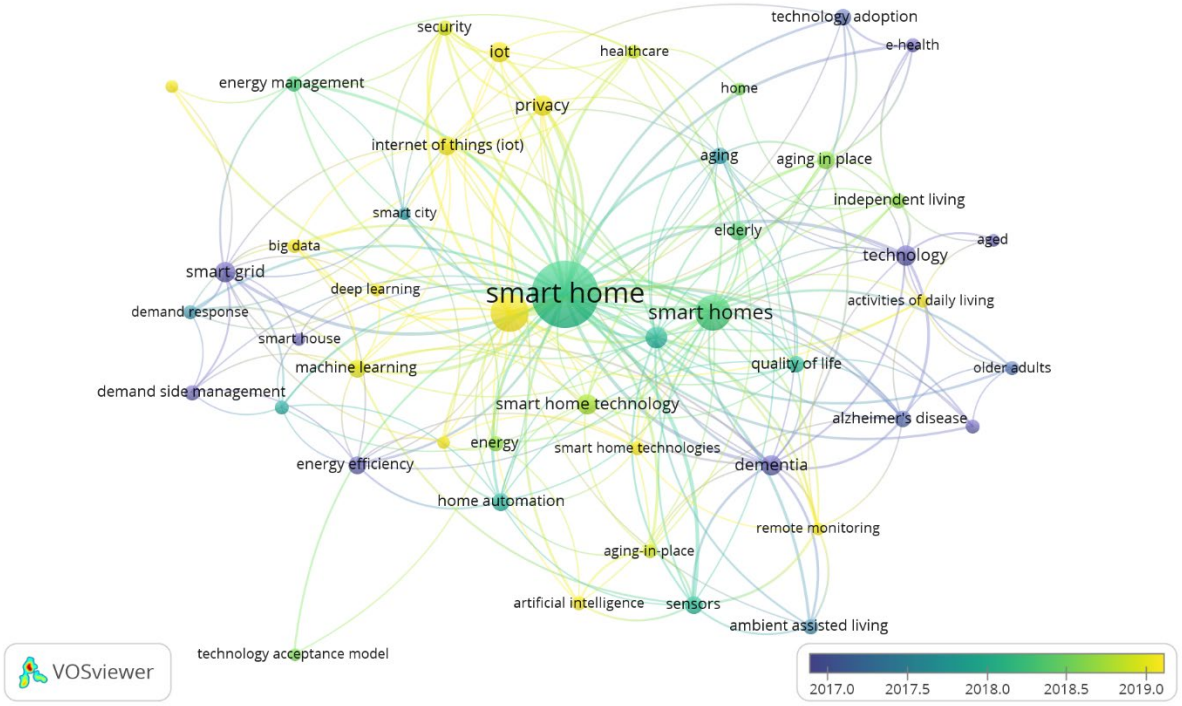

Figure 6 Network of commonly most occurring keywords by year

Keywords plus network

The "Most Occurring Keywords Plus" segment discusses words or phrases that often appear in the titles of the referenced citations. Figure 7 shows the keywords plus data. Each of the circles below represents a keyword: the wider the circle, the more significant the keyword importance in terms of frequency of occurrence. Clusters of the same color are used to group more closely connected terms. The keywords were divided into five groups based on the study of the data. Keywords like technology, smart home, future, behavior, information, technologies, design, consumption, systems, framework, optimization, performance, impact, and energy-consumption make the first cluster (red). Internet, services, things, privacy, management, and challenges provide another cluster (yellow). Model, information technology, user acceptance, adoption, service, technology acceptance model, health care, and trust make up the third cluster (blue). Keywords in the fourth cluster include system, older adults, people, big data, support, older people, activity recognition, and state (green). Acceptance, attitudes, perception, health, and care are the terms in the last cluster (Purple). This finding suggests five main areas of knowledge for current smart home research.

