International Journal of Information Technology and Applications
Volume 1, Issue 1, March 2024 ISSN 3007-7397

Survey on Intelligent Computing Based on Deep Learning of Big Data

Yiou Wang[1], Fuquan Zhang[2,*], Aibing Dai[1], Jianwei Guo[1], Chuhan He[1], Bo Wang[3]

[1]*Institute of Science and Technology Information, Beijing Academy of Science and Technology, China*
[2]*Fujian Provincial Key Laboratory of Information Processing and Intelligent Control, Minjiang University, China*
[3]*Industrial Digital Finance Department, Huaxia Bank, China*

wangyiou90@163.com, 8528750@qq.com, daiab@bjast.ac.cn, guojw@bjast.ac.cn, hech@bjast.ac.cn, brian2do@163.com

Abstract. In the era of big data, using deep learning of intelligent computing to solve the analysis and processing of massive data efficiently and quickly is a hot research field at present. It has attracted many researchers' research interests. A thorough analysis of the current body of knowledge in intelligent computing based on deep learning of big data is conducive to a comprehensive understanding of the research status and future trends in this field. In this paper, a bibliometric analysis of intelligent computing based on deep learning of big data was performed using the Web of Science (WoS) Core Collection dataset. The relevant literatures of WoS were quantitatively analyzed based on a bibliometric analysis method combined with VOSviewer software. The research results show that the number of literatures published in the field of intelligent computing based on deep learning of big data is on the rise over time, especially after 2017, the growth rate is accelerating. China and USA take the lead position in the number of literatures published. Y. Zhang is the most productive author and Y. S. Lv is the most influential author. IEEE Access and Computational Intelligence and Neuroscience are the main journals. Chinese Academy of Sciences has published most literatures. Research hotspots of intelligent computing based on deep learning of big data mainly include Internet of things, neural network, analysis and processing of big data and application research.

Keywords: Intelligent computing, Deep learning, Big data.

1. Introduction

With the continuous expansion of the application field of artificial intelligence, the traditional artificial intelligence methods based on symbol processing mechanism encounter more and more prominent problems, especially in knowledge representation, processing pattern information and solving combination explosion. Then, intelligent computing came into being [1]. The concept of intelligent computing was proposed by James C. Bezdek in 1992 [2]. Intelligent computing, he argued, depended on numerical data provided by the manufacturer, not on knowledge. Intelligent computing is a series of algorithm models for solving complex optimization problems by simulating the phenomena or behavioral characteristics of nature or biology [3]. The main intelligent computing methods include artificial neural network, fuzzy logic, evolutionary algorithm, immune algorithm, genetic algorithm, simulated annealing, tabu search algorithm, particle swarm optimization, ant colony algorithm and so on. Now intelligent computing has been widely used in various fields of system simulation. Zhang et al. analyzed the factor affecting the antenna electrical axis by the antenna structure theoretically and established the finite element model for the mechanical analysis and calculation of

the antenna structure by ANSYS [4]. Yu et al. constructed a landscape design system based on deep neural network based on multimodal intelligent computing [5]. Pandey et al. adopted a decision making of intelligent computing technology-based methodology of simulation named Analytical Hierarchy Process (AHP), a multi criteria decision making approach, for assessing the risk of COVID-19 in different regions of Saudi Arabia [6]. Umar et al. applied an intelligent computing approach to solve Human Immunodeficiency Virus (HIV) infection spread [7]. This approach involves CD4+T-cells by feed-forward artificial neural networks (FF-ANNs) trained with particle swarm optimization (PSO) and interior point method (IPM), i.e., FF-ANN-PSO-IPM.

Furthermore, the recent advances of deep learning methods such as graph neural networks and deep reinforcement learning present novel perspective towards deep and fine-grained simulation and computation. More and more scholars have tried to apply deep learning algorithm to digital simulation. In the era of big data, using deep learning of intelligent computing to solve the analysis and processing of massive data efficiently and quickly is a hot research field at present, which is in a period of rapid development, and technical hot spots keep emerging. Amshed et al. proposed a deep learning (DL) framework using Long Short Term Memory (LSTM) model to accurate prediction of fire events [8]. Zhao et al. devised a system by proposing the offloading strategy intelligently through the deep reinforcement learning algorithm [9]. Zhang et al. proposed Heterogeneous Distributed Deep Neural Network (HDDNN) over the distributed hierarchy, targeting at ubiquitous intelligent computing [10]. Although Intelligent Computing based on Deep learning of Big Data (IC-DBD) has made certain breakthroughs in some fields, the development of the technology is hindered by fragmentation and the huge amount of data. Therefore, it is urgent to systematically study the knowledge system of IC-DBD, study the key technologies, and study the future development trend and hot spots.

