Evolution of scientific knowledge on the internet of things and smart homes

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Abstract
This study aims to characterize the evolution of scientific knowledge about IoT and Smart Homes through the mapping of scientific studies routes, as well as to identify the most emerging knowledge in this area. It uses data from papers from Web of Science published between 2010 and 2021. Network analysis and Source Path Link Count were used to build the citation network and map the main route of knowledge. The results contribute to the current literature in understanding the evolution of this topic and can guide researchers in the direction of future work related to IoT and Smart Homes.

Keywords: internet of things; smart homes; knowledge routes; emerging knowledge.

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1. Introduction

The Internet of Things (IoT) refers to a type of network that allows any object to connect to the Internet, respecting certain interaction protocols through the information detection equipment to conduct the exchange of information and communications between the objects themselves or between object and human being. The IoT concept was created by a member of the Radio Frequency Identification (RFID) in 1999 and has been increasingly relevant in recent years (Patel & Patel, 2016). IoT is popularly disseminated as objects being connected to the Internet and using that connection to provide some kind of useful remote service or monitoring. IoT-enabled products employ embedded technology that allows them to communicate, directly or indirectly, with each other or over the Internet (Chase, 2013).

One of the most promising applications for IoT are those related to Smart Homes, that can be understood as the integration of different services in a house and that use a common communication system among them (Lutolf, 1992). This would ensure energy savings, a safer and more comfortable operation of the houses, besides including a high degree of interoperability (Satpathy, 2006). The houses of the future will be able to provide almost all types of services that are part of our routines, for example, communication services, medicine, energy, entertainment and security (Alam et al., 2012).

As an example of the unification of IoT technologies and Smart Homes, is the application related to home remote health care. An older population needs care and new strategies for health services (Moreno et al., 2016). Another application is related to the optimization of electrical energy consumption (Alaa et al., 2017). When investigating previous works, many of them address the relationship between IoT and Smart Homes from a technological or applied perspective (Mano et al., 2016; Patel & Patel, 2016; Biljana & Kire, 2017), but not from the perspective of how the knowledge of these two topics has evolved simultaneously.

Thus, based on this gap, this study proposes to characterize the evolution of knowledge concerning IoT and Smart Homes by mapping scientific study routes and identifying the most emerging research in this area of knowledge.

2. Review

2.1 Overview on IoT and smart homes

IoT is commonly defined as a network of physical objects with hardware components, sensors and software that enable the possibility of new products to be interconnected through the internet or any other form of connection (Torğul et al., 2016). The devices that make up an IoT-based environment are characterized by having a unique identity; communicate effectively with the environment; obtain and emit data related to itself and have the ability to make decisions about its own operation (Balo et al., 2016).

The IoT technologies are embedded in virtually every sphere of society: agriculture (Tzounis et al., 2018; Cornejo-Velazquez et al., 2020), smart environments like homes and offices (Balo et al., 2016), logistics, transportation and healthcare (Atakul, 2015). Aspects such as security, privacy, data management and interoperability are also points of high criticality when if it aims to interconnect different hardware and software devices (Tsai et al., 2014; Patel & Patel, 2016). Dedehayir, Pîrvan and Le Fever (2019) reinforce the disruptive potential of IoT technologies in the construction of products and services through technological innovation platforms and business models.

As an important component of IoT, smart homes serve users effectively, communicating with various digital devices. Some more classical definitions already pointed out a smart home as being an environment that could help its inhabitants to live independently and comfortably with the help of technologies that facilitate daily routines (Allen et al., 2001; Briere & Hurley, 2011; Satpathy, 2006). For Kim et al. (2015), the automation systems that are enablers of a smart home have become increasingly sophisticated, especially with the evolution

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of telecommunications and internet systems. A smart home is a part of IoT in which different activities of home life can be facilitated with the use of devices connected to the internet. Thus, a local network makes possible the transport of information between objects and a residential "gateway" to connect the smart home network with the external world of the Internet (Ricquebourg et al., 2007).

In addition to sensing and control devices for air conditioning and heating, ventilation, lighting, hardware, and security systems, the modern systems include switches and sensors that communicate with a gateway. This "gateway" allows configuring and controlling all devices through a user interface (Galinina et al., 2015). In terms of benefits, smart home technologies based on the interconnection of IoT devices can provide energy management, privacy and security, enhanced leisure and entertainment services, and extended personal independence through the provision of healthcare and assisted living (Chan et al., 2009; Nyborg & Røpke, 2011; Alam et al., 2012). Possibly the major objection to the non-massification of the use of these technologies is still the cost of equipment and limitations on the speed of wireless internet networks.

