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An overview of the internet of things (IoT) and irrigation approach through bibliometric analysis

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Abstract. This study evaluates the status of the internet of things (IoT) application in irrigation practices by focusing on the research direction, leading countries and productive researchers. The data from this study was extracted from the Scopus database and analysed using a Publish or Perish and a VOSviewer software for citation analysis and bibliometric map, respectively. The present study reveals that rapid increment of the articles in the subject area began in year 2016 and continues growing until today. India become the most productive country (n = 271), followed by China (n = 88), Indonesia (n = 41) and Malaysia (n = 32) in this topic. The most three prolific authors in this subject area are Wenyan Wu (Birmingham City University, UK), Steve Attard (AgriTech Solutions, Australia), and Yvette Everingham (James Cook University, Australia). This study gives insights into an overview of current and frontier research in the application of the IoT in irrigation related approach. It provides an idea to researcher to contribute the knowledge in under explored research domain.

1. Introduction

Bibliometric analysis is a branch of knowledge that is defined as a quantitative approach used to analyse the knowledge structure and growth of research fields based on the study of relevant publications [1]. Scopus database recorded the word 'bibliometric' was the first documented and appeared in one of the articles published in 1969. Bibliometric analysis is a powerful tool [2, 3, 4] for citation and bibliographic to represent the current and future direction of the study area [5, 6, 7].
Internet of Things (IoT) is defined as a system network that connects anything through internet-based protocols for the aim of communication and information exchange between human to machine, human to human or machine to device [8]. IoT has been widely used in agriculture to ease farming activity, increase farm productivity [9], water management, soil monitoring [10] and crop surveillance [11]. The sensors are attached to growing media, plants, and environment as an indicator of crop needs. A microcontroller such as Arduino [12] or Raspberry Pi [13] works like a small computer to gather and send the data to the cloud for further analysis and decision making.

There are a few studies that conducted bibliometric analysis on IoT challenges [5, 14, 15], IoT and innovation [16], IoT and blockchain [17], IoT and food safety [2], IoT and the Arab world [18], and IoT of circular economic [19, 20]. However, little knowledge is available on the IoT approach in irrigation related fields. Therefore, this study was carried out to fill up the potential gap of knowledge. Three research questions guided this study: (i) What are the global IoT application trends in irrigation approach? (ii) What are the leading countries in the research of IoT for irrigation purposes? and (iii)

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Who are the prominent researchers in irrigation approach employing IoT?. The main aim of this study is to overview the status of IoT application in irrigation approach.

2. Methodology

The data analysed from this study was based on Scopus database excessed through E-Resources Citation Database provided by Tuanku Syed Faizuddin Putra Library, Universiti Malaysia Perlis as on December 10, 2020. The Scopus database has been widely and frequently used for bibliometric analysis since it consists of a plethora of articles, peer-reviewed articles and multidisciplinary [22]. Searching strategy used in this study was based on systematic searching proposed by Shaffril et al. [23]. The formulation and selection of search strings are based on synonyms in thesaurus.com, keyword from abstract and keyword suggested by the Scopus. The variation of keywords, boolean operator, quotation marks and truncation symbols are used into the search string to obtain a relevant and rigorous result for further analysis.

After reading the document title and abstract as well as applying exclusion and inclusion criteria, the search yielded 656 documents. The refined and filtered records were extracted from the Scopus database to Microsoft Excel in comma-separated values (CSV) file. The database in the form of research information system (RIS) extension file was also downloaded for extended analysis purpose. Later, the downloaded file was exported to Publish or Perish and VOSviewer software for citation counting and network visualisation, respectively. An outline of the methodology used in this study is presented in Figure 1.