In this paper, a bibliometrics study of the IC-DBD literature was conducted with the aim of revealing some valuable insights to scholars and practitioners of IC-DBD. The results extracted from the bibliometric study in this paper included: (1) the top 20 most cited literatures; (2) the top 10 most popular journals; (3) the top 10 most productive authors; (4) literatures and citation trends; (5) main research institutions; (6) the most published countries/regions; (7) hot spots.

This paper was organized as follows: In Section 2, the data sources, main methods, and research questions were introduced. In Section 3, core literatures, core journals, core authors, overall growth trend, main research institutions, notable countries/regions and hot spots related to IC-DBD from WoS core collections were studied in detail. In Section 4, a brief conclusion was given, and a summary of the future development was made.

2. Data and Methods

2.1. Description of Data Source

The literature data of this paper came from the Sci-Expanded database of Web of Science (WoS) Core Collection of the Institute for Scientific Information (ISI). The knowledge development system of IC-DBD was expected to be fully understood, so the time frame is not limited, which covers the entire period of large-scale scientific production in this field. By November 28, 2022, 141958 references were retrieved in WoS Core Collection datasets under the theme of “big data” or “massive amount of data” or “massive amount of information”. The retrieved literatures were then further refined under all fields "intelligen*" and "deep". At

this time, a total of 2166 literatures were retrieved. The complete records and references of these literature were exported as the data set.

2.2. Research Methods

Based on bibliometric analysis, the main literatures, journals, authors, research institutions, countries/regions and keywords of IC-DBD were statistically studied. Bibliometric analysis is based on mathematics and statistics to quantitatively analyze scientific literatures published in a specific field of knowledge [11].

In recent years, knowledge mapping tools are used in bibliometrics research to transform the table analysis of written data into visual maps that are more visual and easier to read. Visualization of Similarities Viewer (VOSviewer) is a kind of bibliometric analysis and knowledge visualization software jointly developed by N. J. Van Eck and L. Waltman from the Science and Technology Research Centre of Leiden University in the Netherlands in 2010 [12]. In this paper, the clustering algorithm in VOSviewer was used to carry out co-occurrence analysis of published countries and high-frequency keywords. In addition, co-citation networks of cited literature, journals and authors were built for visual analysis of the knowledge maps.

2.3. Research Questions

The following questions need to be answered that will help to identify the dynamics of IC-DBD and provide a holistic means for future research in field. These questions are addressed as follows:

(1) RQ1: What are the most influential literatures of IC-DBD?
(2) RQ2: Which journals are the most popular in the IC-DBD field?
(3) RQ3: Who are leading the IC-DBD study?
(4) RQ4: What is the evolution of IC-DBD research field?
(5) RQ5: What are the main research institutions?
(6) RQ6: What is the research status of IC-DBD in countries/regions around the world?
(7) RQ7: What are the IC-DBD hot spots?

3. Bibliometric Analysis of IC-DBD Literatures

The publication status of literatures is usually regarded as an important indicator to measure the development level of a discipline and the level of scientific research achievements and contributions [13]. Trends in IC-DBD research were studied in this paper using statistical literatures and the frequencies of citations over time.

3.1. Analysis of Core Literatures

The main literatures on IC-DBD were highlighted. The top 20 most cited literatures in the world were listed in Table 1. These literatures have had the widest influence in IC-DBD. The top 10 most cited literatures in Table1 are highlighted below. On top of the list, Lv et al. proposed a novel deep learning-based traffic flow prediction method that considers the spatial and temporal correlations inherently [14]. This was the first time that a deep architecture model was applied using autoencoders as building blocks to represent traffic flow features for prediction. Their literature gets the highest total citations, with a value of 1666. This shows that the literature has a strong impact. Besides, the value of its average citations per year is also very high. In the second place of the list, Topol et al. discussed the current limitations of High-performance medicine, including bias, privacy

Table 1. The top 20 most cited literatures.