2.2 Knowledge evolution through route analysis

The social network analysis (SNA), originated from Sociology, Social Psychology and Anthropology (Freeman, 1996), is a methodology used to study invisible, informal, spontaneous and unintentional networks, which represent, in fact, how the origin of the inter- relationships between the network actors occurs (Bès & Grossetti, 2003). These actors can be both people and companies, as well as collective social units such as, for example, departments within an organization, public service agencies in a city, nation-states of a continent or the world, holders of a patent or even authors of a scientific article (Wasserman & Faust, 1999). Thus, any type of relationship can be represented by nodes (actor or object) and the edges that connect them, this being such a relationship of co- ownership, co-authorship or even a semantic relationship of terms (Liu, 2011; De Paulo & Porto, 2018).

The motivation for identifying a route is to explore the relationship between concepts in different knowledge domains, connecting the investigated concepts with the purpose of forming a logical path through these domains (Chen et al., 2014). The method that underlies the analysis of prospection through the routes has as reference the works of mapping scientific trajectories of Hummon & Doreian (1989). Subsequently, Verspagen (2007) proposed an evolution of the methodology by adopting the SPLC algorithm (Search path link count) in the analysis of patent networks and citations to identify better paths and point out the main routes for a technology. The confirmation about the accuracy of this method can be confirmed in publications on technological routes using ARS and SPLC in different knowledge domains (De Paulo & Porto, 2018; Pereira et al., 2018; De Paulo et al., 2020; Picanço-Castro et al., 2020; Basso et al. 2021).

Given the various studies mentioned above, it is observed that the analysis based on networks and routes have conquered space in the scientific literature, being used as a means of investigating the evolution of scientific knowledge and also as a form of prospection in different technological domains.

3. Methodology

The methodological procedures can be described as follows. The first stage refers to the selection and collection of articles published in the *Web of Science*, using the following search terms in the fields of title, abstract and keywords: *(IOT AND ("Smart Home" OR"home automation" OR "smart-home" OR "smart-house" OR "remote house" OR "remote- home" OR "intelligent home" OR "intelligent house" OR "home automation system" OR "house automation system" OR "automated home" OR "automated house" OR "Smart Home").* A total of 1,977 articles published between 2010 and 2021 were obtained. There are several studies that evaluate the two largest academic databases (WoS and Scopus), comparing the advantages and disadvantages of each one of them (Chadegani et al., 2013; Pranckutė, 2021; Singh et al., 2021). According to these authors, Scopus has a larger number of articles and also more recent ones. However, WoS has papers with greater longevity and manuscripts with more citations. Considering that in the present work the objective is to trace the trajectory of knowledge, the variables time and number of citations directly affect the design of the route on the subject of IoT and Smart homes. Thus, it was decided to use only the WoS collection for the present study.

The second stage, data treatment, consisted of data cleaning, duplicate removal, syntax validation of different fields and date format adjustment. The result of this stage produced a base of articles on IoT and Smart Homes that was used for descriptive data analysis, totaling 1,897 articles after cleaning. By using *backward citations* for the citation network, the DOI (Digital Object Identifier) attribute was established as key so that one can analyze the references that each article on IoT and Smart Homes made to other previous works. This data file, considering the articles about IoT/Smart Homes and their references with valid DOI, obtained a file with 21,183 records containing the citation relationships.

The third step consisted of a brief exploratory analysis of the data through frequency analysis and temporal clippings of the data based on bibliometric analysis literature (Ellegaard & Wallin, 2015; Donthu et al., 2021). After, it was designed the citation network and extracted the main knowledge route. The knowledge route is designed by means of the SPLC (*Source Path Link Count)* algorithm applied to the citation network. The SPLC measures the frequency of citation relationships (edges) that are located in different paths of the network. In this study, the nodes are the scientific articles and the ties are the citations referenced in the articles. The edges that have more connections signal the main route in that knowledge domain (Hummon & Doreian, 1989; Verspagen, 2007). The SPLC algorithm based on Verspagen (2007) is implemented in 4 steps:

- *Step 1:* for each starpoint in a network, get the outer edge and the highest value (according to SPLC count) among all edges leaving the starpoint. If there is a tie in the count, select all tied edges.

- *Step 2:* select the edge where the value obtained in step 1 is maximum. This will be the starting node of the main route. If there is a tie, there may be more than one starting node.

- *Step 3:* point out the nodes that were cited by the edges selected in the previous step.

