Research on the Development Situation of Industrial Internet of Things Based on Mapping Knowledge Domain

Hong-fei Guo[1], Ru Zhang[1,2(✉)], Ting Qu[1], Cong-dong Li[1], Zheng-wei Zou[5], Yi Zhou[1], Qiu-fan Chen[1], Hao Jiang[1], Bao Chao[1,4], Xiao-feng Luo[5], and Zhi-hui He[3]

[1] Institute of Physical Internet, Jinan University, Zhuhai 519070, China
zhangru@stu2016.jnu.edu.cn

[2] Institute of Management Science and Engineering, Jinan University, Zhuhai 519070, China

[3] Zhuhai Hengqin Building & Construction Quality Inspection Centre Co., Ltd., Zhuhai 519031, China

[4] School of Mechanical Engineering, Inner Mongolia University of Technology, Hohhot 010051, China

[5] School of Statistics, Jiangxi University of Finance and Economics, Nanchang 330013, China

Abstract. The rapid development of Industrial Internet of Things has attracted extensive attention of scholars in related fields. In order to fully understand the research progress in the field of Industrial Internet of Things, the WOS (Web of Science) database is used as the data source, the qualitative research and quantitative research are combined, the CiteSpace III software is used as the data visualization tool, and the literature published in the field of Industrial Internet of Things from 2011 to 2019 is used as the research basis to draw the map of scientific knowledge. From three aspects of research hotspot, knowledge base and development trend, it is concluded that the integrated application of information technology such as Internet, big data, 5G and cloud computing will be the direction of development in the field of Industrial Internet of Things.

Keywords: Industrial Internet of Things · Bibliometrics · Mapping knowledge domain · CiteSpace · Research progress

1 Introduction

The Industrial Internet of Things integrates various acquisition and control sensors or controllers with sensing and monitoring capabilities, as well as mobile communication and intelligent analysis technologies into all aspects of the industrial production process, thereby greatly improving manufacturing efficiency, improving product quality, and reducing products cost and resource consumption, eventually bringing the traditional industry to a new stage of intelligence. From the application form, the Industrial Internet of Things application has the characteristics of real-time, automation, embedded (software), security and information interconnection.

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The academician of the Chinese Academy of Engineering, Hequan Wu, expands the application of the Internet of Things in the field of production and life on the basis of systematically introducing the composition, network relationship, technology and functions of the Internet of Things [1]. Qibo Sun et al. used the literature analysis method to analyze the basic concepts, features, architecture, key technologies and standardization of the Internet of Things, and sorted them out in different categories [2]. Jorge E. Ibarra-Esquer et al. analyzed the evolution process of various application fields from the perspective of the evolution of Internet of Things theory and technology [3]. Yang et al. classified and systematically reviewed the commercial literature of the Internet of Things from the perspective of individual users and organizations. Some researchers have conducted more in-depth quantitative analysis of information science from the field of Internet of Things research [4]. Yangping He based on the core collection of WOS, through the CiteSpace, HistCite and Pajek tools to analyze and summarize the Internet of Things literature, to obtain visual results [5]. Xinli Zhou et al. applied scientific measurement and visualization method to statistically analyzed the data of the Internet of Things research papers of CNKI (china national knowledge infrastructure) literature database from 2003 to 2012 [6]. Ruiying Sun et al. mapped the mapping knowledge domain and analysis of the Internet of Things related literature in the CNKI literature database from 2005 to 2015 [7]. Juan et al. used the ScientoPy tool developed in Python language to conduct quantitative statistical analysis of the Internet of Things research in WOS and Scopus literature database between 2002 and 2016 [8]. Erfanmanesh further carried out bibliometric analysis, altmetric analysis and network analysis on the literature data related to the Internet of Things research of the Scopus database from 2006 to 2015 [9].

The current Industry 4.0 has an important connection with the Industrial Internet of Things. From the development of industry and the use of intelligent machines related to the Internet to achieve intelligent mechanical production, it can be seen that the Industrial Internet of Things is based on the development of 5G technology. Industrial Internet of Things will be more likely to grow with the support of 5G networks. However, because the Industrial Internet of Things has not been produced for a long time, the topics, contents and methods involved are also extensive. Therefore, it is necessary to fully understand the research hotspots, knowledge bases and development trends in the field of Industrial INTERNET OF THINGS in recent years. Therefore, based on bibliometrics theory and CiteSpace software, this paper sorts out and analyzes the related research in SCI, core journals and Industrial Internet of Things from 2011 to 2019, in order to provide a certain degree of guidance and reference for the theoretical research and development direction of the Industrial Internet of Things.