No.	Literature Title	Total Citation	Average Citation Per Year	Year	Category
1	Traffic flow prediction with big data: a deep learning approach [14]	1666	208.25	2015	Traffic
2	High-performance medicine: the convergence of human and artificial intelligence [15]	1455	363.75	2019	Healthcare
3	Explainable Artificial Intelligence (XAI): Concepts, taxonomies, opportunities and challenges toward responsible AI [16]	1278	426	2020	Basic Theory
4	Artificial intelligence in healthcare: past, present and future [17]	850	141.67	2017	Healthcare
5	Deep learning for health informatics [18]	775	129.17	2017	Healthcare
6	Deep learning for healthcare: review, opportunities and challenges [19]	700	140	2018	Healthcare
7	Deep learning for smart manufacturing: methods and applications [20]	632	126.4	2018	Industrial Manufacturing
8	Deep learning in mobile and wireless networking: a survey [21]	579	144.75	2019	Wireless Network
9	Edge intelligence: paving the last mile of artificial intelligence with edge computing [22]	569	142.25	2019	Wireless Network
10	A light CNN for deep face representation with noisy labels [23]	526	105.2	2018	Biometric Identification
11	Deep learning for IoT big data and streaming analytics: a survey [24]	508	101.6	2018	Wireless Network
12	Deep learning in medical imaging: general overview [25]	484	80.67	2017	Healthcare
13	Deep learning Approach for intelligent intrusion detection system [26]	396	99	2019	Network Security
14	Automatically identifying, counting, and describing wild animals in camera-trap images with deep learning [27]	358	71.6	2018	Biometric Identification
15	Artificial intelligence in precision cardiovascular medicine [28]	342	57	2017	Healthcare
16	convergence of edge computing and deep learning: a comprehensive survey [29]	337	112.33	2020	Wireless Network
17	Artificial intelligence in surgery: promises and perils [30]	282	56.4	2018	Healthcare
18	A deep CNN-LSTM model for particulate matter (PM2.5) forecasting in smart cities [31]	276	55.2	2018	Cities
19	Design of deep convolutional neural network architectures for automated feature extraction in industrial inspection [32]	266	38	2016	Industrial Manufacturing
20	A survey of machine and deep learning methods for Internet of Things (IoT) security [33]	263	87.67	2020	Wireless Network

and security, and lack of transparency [15]. Their literature gets the second highest total citations, with a value of 1455. In the third place of the list, Alejandro et al. proposed and discussed about a taxonomy of recent contributions related to the explainability of different Machine Learning models, including those aimed at explaining deep Learning methods for which a second dedicated taxonomy is built and examined in detail [16]. This literature gets the third highest total citations, with a value of 1278. And its average citations per year is the highest, with a value of 426. This literature was published in 2020. As a relatively new literature, it obtains such a high value of citation, indicating that it is a very influential literature in the recent three years. The next three literatures are all about the application of deep digital simulation and intelligent computing in the field

of smart healthcare. Jiang et al. surveyed the current status of artificial intelligence applications in healthcare and discuss its future [17]. Artificial intelligence could be applied to various types of healthcare data (structured and unstructured). Ravi et al. presented a comprehensive up-to-date review of research employing deep learning in health informatics, providing a critical analysis of the relative merit, and potential pitfalls of the technique as well as its future outlook [18]. The literature focused on key applications of deep learning in the fields of translational bioinformatics, medical imaging, pervasive sensing, medical informatics, and public health. Miotto et al. suggested that deep learning approaches could be the vehicle for translating big biomedical data into improved human health and advised developing holistic and meaningful interpretable architectures to bridge deep learning models and human interpretability [19]. In addition, Wang et al. presented a comprehensive survey of commonly used deep learning algorithms and discusses their applications toward making manufacturing "smart" [20]. Zhang et al. provided an encyclopedic review of mobile and wireless networking research based on deep learning, which they categorized by different domains [21]. Zhou et al. conducted a comprehensive survey of the recent research efforts on edge computing [22]. Wu et al. presented a Light CNN framework to learn a compact embedding on the large-scale face data with massive noisy labels [23].

As can be seen from Table 1, among the top 20 most cited literatures of IC-DBD, there are 7 literatures on healthcare, 5 literatures on wireless network (including 2 literatures on edge computing and 2 literatures on internet of things), 2 literatures on industrial manufacturing, 2 literatures on biometric identification, 1 literature on basic theory, 1 literature on traffic, 1 literature on cities and 1 literature on network security. The application of IC-DBD in different fields, especially in the healthcare field, has become a research hotspot in recent years.

3.2. Analysis of Core Journals

In the development of IC-DBD, journals play an important role as the main disseminators of the process of studies. The top 10 leading journals with the most published literatures in the IC-DBD field were listed in Table 2.

Table 2. The top 10 leading journals with the most published literatures.

No.	Journal Title	Number of Literatures Published	% of 2166	Impact Factor (2021)
1	IEEE Access	152	7.02	3.476
2	Computational Intelligence and Neuroscience	71	3.28	3.12
3	Sensors	49	2.26	3.847
4	Applied Sciences Basel	42	1.93	2.838
5	IEEE Transactions on Industrial Informatics	32	1.48	11.648
6	Journal of Intelligent & Fuzzy Systems	32	1.48	1.737
7	IEEE Transactions on Intelligent Transportation Systems	30	1.39	9.551
8	IEEE Internet of Things Journal	26	1.20	10.238
9	Wireless Communications & Mobile Computing	26	1.20	2.146
10	Neurocomputing	24	1.11	5.779

According to Table 2, IEEE Access and Computational Intelligence and Neuroscience are the most popular journals in the IC-DBD field, and they have the greatest number of literatures published. Among them, IEEE Access has published 152 literatures in this field, ranking first. Meanwhile, the total number of literatures published by the journals listed in Table2 reaches 484, accounting for about 22.35% of all literatures retrieved. These journals provide significant supports for research and development in the IC-DBD field.