- *Step 4:* from the target nodes pointed out in step 3, select again the output edges that have the maximum value among the output edges from the target nodes. If there is a tie, select all the edges that tie. Add these nodes to the main route. If all edges point to an end node in the network, the algorithm can be terminated; otherwise, go back to step 3 and continue.

After finishing the algorithm, there is then the most important route referring to that domain of knowledge, IoT in the case of this article. The objective of the main path (or route) is to represent for the step the option that has obtained the most weight in the SPLC algorithm and, in this way, the largest flow of ideas in the network may have been represented. In the present article, SPLC was implemented in Gephi 0.8.2 through a plugin developed by Linares (2014) and which made it possible to obtain the main route about IoT and Smart Homes.

Once obtained the route of knowledge about IoT and Smart Homes, it was calculated the betweenness centrality of the nodes of the route. This type of centrality refers to the number of times that a node *k* links pairs of other nodes *i* and *j* in such a way that without the intermediation of node *k*, nodes *i* and *j* would not be able to communicate (Newman, 2010). Consider $P_i(kj)$ to be the number of geodetic distances (shortest paths) between *k* and *j* to which *i* belongs and *P(kj)* to be the total number of geodetic distances between k and j. Evaluating the ratio *Pi(kj) = P(kj)* it is possible to observe the importance of *i* in terms of intermediation by connecting *k* e *j* in such a way that the closer to 1 the result of this ratio is, the more relevant is the node *i* in the path between the nodes *k* e *j*. Applying the average to all pairs of nodes, the betweenness centrality of a node *i* can be expressed as:

$$Ce_i^B(g) = \sum_{k \neq j : i \notin \{k,j\}} \frac{P_i(kj)/P(kj)}{(n-1)(n-2)/2}$$

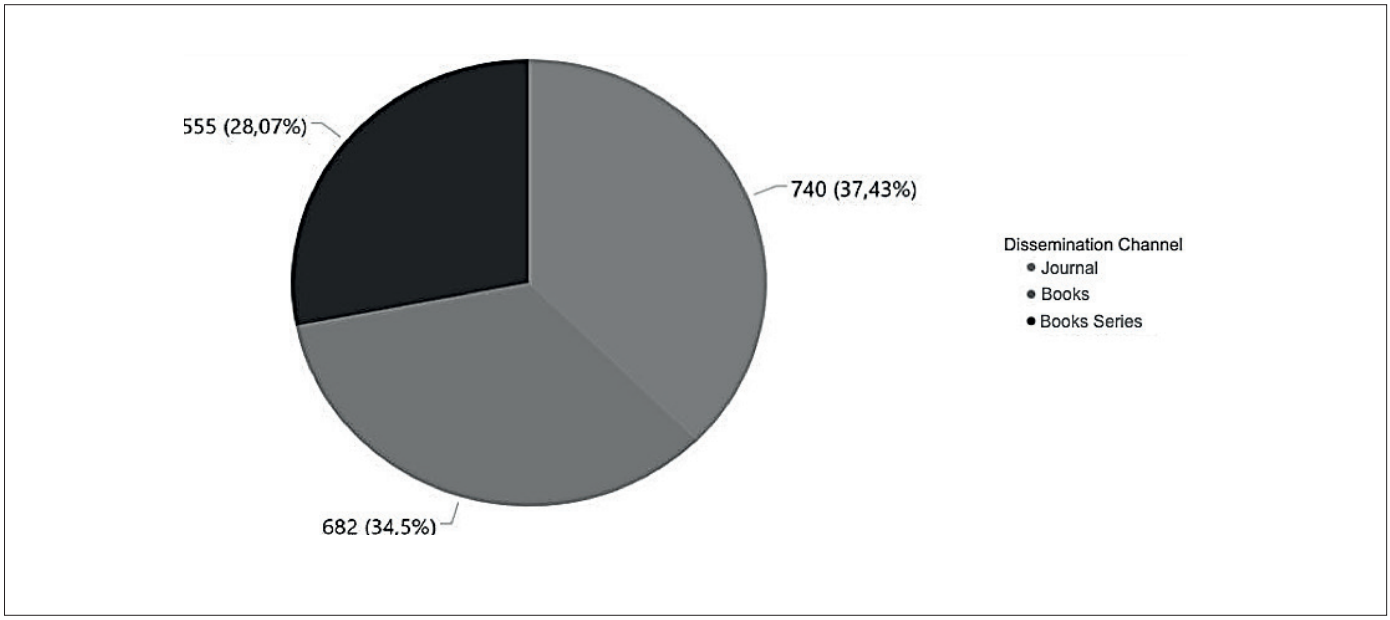
This centrality measure is purely a structural metric of popularity, efficiency and power in a network and shows the relevance of a node before the others in the route (Newman, 2010; Easley & Kleinberg, 2012). Once this is done, the route is analyzed at three different levels of aggregate knowledge (basic, intermediate and emerging), knowledge which is responsible for the conceptual construction over time concerning the IoT and Smart Homes theme.