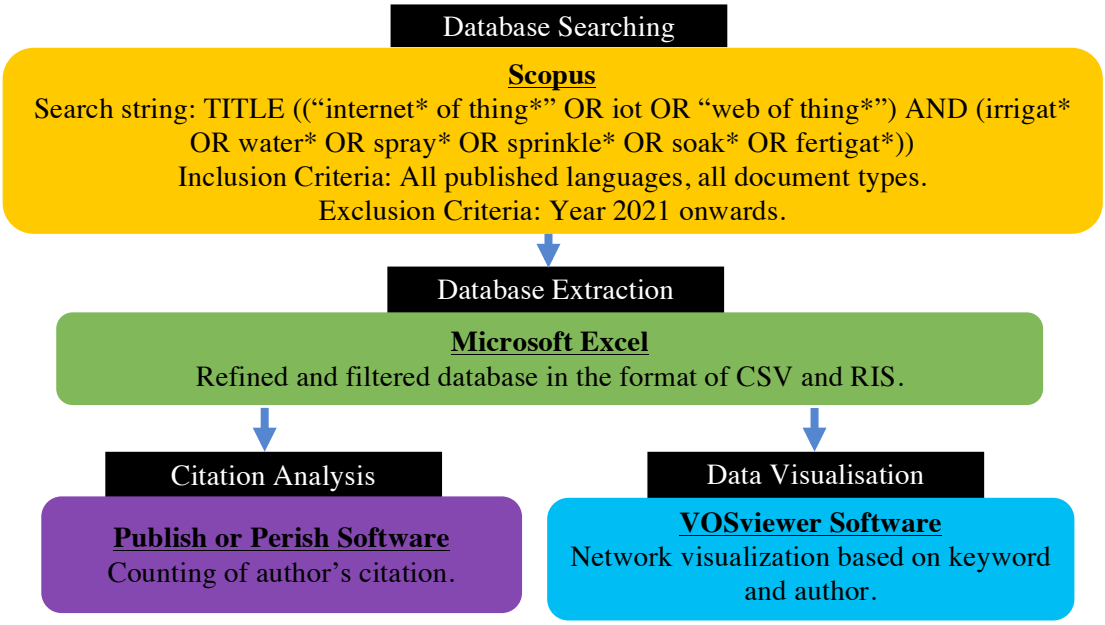

Figure 1. An outline of the methodology used in the proposed study.

3. Results and Discussion

Figure 2 shows the trends of publications related to the IoT and irrigation for ten years from year 2010 until 2020. It can be seen clearly that the publication trend can be divided into two stages. At the first stage of research development from year 2010 to 2016, only a few researchers are concentrating on IoT and irrigation practices. One of the possible reasons is IoT is a quiet new research area at the beginning of the new millennium era. Therefore, the researchers begin to explore more on the subject area to suit their current research interest. The second stage, which is classified as rapid increment, was found between year 2017 and 2020 similar to IoT trends in other IoT applications [14, 16]. In year 2020, the number of publications is slightly decreased if compared to the year 2019 because the data extracted is limited to early December 2020 and reminder data is not being uploaded yet by the

publisher into the Scopus database. Most of the articles published were in English and some in other languages such as Chinese, Spanish and Turkish (Figure 3). Although the search string does not limit the time frame, the results reveal that IoT related to irrigation research began in 2010. Researchers have prioritised [16] the research in IoT and irrigation worldwide since it showed increasing trends for the last five years. Many of these topics have been presented at local and international conferences (Figure 4).

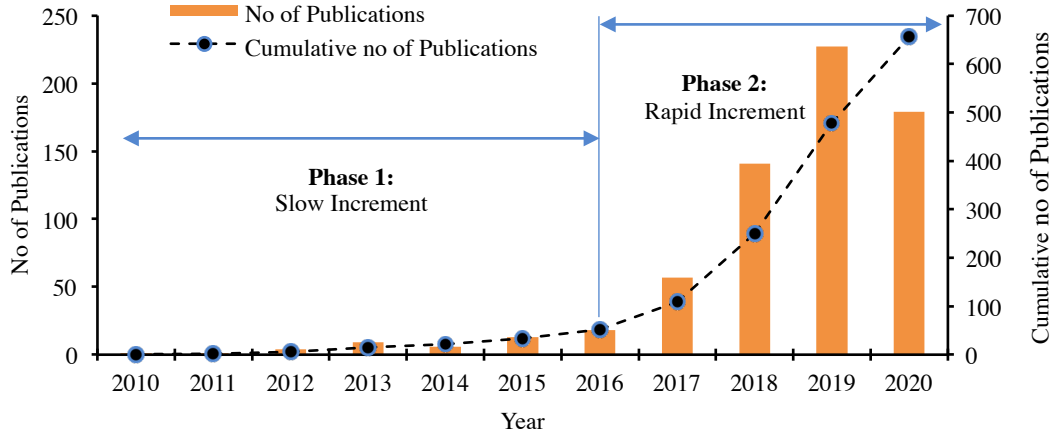

Figure 2. Trends of publications related to the IoT and irrigation for the last ten years.