Next, the journal citation totals [34, 35, 36] were studied, that is, the most cited journal and the journal frequently cited by the same source. The minimum number of citations of journals was set 5 in VOSviewer. Then there are 89 journals being selected. A visualization of journal co-citation network is shown in Figure 1. In Figure 1, the sizes of dots and words represent the cited times. The larger the dots and words are, the more times they are cited. It can be seen from Figure 1 that IEEE Access is cited the most times, indicating that this journal has very strong influence in the IC-DBD field. Computational Intelligence and Neuroscience with the second place in Table 2 has been cited much less often. And Sensor is in third place.

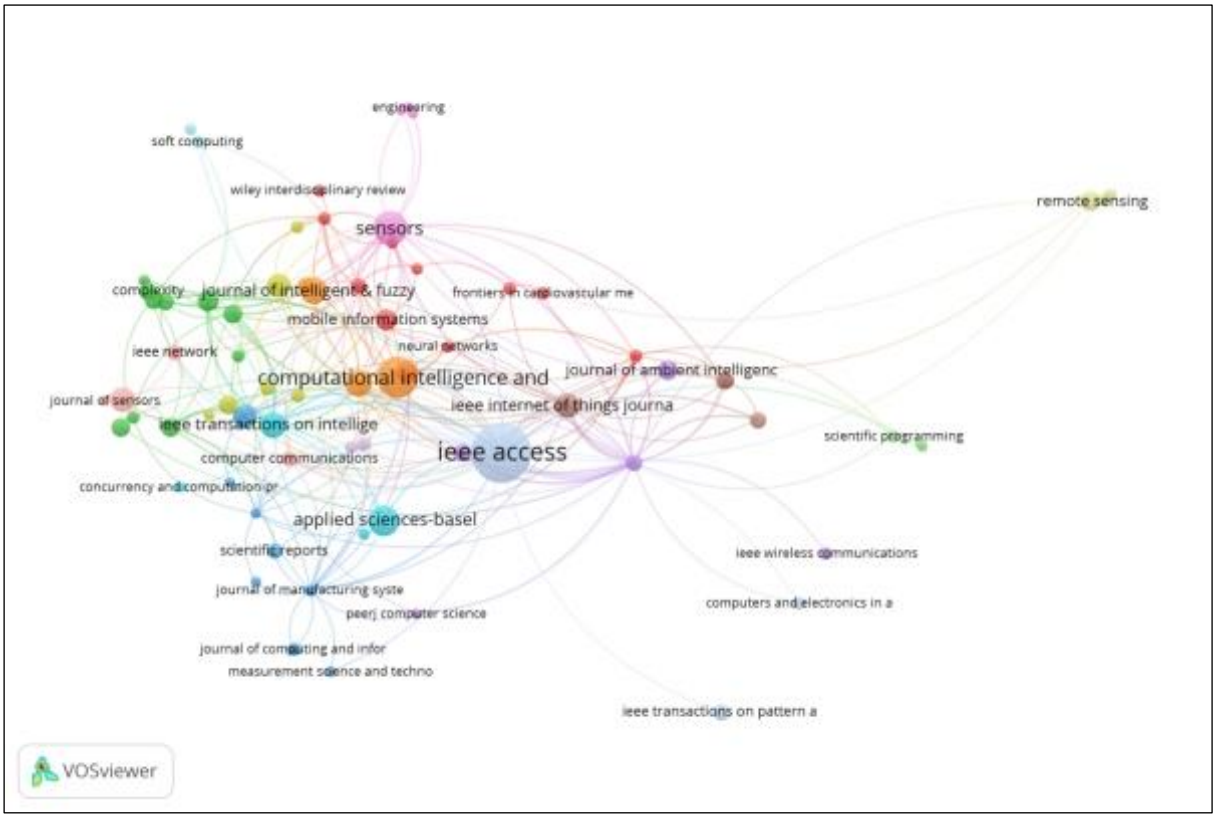

Figure 1. A visualization of journal co-citation network.