4. Results and Discussion

4.1 Knowledge exploitation on IoT and smart homes

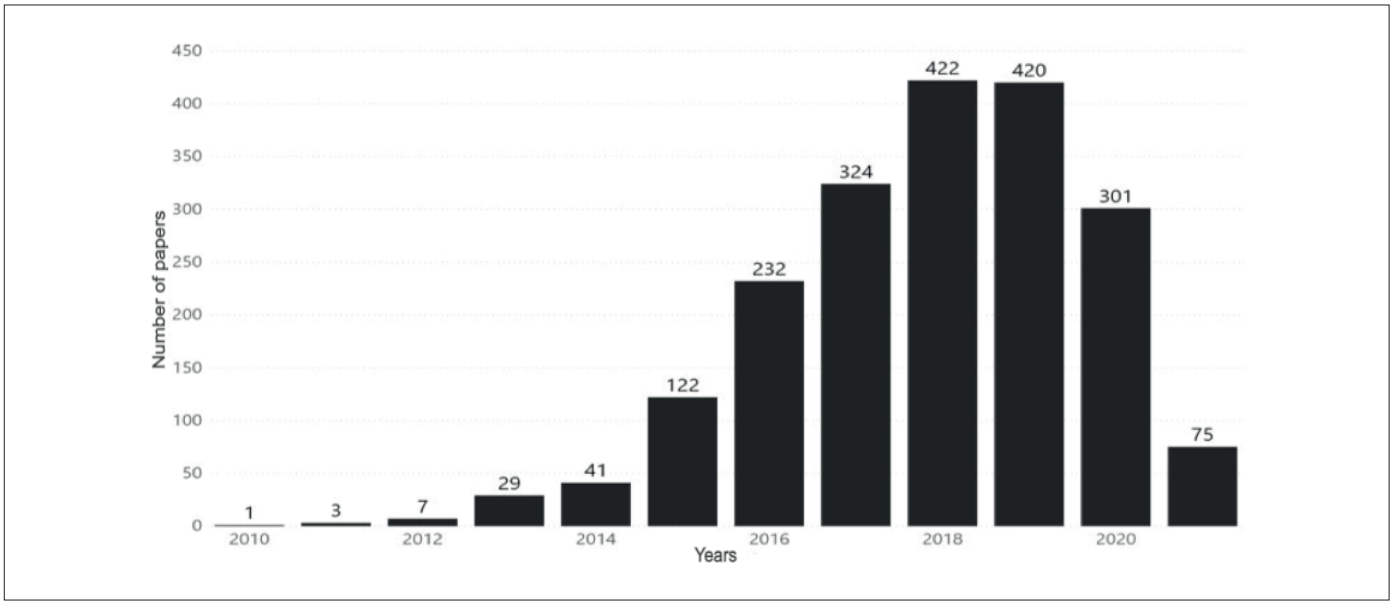
Initially one notices that there is no clear predominance of IoT and Smart Homes knowledge dissemination media (Figure 1). There are more articles published in journals, representing 37.43% of total selected documents but the representativeness of works already published in books and collections (series) calls attention. One inference refers to the maturity of knowledge on IoT and Smart Homes themes since publications in books imply that scientific affirmation of the themes has already been materialized by means of the previous conceptual exploration conducted in periodicals. Thus, one understands that IoT and Smart Homes are no longer new concepts or bring in new and poorly developed knowledge, with publications having already sought to explore the massification of concepts and even already enabling marketable use by means of commercial applications.

Figure 1: Number of papers by means of publication



The growth of theme related studies can be observed by analyzing the temporal evolution of publications on IoT and Smart Homes (Figure 2). One notices that the first moment researchers began to associate the concepts of IoT and Smart Homes together was 2010. It is interesting to note that in just a decade, the scientific knowledge generated on the topic reached its peak in 2018 and 2019, possibly the maximum point of maturity on such knowledge. After this period, publications shall be focused on the different applicability of IoT and Smart Homes, with eventual conceptual improvements.