2 Research Method and Data Source

2.1 Research Method

The research method in this paper is a combination of qualitative analysis and quantitative analysis. Qualitative analysis is to sort out the main content of the literature in the field of Industrial Internet of things, especially the classic literature, and analyze its role in the development of the discipline. Quantitative analysis is a statistical analysis of high-frequency vocabulary and frequency in the field of Industrial Internet of Things through bibliometrics, using CiteSpace V as a visualization tool for research, to draw the keyword network, literature indexing network, and distribution time series map, to analyze the research hotspots, knowledge base and evolution trend in the field of Industrial Internet of Things.

CiteSpace is a data visualization analysis software developed by Professor Chaomei Chen from Drexel University. It combines the disciplines of bibliometrics, statistics, information science, etc., and uses the visual form of spatial form to visually display the research hotspots, knowledge structure, development history and distribution of the Industrial Internet of Things researched in this paper.

2.2 Data Source

The research object of this paper is related literature in the field of international Industrial Internet of Things. The data comes from the WOS database and the retrieval time is July 24, 2019. In order to cover the research situation in the field of Industrial Internet of Things as much as possible, this paper selects the topic retrieval method, the time range is defined as 2011–2019, and the keyword is "Industrial Internet of Things". In addition, through manual identification and screening, the invalid records such as call notice, journal statement, conference news and unrelated documents were excluded. This paper finally determined 2055 related documents of WOS database.

3 Analysis of Research Hotspots in Industrial Internet of Things

High-frequency keywords can highlight research hotspots in the subject area. The higher the frequency of similar keywords, the more attention is paid to the research content of the keyword. The more concerned research content usually indicates the future development trend of the field, which is beneficial for researchers to understand the development of the field as a whole. Therefore, in order to understand the latest developments in the field of Internet of Things, using the literature data of WOS data, draw a mapping knowledge domain of research hotspots in the field of knowledge management, as in Fig. 1. There are 413 nodes in the formed map, and the size of the nodes represents the frequency of occurrence of keywords. The top ten research hotspots are listed in the order of the frequency of occurrence of keywords, as shown in Table I.

Analysis of Fig. 1 and Table I shows that in the mapping knowledge domain-co-word network diagram, the co-word network uses "internet" as the network center, and the keywords "thing", "system", "internet of thing" and so on closely surround the network center. The vast majority of keywords at or near the core of Internet of Things research are highly representative of the latest research in this field. In general, the mapping knowledge domain -co-word network has many nodes with similar sizes, and the keyword frequency distribution is balanced. The difference in network center degree between different high-frequency words is small, indicating that there are many