3.3. Analysis of Core Authors

The core authors are the most productive authors. They are researchers who have published many literatures in a certain research field. Studying the core authors is conducive to analyzing and finding authoritative IC-DBD experts. Price 's law in bibliometrics can be used to determine the core author in a research field [37]. Place' s law pointed out the core authors, which can be expressed as follows:

$$M = 0.749\sqrt{N_{max}} \quad (1)$$

where N_{max} is the maximum number of literatures published by the same author, and M is the minimum number of literatures published by the core authors. The authors who published more than M literatures are the core authors. As shown in Table 3, the maximum number of literatures published by the same author in the IC-DBD field is 23. Then, $M = 4$. Therefore, the authors who have published more than 4 literatures are the core authors, totaling 171. The number of literatures published by these 171 core authors accounted for nearly 50% of all published literatures.

Table 3. The top 10 authors with the most published literatures.

No.	Author Name	Number of Literatures Published
1	Y. Zhang	23
2	Y. Li	19
3	J. Liu	16
4	Mosavi	16
5	J. Wang	16
6	Y. Liu	15
7	Y. Wang	15
8	F. Al-turjman	13
9	K. Muhammad	13
10	L. Zhang	13

According to Table 3, Y. Zhang is the most productive author. However, scientometrics have done a great deal of work on how to meaningfully quantify the publication of academic results. They believe that counting the number of literatures is one way, and that counting the total number of citations is considered the other way that is more meaningful.

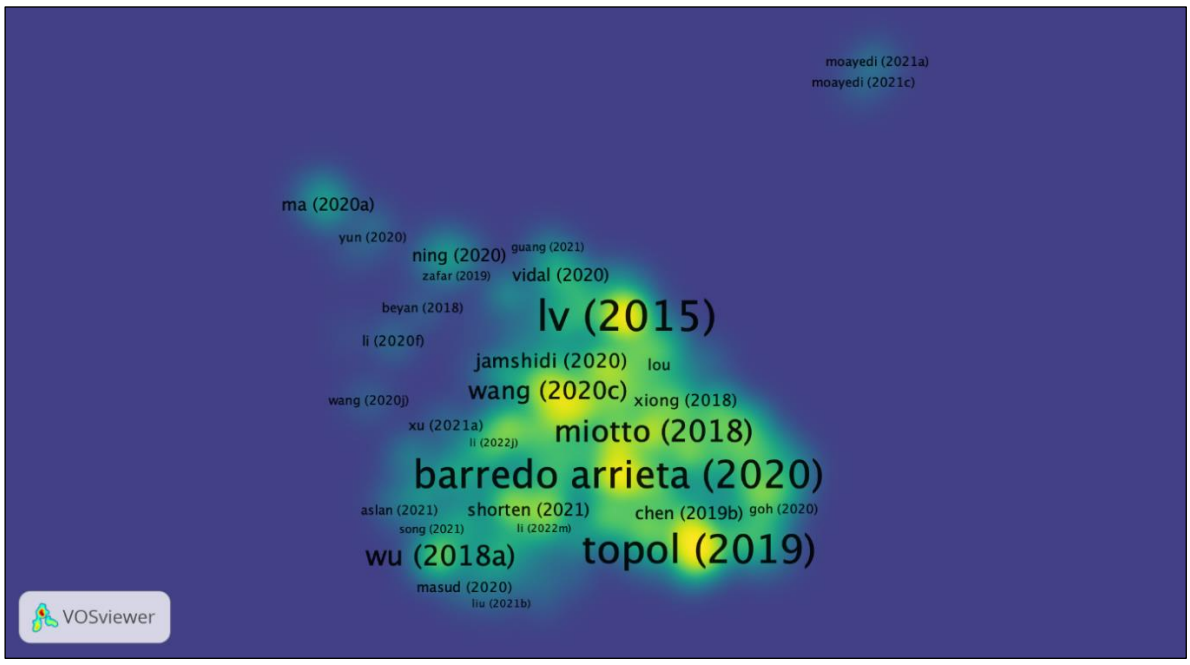

Figure 2. A visualization of authors of cited literatures.

The minimum number of citations of the literatures was set 50 in VOSviewer. Then, of the 2166 authors, 215 meet this threshold. A visualization of authors of cited literatures is shown in Figure 2. If the color is lighter and the words are larger, the author's number of citations are higher. As can be seen in Figure 2, Y. S. Lv, E. J. Topol, and A. B. Arrieta have the highest authors' number of citations. This indicates that their work is recognized by many researchers and has a strong impact in the IC-DBD field.

3.4. Analysis of the Overall Growth Trend

When downloading literatures from the WoS Core Collection database, they showed that the earliest IC-DBD literature appeared in 2004. Therefore, the data we used were from 2004 to 2022. Numbers of literatures and total numbers of citations by year are shown in Figure 3.