Figure 2: Number of publications per year



We can also observe a significant drop of approximately 30% in publications in 2020. This is not the object of this study, but one hypothesis is that the pandemic may have limited or delayed publications on the subject. Added to this is the indication that the conceptual maturity of these themes has been reached, so that they have become more applied concepts than knowledge that needs to be explored in basic scientific research.

Table 1 shows the top 10 research areas, ordered by decreasing number of publications. It is interesting to note that the first three research areas have a much higher proportion than the others. Headed by the fields of Computer Science, Engineering and Telecommunications, one notices that 66% of occurrences concerning IoT and Smart Homes are related to such knowledge areas. This result corroborates with the theory addressed by Satpathy (2006) whereby he states that IoT and Smart Homes are concerned with technological devices that automatically communicate with each other and with people.

Table 1: Occurrences by research area

Research areas	Occurrences
Computer Science	1315
Engineering	1057
Telecommunications	595
Instruments & Instrumentation	90
Chemistry	87
Automation & Control Systems	79
Science and Technology	57
Physics	47
Energy & Fuels	43

Directly correlated to the areas of knowledge, the most relevant journals also have a predominantly technical scope (Table 2). Of the 10 journals with the most publications, 8 are in the computational area, either computer science or information systems. This is not surprising after the data in Table 1 are directly related to this academic area. However, it is worth highlighting some interesting points of these publication sites, in addition to exploring the dissemination channels that are not directly related to the area of computing.

Table 2: Most relevant journals

Rank	Periodicals	Qty citations	Qty publications	Averagecitations
1	IEEE Internet of Things Journal	2689	59	46
2	Sensors	907	68	13
3	Journal of Network and Computer Applications	882	11	80
4	Future Generation Computer Systems	776	20	39
5	IEEE Access	643	59	11
6	IEEE Sensors Journal	472	6	79
7	Journal of Cleaner Production	383	1	383
8	IEEE Communications Surveys and Tutorials	356	4	89
9	Computer Networks	299	8	37
10	IEEE Transactions on Industrial Informatics	267	4	67

In the first position of the 'top 10', we have the *IEEE Internet of Things Journal*. The journal was launched in 2014 and brings together the latest advances in IoT related research. The issues discussed in the articles of this journal refer to the impacts, demands and implications of this technology in the various uses of IoT in the future, for example, in smart homes. The journal stands out for the 2689 citations that were made because of the 59 publications on Smart Homes, resulting in an average of 46 citations per article, showing the value of the scientific articles published and the value of this theme, since there is a journal dedicated to it.

It also highlights the involvement of scientific channels on sensors adding 74publications with an average of 19 citations in each. In this list, we have *Sensors* and the *IEEESensors Journal*, where both magazines gather the publications on the new technological advances on sensors. It is understandable the reason for this area to be one of the main ones ofIoT and Smart Homes, since the intercommunication of devices is one of the pillars of its concept and sensors play a key role in enabling intercommunication through their technology.

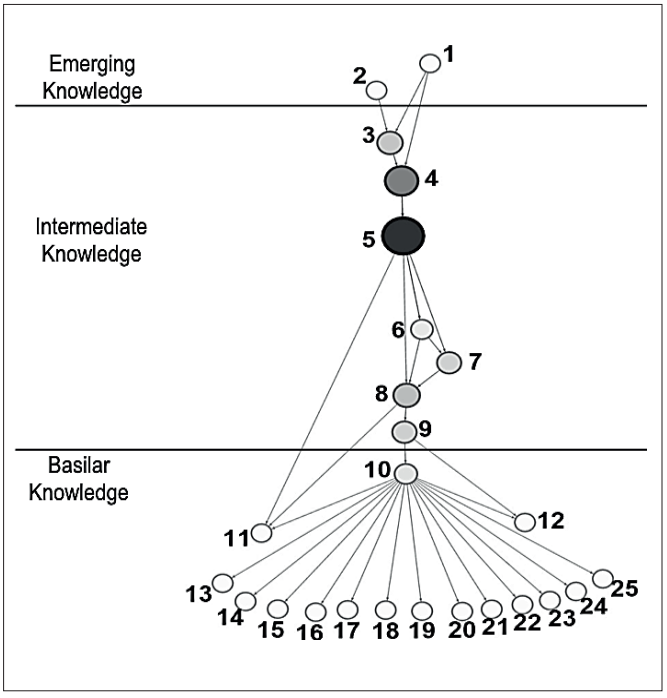
To complement what was previously explained about the studies that seek ways to enable effective intercommunication between IoT technological devices and Smart Homes, it is worth commenting on the presence of *IEEE Communications Surveys and Tutorials*. The journal covers tutorials and research on all aspects of the communications field, aiming at the speed of evolution of technologies within this field. This journal has 4 publications on IoT and Smart Homes, but has 356 citations on them and resulting in an average of 89 citations per article. This directs to the importance of this area for the subject of this research, also complementing the data extracted from Table 1, where the Telecommunications research area is part of 30% of the publications on the subject.