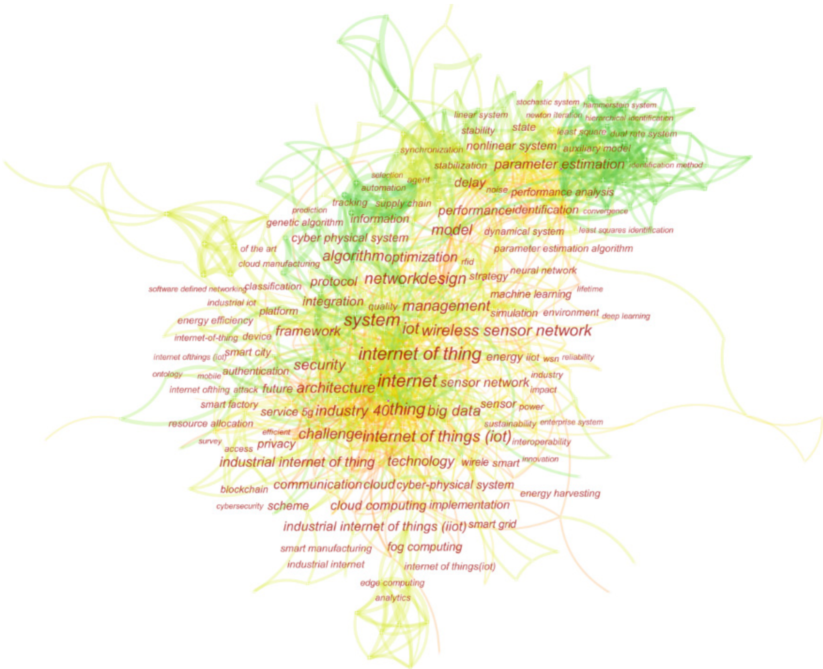

Fig. 1. Mapping knowledge domain – co-word network

Table 1. Top ten research hotspot statistics

Ranking	High frequency word	Frequency	Centrality
1	Internet	331	0.03
2	Internet of Thing	305	0.04
3	System	265	0.03
4	Thing	225	0.03
5	Design	170	0.12
6	IoT	154	0.06
7	Network	145	0.05
8	Internet of Things	143	0.02
9	Wireless sensor network	142	0.02
10	Model	123	0.18

research directions in the Industrial Internet of Things field. The focus of research hotspots is relatively close. Moreover, the overall density of the common word network is high, the network knowledge points are clustered, and there are many cross-disciplinary studies in the field, indicating that the interdisciplinary cooperation in the field of Industrial Internet of Things research is both normal and close. The specific analysis of research hotspots from 2011 to 2019 is as follows:

(1) Communication and data processing area: The frontier technologies of the Internet of Things and computer science, such as big data, artificial intelligence, and cloud computing, are closely combined. Through literature analysis, many scholars have used the relevant theories and technologies of big data, artificial intelligence and cloud computing to innovate and expand the Industrial Internet of Things function.
(2) wireless sensor network area: Industrial Internet of Things development requires more accurate, smarter, more efficient and more compatible sensor technology, wireless sensor network as the basic technology for the development of Industrial Internet of Things technology. With the ubiquity of information, Industrial sensors and sensing devices are required to be more miniaturized, intelligent, and low-power.
(3) Smart factory: Smart factory construction is one of the most widely used applications for Industrial Internet of Things, it mainly includes resource allocation optimization, production process optimization, and management visualization in intelligent industrial production.

4 Evolution Trend of International Industrial Internet of Things

When analyzing the evolution trend, we can use Burst Detection in CiteSpace software to get the research topic of sudden increase in frequency or obvious increase in frequency from keywords. According to the display of the burst terms in the map at different time periods, this method can clearly analyze the evolutionary trend of the Industrial Internet of Things field. Using “keyword” as a node, draw a high-frequency burst terms sequence diagram in the field of Industrial Internet of Things. The “keyword” is used as the analysis node, and the “Timezone” method is used to display the time distribution sequence diagram of the burst terms in international Industrial Internet of Things field, as in Fig. 2.

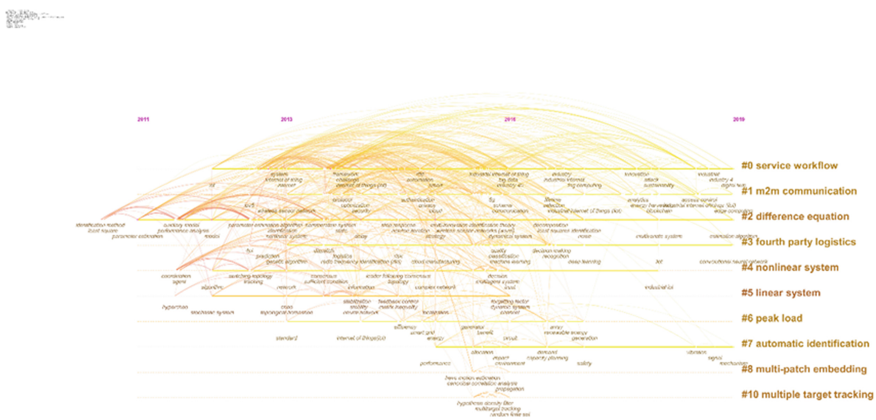

Fig. 2. Burst terms sequence diagram of international Industrial Internet of Things

In-depth analysis of the evolution trend of the 2011–2019 Industrial Internet of Things field, as follows:

During 2011 to 2013, the key words with high international mutation intensity are "IoT", "parameter estimation" and "model", indicating that during this period, the international focus on the integration process of industry and the Internet of Things. It is expected that by analyzing the Internet of Things itself and parameter estimation and experiments applied to the industrial field to build a better model to optimally combine industrial production and Internet of Things technology,