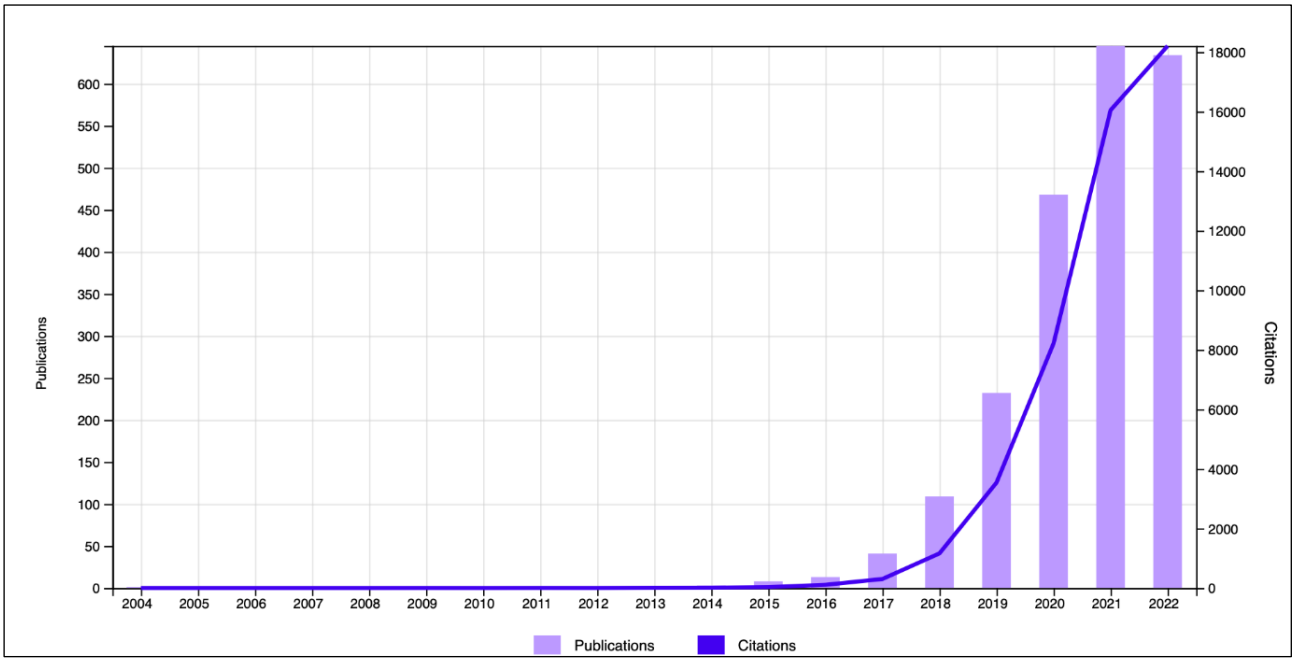

Figure 3. Numbers of literatures published and total numbers of citations by year.

As can be seen from Figure 3, numbers of literatures and total numbers of citations generally shows an upward trend in the IC-DBD field. Their growth accelerated rapidly after 2017, almost exponentially. As such, IC-DBD is in the explosion stage, and future research in this field is likely to continue for a long time.

3.5. Analysis of Main Research Institutions

From 2004 to 2022, Chinese Academy of Sciences has published 75 literatures, accounting for 3.463% of all literatures, which ranks first in the number of published literatures of IC-DBD. University of California System ranks second, with 34 published literatures. It was followed by Tsing University and Egyptian Knowledge Bank EKB. The top 10 research institutions with the most published literatures are shown in Figure 4.

As can be seen from Figure 4, there are 8 universities among the most published literatures. And Chinese research institutions are the majority, the number of Chinese research institutions is 6. The number of American research institutions is 2, and the numbers of research institutions in Egypt and Korea are both 1.

Figure 4. The top 10 research institutions with the most published literatures.

3.6. Analysis of Notable Countries/Regions

All countries have made efforts for the development of IC-DBD. A visualization of countries of cited literatures is shown in Figure 5.