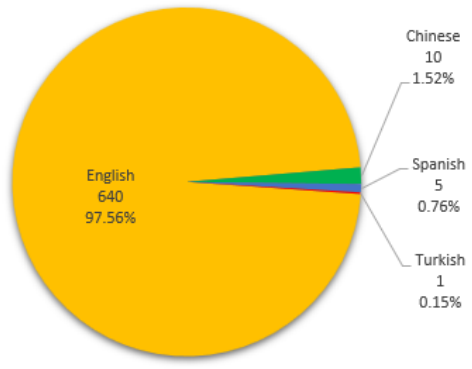

Figure 3. Different languages of articles of the accessed database.

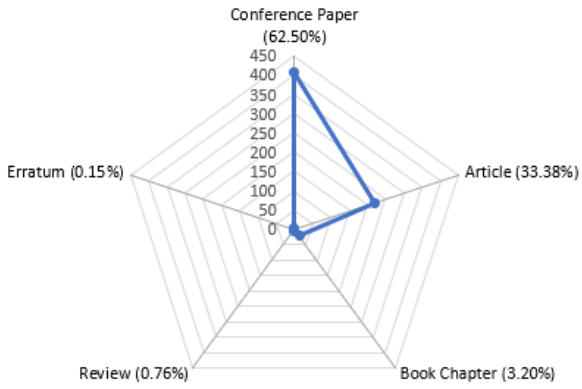

Figure 4. Spider web of different types of publications on related articles.

IoT prospects with global economic value forecasts ranging from US$1.9 trillion to US$7.1 trillion in 2020 as expected by [23]. IoT implementation is challenging since it pruned to uncertainty in decision making. As described by [24], IoT problems are becoming more critical and are undergoing drastic changes in many fields. IoT production brings with it many new technologies and new issues. Among the mentioned issues are integration between IoT and decision support system [25], real-time monitoring of soil properties [26], and sustainable controlling or smart irrigation system [27, 28]. Based on network visualisation on keyword occurrence (Figure 5), the topic is divided into five clusters which are internet of things cluster, irrigation system cluster, water management cluster, water quality cluster and water consumption cluster. Figure 6 illustrates the top 20 productive countries related to IoT and irrigation. The most productive country is India, with 271 articles followed by China (88) and Indonesia (41). Malaysia is ranked no fourth with total publications of 32. The countries mentioned are based on the affiliation of the authors. Although China [29] produced the highest

number of IoT publications during 2011 and 2016, India is ranked first in terms of the research works on IoT and irrigation approach. Asia and Europe are the among influential countries who led the study on IoT and irrigation based on the top twenty countries. These countries received a tremendous amount of grant-funded by various institutions, as depicted in Table 1. In the Asia region, China, Singapore, Malaysia and India give special attention to IoT and irrigation related research. European Union (Italy, Greece, Spain, France, Portugal, and Romania) including the United Kingdom also spend some money on accelerating this field research.

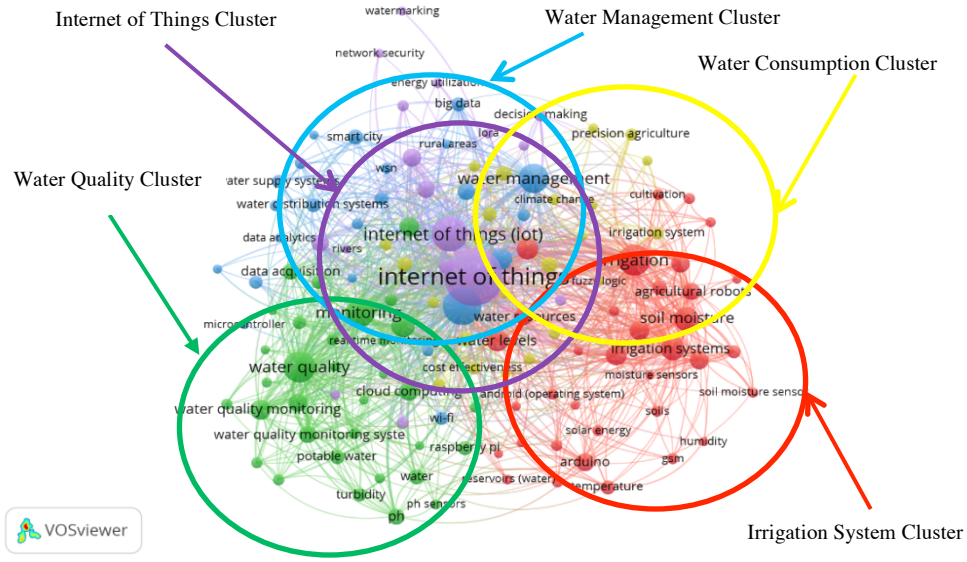

Figure 5. Network visualisation map for all keywords by using a full counting method with at least ten minimum number of keyword occurrences.