During 2013 to 2016, keywords such as "network", "machine learning" and "wireless sensor network" emerged, indicating that, internationally, further application of network technology and processing of information in a more advanced manner were valued in the field of Industrial Internet of Things. The network is one of the core components of the Industrial Internet of Things, and data is transmitted over the network between different levels of the system. The network is divided into a wired network and a wireless network. The wired network is generally applied to cluster server of a data processing center, local area network of factory and some of the field bus control network, it can provide a high-speed and high-bandwidth data transmission channel. Industrial wireless sensor networks are an emerging technology that uses wireless technology for sensor networking and data transmission. The application of wireless network technology can greatly reduce the wiring cost of industrial sensors, which is conducive to the expansion of sensor functions, thus attracting the attention of many enterprises and scientific research institutions at home and abroad.

During 2016 to 2019, themes such as "Industrial Internet of Things" and "fog computing" were emerged, this indicates that the international Industrial Internet of Things system has been initially completed and is trying to expand it into new areas. With the popularization of information technology and the strengthening of global information trends, the integration of Industrial Internet of Things with other advanced information technologies such as cloud computing and big data will become an area worthy of further study.

5 Knowledge Base Analysis in the Field of International Industrial Internet of Things

The knowledge base is the citation and co-introduction trajectory in the scientific literature at the forefront of research in a certain field. Select "cited reference" as the network node, find out the authoritative classic literature in the field of international Industrial Internet of Things, and conduct knowledge base analysis, so as to further clarify its development context and knowledge research foundation. Through the "Generate a narrative" operation in CiteSpace V, you can get list information of important literatures, as in Fig. 3. After many search and screening, it has identified 10 international articles on the international Industrial Internet of Things with high frequency. Analysis shows: Based on the system performance index, Xu Ling uses the delay of the first-order Taylor expansion approximation system, and proposes an algorithm to determine the controller parameters, so that the system achieves the expected dynamic performance [10].