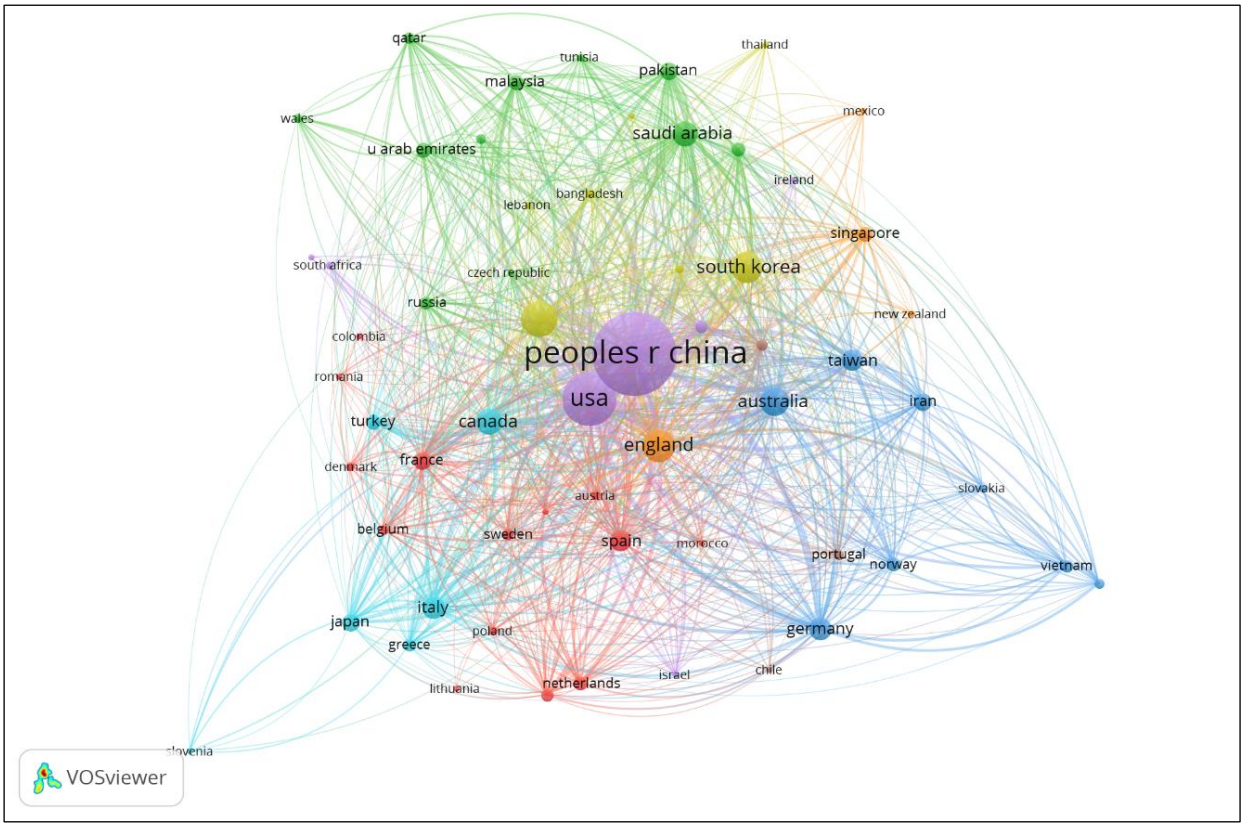

Figure 5. A visualization of countries of cited literatures.

The minimum number of citations of the literatures was set 5 in VOSviewer. Then, of the 91 countries, 60 meet this threshold. It can be seen from Figure 5 that China is the country with the highest productivity, which produced 1020 literatures in total. It is followed by USA, which produced 430 literatures. Then comes England, India, and Australia. Many literatures in the IC-DBD field have been published by these five countries, which provide a good foundation for this work. This gives these countries a leading position in research and a better opportunity and development prospect in the future application development.

3.7. Analysis of Hot Spots

Keywords are an important part of the literature, which highly condenses the content of the literature. The co-occurrence network analysis of keywords can effectively reflect the research hotspots in the subject area. The minimum number of occurrences of a keyword was set 10 in VOSviewer. Then, of the 8471 keywords, 230 meet the threshold.