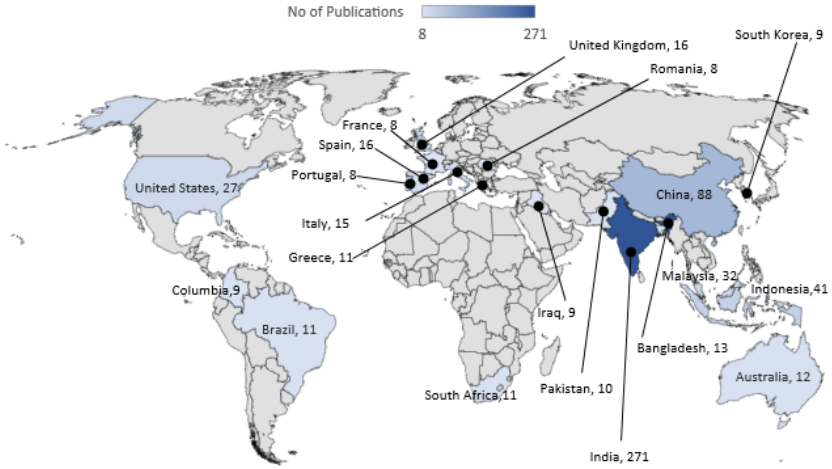

Figure 6. Top 20 most productive countries which published documents related to IoT and irrigation related fields.

Figure 7 illustrates the network visualisation map of the co-authorship. Some authors are group together and interconnected with each other for instance, green group (Wu. J., Li. J. Liu. Y.), blue group (Attard. S, Everingham. Y.) and red group (Wang, X, Zhang. H, He. H.). The author might be from the same institution or internationally collaborated in articles publishing. Table 2 lists the ranking of the top twenty most productive authors in IoT and irrigation related field. The top 20 the most

productive authors received a total of 259 citations and had a mean of 19.95 as recorded from the Scopus database.

The most productive author on IoT and irrigation approach is Wenyan Wu, with the affiliation from Birmingham City University, United Kingdom. She is a professor and expertise in smart sensor, water distribution system, hydro informatics and water resource management [30]. The first rank author was contributing six articles between 2016 and 2019. However, the author with the highest total citation, the highest average citations per publication and the highest average citations per cited publication is Kamienski (Universidade Federal do ABC, Brazil), who published three articles between 2018 and 2019. Besides, this author has published the articles in Scopus since 2001.

Table 1. Top 20 most active funding institutions funded the project and research grant related to IoT and irrigation related field.

Region	Funding Institution	Country Involved
Asia (42.69%)	National Natural Science Foundation, Fundamental Research Funds for the Central Universities, Building and Construction Authority, Universiti Teknologi MARA, Agency for Science Technology and Research of Singapore, Ministry of Science and Technology of India.	China, Singapore, Malaysia, India
Europe (40.24%)	European Commission, Horizon 2020 Framework Programme, European Regional Development Fund, Seventh Framework Programme, Engineering and Physical Sciences Research Council, Ministerio de Economía y Competitividad, Fundació Catalana de Trasplantament, Marie Curie, Spain Ministry of Economy.	European Union countries including the United Kingdom
South America (17.07%)	Conselho Nacional de Desenvolvimento Científico e Tecnológico, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Financiadora de Estudos e Projetos, Fundação de Amparo à Pesquisa do Estado do Rio Grande do Sul, Instituto Nacional de Ciência e Tecnologia para Excitotoxicidade e Neuroproteção.	Brazil

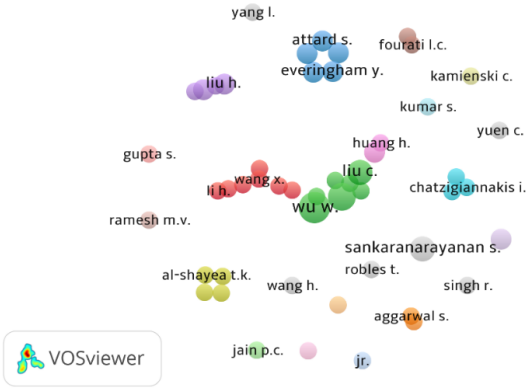

Figure 7. Network visualisation map of the co-authorship by using full counting method with five minimum number of an author.