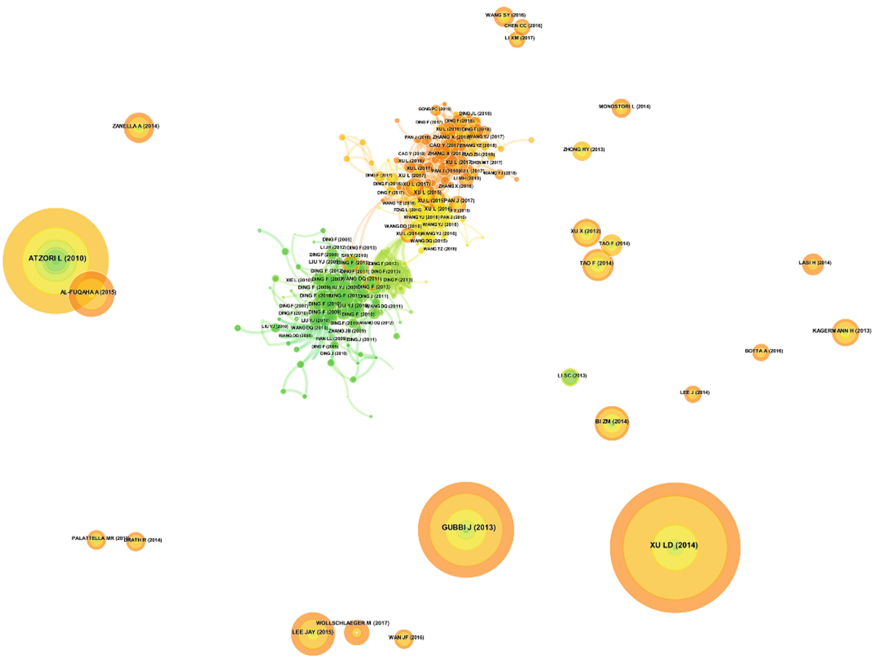

Fig. 3. Mapping knowledge domain - citation network

Ding Feng et al. used a decomposition-based hierarchical recognition principle to derive a Hammerstein system iterative algorithm based on least squares and a gradient-based iterative algorithm for Hammerstein systems [11]. Based on the step response analysis, Xu Ling proposed the Newton iterative algorithm. In addition, in order to verify the accuracy of the estimated parameters, the frequency and step response experiments were applied to the dynamical system between the estimated model and the real model [12]. Xu Ling et al. proposed a Newton iterative identification method for estimating the parameters of second-order dynamic systems using step response data. In addition, in order to obtain the ideal dynamic performance, a controller design method based on root locus is proposed to meet the requirements of overshoot dynamic performance [13]. Dongqing Wang et al. derived a Wiener nonlinear system iterative identification algorithm based on least squares and gradients. This method decomposes a bilinear cost function into two linear cost functions and directly estimates the parameters of the Wiener system. There is no need to re-parameterize, resulting in redundant estimates [14]. Zhang Xiao et al. studied the identification problem of bilinear systems that can measure noise in the form of moving average model, and proposed an unmeasurable state based on hierarchical identification principle and interactive estimation algorithm based on parameters [15]. Yuan Cao et al. According to CTCS-3 (China's train control system level 3) GSM wireless system standard—the control data transmission delay should be no more than 500 ms, the probability is greater than 99%, considering the coverage of non-redundant networks and cross-redundant networks, and in the case of single-row MTs (mobile terminals) and redundant MTs, the corresponding vehicle-to-ground communication model, delay model and fault model are established [16]. Chen Jing et al. studied the identification problem of multi-input and multi-output nonlinear systems. The difficulty in identifying such system parameters is that the information vector in the identification model contains unknown variables. The solution of Jing Chen et al. is to overcome this difficulty by using auxiliary model identification ideas, and to extend the innovation vector into an innovation matrix, and propose a multi-innovation extended stochastic gradient algorithm based on the auxiliary model [17]. Xiangkui Wan et al. introduced a method combining MMF and WT to overcome the shortcomings of existing methods in suppressing BW (baseline wander). In order to verify the effectiveness of the proposed method, Xiangkui Wan et al. used artificial ECG signals containing clinical BW for numerical simulation and established a realistic baseline drift model. The results show that the BW effect of this method is better than other methods [18]. Yanjun Liu et al. applying the idea of auxiliary model identification and the theory of multi-innovation identification, proposed a multi-innovation stochastic gradient algorithm based on the auxiliary model, and the simulation example shows that the algorithm works well [19].

6 Conclusion

Research uses the CiteSpace tool to draw a visual mapping knowledge domain, the relevant literatures in the field of Industrial Internet at home and abroad in the WOS database from 2011 to 2019 are used as research data samples to scientifically analyze the research hotspots, knowledge structure, development process and distribution of sample literatures, obtained the following research conclusions and corresponding recommendations:

(1) From the research hotspot level, there are close links between high-frequency keywords in the Industrial Internet field worldwide, forming a wide range of cross-research fields, and the research direction is relatively scattered. On the basis of maintaining in-depth exploration and discussion of basic knowledge theory, the related literature pays close attention to the practical application and method research of communication data processing, wireless sensor network, smart factory construction, etc. Most of them focus on a single subject research field, and relatively lack scientific research on each crossing field.
(2) From the knowledge base, the main knowledge base of Industrial Internet research at home and abroad is Industrial Internet system design, parameter control, model construction, algorithm deduction, basic theoretical research is more in-depth, and the connection between research scholars is relatively close, the technology application research needs continuous exploration, lacking the emerging power of more fruitful results.
(3) From the perspective of evolutionary trends, relevant research scholars at home and abroad have paid close attention to the development history and application prospect for Industrial Internet. In recent years, research directions have gradually turned to network information processing, wireless sensing control, cloud

computing and big data. The development status of the Industrial Internet field in the new era is changing with each passing day, but the comprehensive research in related fields has not yet attracted widespread attention, the integrated application research in the aspects of modern new information technology also needs to be explored.

In response to the above research conclusions, the corresponding scientific recommendations for promoting the development of China's Industrial Internet: On the one hand, the academic and industrial circles should keep abreast of and grasp the first dynamics in the field of international Industrial Internet, strengthen the informationization, technicalization and integration in the field of Industrial Internet, and continuously develop and improve the basic theoretical system of the Industrial Internet field in our country. On the other hand, industrial enterprises should be the mainstay and guided by national policies, leading the relevant industries to develop towards modernization and interconnection. Focus on promoting technological innovation and application innovation simultaneously, and promote the diversification, phase, generalization, collaboration and integration of the Industrial Internet.

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