The last point to highlight here is the relevance of the *Journal of Cleaner Production* (JCP). This journal published only 1 article on IoT and Smart Homes, but has 383 citations. The JCP is an international transdisciplinary journal focused on research and best practices on environment and sustainability. This discovery reinforces the importance of IoT and Smart Home technologies to collaborate in one of the most debated sectors within our society, being able to fill gaps on how to make our ecosystem more sustainable through its technology.

4.2 Knowledge route of IoT and smart homes

From the articles citation network, composed of 16,412 nodes and 21,177 edges it was extracted the knowledge route about IoT and Smart Homes. The route composed of 25 nodes (articles) demonstrates the evolutionary path of knowledge on the theme of this article. The nodes of larger size are those that stand out for the intermediation centrality. That is, they are nodes with high influence on the flow of knowledge in the route. For better analysis and understanding of the route, it was decided to segment it into three levels of knowledge: emerging, intermediate and basilar. To exemplify the reading of this route, the top articles are the most recent ones and, the connections they have below, represent the previous articles and have been cited (Figure 3).

Figure 3: Knowledge route on IoT and Smart Homes



The so-called emerging knowledge is represented by the most recent articles and portray theoretical or practical aspects about the main theme analyzed. Similar to the analysis of emerging and promising technologies through patents (Pereira et al., 2018a; De Paulo et al., 2020), the articles found herein at the top of the route refer to what is newest and most relevant on the subject of IoT and Smart Homes: new for being a more recent publication than the other articles of the route; and relevant for being a constituent part of a trajectory that interconnects the most referenced knowledge chain on IoT and Smart Homes. The intermediate level of knowledge, on its turn, represents scientific contributions that mediate basic research on the theme with more recent ones. Knowledge at this level plays a fundamental role precisely because they manage to expand and aggregate discussions and results based on a larger set of basic research. The basilar knowledge level comprises articles that are older than those of other levels, mostly constituting works and research that are already consolidated and commonly accepted in the literature concerning IoT and Smart Homes. Table 3 shows in detail the articles that comprise the knowledge pathway concerning IoT and Smart Homes in their different levels.

Table 3: Composition of the IoT and Smart Home's route by level of knowledge

Level	ID	Paper Title	Authors			Year
			Names	Institutions	Countries	
Emerging	1	Smart Homes: How Much Will They Support Us? A Research on Recent Trends and Advances	Zielonka, A, Wozniak, M, Garg, S, Kaddoum, G, Piran, MJ, Muhammad, G	Silesian University of Technology, Université du Québec, Sejong University, King Saud University,	Poland, Canada, South Korea, Saudi Arabia,	2021
	2	IoT Platform for COVID-19 Prevention and Control: A Survey	Dong, Y, Yao YD	Stevens Institute of Technology,	United States of America	2021
Intermediate	3	IoT Wearable Sensor and Deep Learning: An Integrated Approach for Personalized Human Activity Recognition in a Smart Home Environment	Bianchi, V, Bassoli, M, Lombardo, G, Fornacciari, P, Mordonini, M, De Munari, I	University of Parma	Italy	2019
	4	A Plug and Play IoT Wi-Fi Smart Home System for Human Monitoring	Bassoli, M, Bianchi, V, De Munari, I	University of Parma	Italy	2018
	5	Design, Implementation and Practical Evaluation of an IoT Home Automation System for Fog Computing Applications Based on MQTT and ZigBee-WiFi Sensor Nodes	**F**roiz Miguez, I, Fernandez-Carames, TM, Fraga-Lamas, P, Castedo, L	University of Coruña	Spain	2018
	6	A Cost-Effective IoT System for Monitoring Indoor Radon Gas Concentration	Blanco-Novoa, O, Fernandez-Carames, TM, Fraga-Lamas, P, Castedo, L	University of Coruña	Spain	2018
	7	An Electricity Price-Aware Open-Source Smart Socket for the Internet of Energy	Blanco-Novoa, O, Fernandez-Carames, TM, Fraga-Lamas, P, Castedo, L	University of Coruña	Spain	2017
	8	Home Automation System Based on Intelligent Transducer Enablers	Suarez-Albela, M, Fraga-Lamas, P, Fernandez-Carames, TM, Dapena, A, Gonzalez-Lopez, M	University of Coruña	Spain	2016
	9	Domotic Evolution towards the IoT	Miori, V, Russo, D	Institute of Information Science and Technology	Italy	2014