Most of the prominent authors are with the affiliation from Australia (5), India (3), China (2), Tunisia (2), Greece (2), Cyprus (2), UK (1), Italy (1), Brazil (1), and Romania (1). The impact of the authors is expressed in the form of an h-index and g-index. In the category of the h- and g-index, Wu, W., Sankaranarayanan S. Chatzigiannakis, I., Jain, P.C., Kamienski, C. and Liu, H. are among the top twenty scientists based on their total citation. The h-index and g-index do not replace each other, but these indexes are complementary [31]. From this study, the scope of IoT application in irrigation is enormous. The researchers need to narrow down their focus area based on the research cluster as

visualised in Figure 5. The research hotspots can be explored in various aspects, for instance, utilisation of sensor [32], media properties [33, 34], the innovative method of crop water requirement measurement [35, 36], crop monitoring [37] and yield prediction [38]. Most of the recent research topics are toward sustainable irrigation and optimisation of irrigation water usage.

Table 2. Top 20 most productive authors in IoT and irrigation related field.

Rank	Author's name	Country	NP[a]	TC[b]	C/P[c]	NCP[d]	C/CP[e]	h-index	g-index
1	Wu, W.	UK	6	18	3.00	6	3.00	3	3
2	Attard, S.	Australia	4	5	1.25	2	2.50	2	2
3	Everingham, Y.	Australia	4	5	1.25	2	2.50	2	2
4	Philippa, B.	Australia	4	5	1.25	2	2.50	2	2
5	Sankaranarayanan S.	India	4	35	8.75	3	11.67	2	4
6	Wang, E.	Australia	4	5	1.25	2	2.50	2	2
7	Xiang, W.	Australia	4	5	1.25	2	2.50	2	2
8	Aggarwal, S.	India	3	1	0.33	1	1.00	1	1
9	Al-Shayea, T.K.	Cyprus	3	6	2.00	2	3.00	2	2
10	Chatzigiannakis, I.	Italy	3	12	4.00	3	4.00	2	3
11	Fourati, L.C.	Tunisia	3	8	2.67	3	2.67	1	2
12	Fourati, M.	Tunisia	3	8	2.67	3	2.67	1	2
13	Huang, H.	China	3	2	0.67	1	2.00	1	1
14	Jain, P.C.	India	3	28	9.33	3	9.33	2	3
15	Kamienski, C.	Brazil	3	68	22.67	3	22.67	3	3
16	Liu, H.	China	3	12	4.00	3	4.00	3	3
17	Mastorakis, G.	Greece	3	6	2.00	2	3.00	2	2
18	Mavrommati, I.	Greece	3	12	4.00	3	4.00	2	3
19	Mavromoustakis, C.X.	Cyprus	3	6	2.00	2	3.00	2	2
20	Mocanu, M.	Romania	3	12	4.00	3	4.00	1	3
		Total	69	259	-	51	-	38	47

[a] NP refers to the number of publications by the author.
[b] TC refers to the total citations by the author.
[c] C/P refer to average citations per publication by the author.
[d] NCP refers to the number of cited publications by the author.
[e] C/CP refers to average citations per cited publication by the author.

4. Conclusion

In this paper, an overview of IoT and irrigation approach has been discovered through bibliometric analysis. The research questions have been answered from the result, which was analysed through citation analysis and network visualisation. Since water management is an essential component in agriculture, the particular interest on the topics has been given full attention from the researchers. The global warming, climatic change, agriculture water quality and irrigation in a controlled environment structure are challenging issues that trigger farmers and researchers to manage water sources and use them wisely and efficiently. Moreover, the Covid-19 pandemic has accelerated smart farming technologies and force farmer to apply IoT in their farming system. An investigation with a load cell sensor in assisting irrigation and managing crop water requirements towards precision irrigation approach is being studied and explored for future work.

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