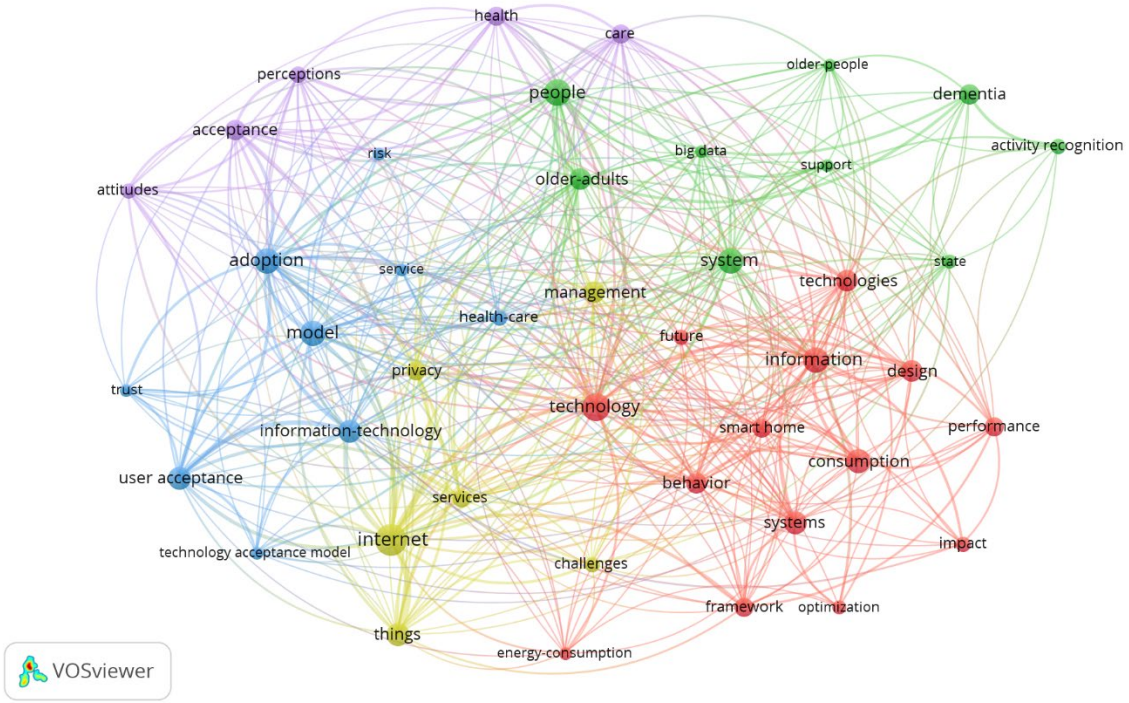

Figure 7 Keywords plus network

Discussion and conclusions

This article presents a complete review of the Smart home research using scientific output from the Web of Science database. The study's findings indicate that during the last twelve years (2010-2021), 399 research have been published by 1350 authors associated with 58 countries. The number of publications per year was increasing steadily. The most research was conducted in 2020, when 83 documents were made public.

The smart home has grown into a global model for urban development. As the world's population grows and resources become scarce, affecting the environment, addressing these concerns will be difficult. Nowadays, people are embracing smart home concepts. Globally, states are willing to place their trust in the modern smart home growth notion of consuming the natural quantity of sustainably using resources effectively. By implementing the concept of a smart home in the current environment, the government can manage a limited quantity of resources. It lowers pollutants in the environment and also prepares for urbanizations' demands. It has been noted that emerging nations are interested in the smart home. It demonstrates their commitment to societal growth that is both green and smart. New technologies such as big data must be used to construct a smart home model. Internet of Things, cloud computing, and edge computing are all terms that have been used to describe these technologies. These technologies are combined with smart homes' deployment and monitoring. These cutting-edge technologies are essential for the model for a smart citys' effective deployment.

According to our observations, most research papers have been published in 2019 and 2020, indicating that smart homes are receiving more attention from researchers. We discovered the top journals, authors, and nations involved in this study topic through analysis. We were able to create numerous clusters connected to smart homes and modern technologies with the assistance of analytics. The cluster we get illustrates the numerous factors that must be

considered while implementing smart homes. These factors provide context for the smart homes' conceptual framework. It shows you how to use the many technical phrases associated with implementing the smart home concept.

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