Level	ID	Paper Title	Authors			Year
			Names	Institutions	Countries	
Basilar	10	IPv6 Addressing Proxy: Mapping Native Addressing from Legacy Technologies and Devices to the Internet of Things (IPv6)	Jara, AJ, Moreno-Sanchez, P, Skarmeta, AF, Varakliotis, S, Kirstein, P	University of Western Switzerland, University of Murcia, University of Murcia, University College London	Switzerland, Spain, England	2013
	11	An Integral and Networked Home Automation Solution for Indoor Ambient Intelligence	Zamora-Izquierdo, M, Skarmeta, AF, Santa, J	University of Murcia	Spain	2010
	12	The Internet of Things: A survey	Atzori, L, Iera, A, Morabito G	University of Cagliari, University of Reggio Calabria, University of Catania	Italy	2010
	13	An overview of Controller Area Network	Farsi, M, Ratcliff, K, Barbosa, M	Newcastle University	England	1999
	14	Introduction to Building Automation	Hermann Merz, H, Hansemann, T, Hübner, C,	Hochschule Mannheim University of Applied Sciences	Germany	2009
	15	WebTag: Web Browsing into Sensor Tags over NFC	Echevarria, JJ, Ruiz-de-Garibay, J, Legarda, J, Álvarez, M, Ayerbe, A, Vasquez, JI	University of Deusto, Parque Tecnológico de Bizkai	Spain	2012
	16	The Internet of Things — A problem statement	Lee, GM, Kim, JY	Telecom & Management SudParis, Electronics & Telecommunications Research Institute	France, South Korea	2010
	17	Architecture for Improving Terrestrial Logistics Based on the Web of Things	Castro, M, Jara, AJ, Skarmeta, AF	University of Murcia	Spain	2012
	18	Embedded web services	Shelby, Z	Centre for Wireless Communications	Finlândia	2010
	19	A survey on IP-based wireless sensor network solutions	Rodrigues, JJ, Neves, P	University of Beira Interior	Portugal	2010
	20	Glowbal IP: An Adaptive and Transparent IPv6 Integration in the Internet of Things	Jara, AJ, Zamora-Izquierdo, M, Skarmeta, AF	University of Murcia	Spain	2012
	21	Forwarding Techniques for IP Fragmented Packets in a Real 6LoWPAN Network	Ludovici, A, Calveras, A, Casademont, J	Universitat Politècnica de Catalunya	Spain	2011
	22	Extending IP to Low-Power, Wireless Personal Area Networks	W. Hui, J, E. Culler, D	University of California	United States of America	2008
	23	Web Services in Building Automation: Mapping KNX to oBIX	Neugschwandtner, M, Neugschwandtner, G, Kastner, W	Vienna University of Technology	Austria	2007
	24	A Transparent IPv6 Multi-protocol Gateway to Integrate Building Automation Systems in the Internet of Things	Jung, M, Weidinger, J, Reinisch, C, Kastner, W, Crettaz, C, Olivieri, A, Bocchi, Y	Vienna University of Technology, Mandat International, University of Western Switzerland	Austria, Switzerland	2012
	25	Drug identification and interaction checker based on IoT to minimize adverse drug reactions and improve drug compliance	Jara, AJ, Zamora-Izquierdo, M, Skarmeta, AF	University of Murcia	Spain	2012

Conclusions, implications, and limitations

Considering the exposed results, it was possible to characterize the evolution of knowledge concerning IoT and Smart Homes by mapping and interpreting the route ofknowledge extracted from scientific studies in this field of study, in addition to identifying research that is at the frontier of knowledge and that may be analysed as more emerging knowledge in the area. General statistics were also extracted, in order to understand an overview of the scientific publications concerning IoT and Smart Homes. After analysing all results, it was possible to observe how the IoT and Smart Homes research field has evolved.

In 2010, the first scientific contributions began to bring together the two terms seekingto evolve in practice, the smart home technologies from the IoT context. However, thepossibility of there being a connected home has been debated since the beginning of IoT studies, the technologies that could be developed, had space to be applied in the domestic environment of people, in order to provide more comfort and safety when automating the routines of their homes. It is identified that the field of study is vast and promising, since it is possible to observe that several technologies and applications are being developed and, because of this, the evolution of the area is something natural.