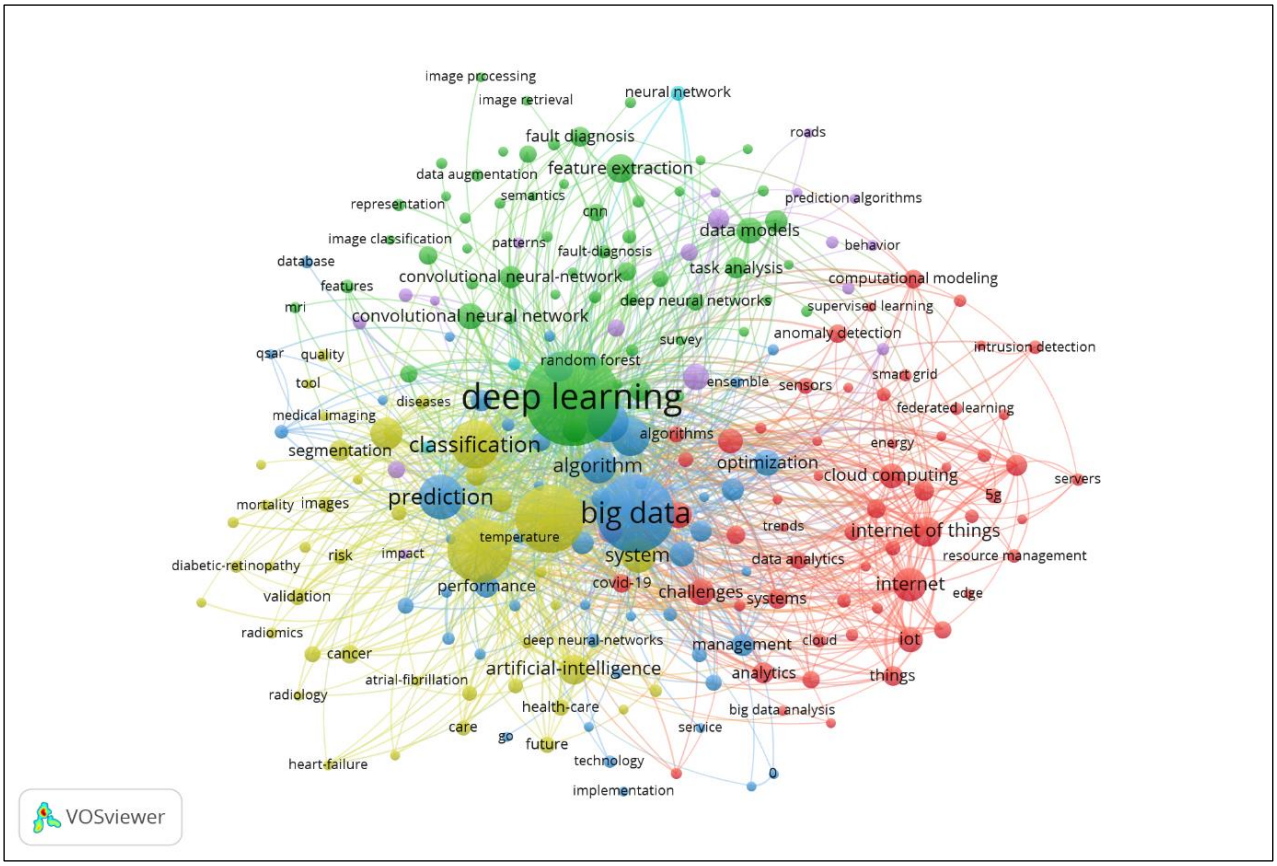

Figure 6. A visualization of keywords co-occurrence network.

After merging IC-DBD and its synonyms, four clusters of high-frequency keywords were obtained, whose nodes of the same color belong to the same cluster. A visualization of keywords co-occurrence network is shown in Figure 6.

(1) Cluster 1 is the study of Internet of things based on IC-DBD, as shown in the red node region. The high-frequency keywords in this region include internet of things, edge computing, cloud computing, 5g, sensors, etc.

(2) Cluster 2 is the study of neural network, as shown in the green node region. The high-frequency keywords

in this region include deep learning, convolutional neural network, feature extraction, data models, task analysis, etc.

(3) Cluster 3 is the study of analysis and processing of big data, as shown in the blue node region. The high-frequency keywords in this region include big data, optimization, prediction, framework, time series, model, support vector machine, artificial intelligence, etc.

(4) Cluster 4 is the study of application based on artificial intelligence, especially the study of intelligent medicine, as shown in the yellow node region. The high-frequency keywords in this region include artificial intelligence, health, cancer, personalized medicine, diagnosis, radiology, etc.

Research hotspots of IC-DBD are understood through the statistics of keywords with frequent co-occurrence. In summary, it includes four aspects: Internet of things, neural network, analysis and processing of big data and application research.

The literature keyword analysis not only clarifies the current hot spots, but also helps us predict the future development. Therefore, it can be speculated that in the future, IC-DBD will be further combined with the Internet of Things technology and promote in many fields, such as medical treatment.

4. Conclusion

Significant influential aspects of intelligent computing based on deep learning of big data literatures were studied in this paper. It can be summarized as follows: The most influential literature in the world was written by Lv et al. IEEE Access has published the most literatures. According to Price's Law, there are 171 core authors in the world, among which Y. Zhang is the most productive author. Both the numbers of literatures and the total numbers of citations generally show an upward trend. Especially after 2017, the trend is almost exponentially. Chinese Academy of Sciences has published the most literatures. Countries around the world attach great importance to intelligent computing based on deep learning of big data research, among which China and the United States are the countries with the largest number of published papers. In addition, the research hotspots mainly focus on four aspects, including Internet of things, neural network, analysis and processing of big data and application research. In the future, intelligent computing based on deep learning of big data will be further combined with the Internet of Things technology and promote in many fields, such as medical treatment.

Acknowledgements

This research was funded by the Innovation Cultivation Project (Project Name: Research on Online Behavior Security Detection Model based on Deep Learning Network).

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