The major initial concern of researchers is to understand the real possibility of building a connected environment in people's homes. As observed in the knowledge base, as of the route, the studies are focused on introductory concepts of the field and on how to use the already existing internet infrastructure of homes to evolve it into a fully integrated environment. The common justification found to continue research in the field is that the benefits of this technology will generate comfort, autonomy and safety for people in their home environment.

After understanding that the possibility is real, researchers are dedicated to optimizing the costs for the end consumer to increase the uptake of the technologies and begin application tests in various sectors of society in order to understand where the focus of research needs to be chosen to justify the investment of efforts in the evolution of this field.

It is interesting to separate the advances in academia and in the market to explain the general context. One can notice, that academia has all the knowledge base that the marketuses to develop its commercial applications. Researchers seek to evolve the area as a whole, developing more effective sensors, longer-lasting batteries or technologies that help people have more comfort and security at home. It is important to recognize, that commerce already explores and sells home automation technologies, but it is worth highlighting that we are far from where researchers believe we can reach, as it is still expensive and therefore, less accessible.

After analysing and interpreting the results obtained, it is possible to draw some interesting conclusions about the entire subject matter addressed in this study. It is possible to confirm what the articles in the knowledge route, 80% are concerned about how to reduce the energy consumption of homes, either related to the own equipment of Smart Homes as the reduction of the cost of energy of the house from the use of the appliances of a smart environment. This corroborates with Alaa et al. (2017) when pointing out that the smart home energy consumption is a gap that can be filled with IoT technologies and Smart Homes. It is worth mentioning here the knowledge provided by the article An Electricity Price-Aware Open-Source Smart Socket for the Internet of Energy, located in the intermediary level of the route, where it was possible to reduce 15% of annual electric power expenses in the residential environment by means of the use of the Smart House technology.

Results also demonstrate that the healthcare sector is quite promising when analysing IoT research associated with Smart Homes. The following was identified in the relevant studies in the health area, including during the COVID-19 crisis, in which researchers seek to develop IoT applications and Smart Homes that assist people within their homes. This finding complements Moreno et al. (2016) on the importance of creating new strategies to deal with a health system that will need to be broader because of the aging of the global population and homes, with IoT resources, should be an element to which one should add intelligence and association with health. It is noteworthy in this case, the article IoT Platform for COVID-19 Prevention and Control: A Survey, belonging to the emerging level, where researchers developed a form of prevention and control of COVID-19 and future respiratory diseases by means of intelligent equipment inserted within our homes.

Other sectors are still evolving and maturing on ways to create solutions for people's home needs. This is identified in the other study, located at the emerging level of the route, which refers to an overview of the IoT applications and Smart Homes in all contexts and that aims to offer a path for further researches. This result supports the results obtained by Li, Da Xu and Zhao (2015), where they state that the development of IoT applications brings with it very complex problems that we still need to learn to deal with.

The results also allow us to notice the challenge that still exists for the massification and commercialization of the technologies recommended in scientific works about IoT and Smart Homes, especially those related to the connectivity and interoperability of things. One notices that most scientific articles belonging to the knowledge base in the route, are concentrated on themes related to the ways of connecting devices to the internet and what is the best way for a system to store all information generated from a home equipment. Such challenges are confirmed here as it was also already pointed out by Tsai et al. (2014) when commenting the technological limitation in having a decent infrastructure to sustain a 100% intelligent environment.

In addition to the contributions obtained from the interpretation of the route of knowledge about IoT and Smart Homes, it is also considered a relevant aspect of this article the successful use of the knowledge analysis method based on scientific publications supported by the network analysis technique and the SPLC algorithm. Articles are legitimate sources of scientific knowledge, thus being fundamental artifacts for understandingknowledge domains. Route mapping enabled an understanding of existing themes over time concerning these two subjects (IoT and Smart Home). Furthermore, the route enabled the

visualization of this informational flow thus becoming a practical tool for other researchers to understand the entire evolutionary aspect of a given knowledge domain.

About the limitations, it can be mentioned the cut out of a single database, which despite being one of the main repositories of scientific research in the world, there are other data sources of scientific publications that were not explored. Another limitation was the need that all articles and citations should have DOI for the development of the citation network and the knowledge route. As future works, it is intended to apply the method to other areas of knowledge and also using patents, in such a way as to evaluate the transition from scientific knowledge to technological knowledge about the theme IoT and Smart Homes.

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