Research Situation Analysis of Global 3D Printing based on Bibliometrics

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Abstract: The research on the development trend of 3D printing technology is helpful to provide useful competitive intelligence for the practical application and industrial development of 3D printing. Based on the web of Sciences core database, this paper uses the visual analysis software CiteSpace to analysis the annual number of papers, core authors, discipline layout, institutions, countries and keywords, and comprehensively reveals the research trend, research capacity and research hotspots in the field of global 3D printing from 2011 to 2020. The results show that the overall development trend of global 3D printing shows an increasing trend. The United States, China, Britain and other countries are at the leading level of technological development, and most of countries have close international cooperation relations, advanced countries are at the centre of cooperation network, bioengineering and printing materials will continue to become research hotspots.

1 INTRODUCTION

3D printing technology (3D printing), also known as additive manufacturing technology, is a technology based on the principle of layering / accumulation, using computer-aided technology, selecting appropriate materials based on digital model files, printing layer by layer according to the two-dimensional digital path of each layer, and finally superimposing to form a three-dimensional solid (Shahrubudin, Lee, Ramlan, 2019).

Compared with traditional processing and manufacturing technology, 3D printing technology is a revolutionary innovation technology in the production and manufacturing industry. It can not only save materials and improve material utilization, but also reduce time cost and meet consumer needs to a greater extent. With the rapid development of 3D printing technology, more and more kinds of materials are involved in this technology, the 3D solid structure is more complex, the accuracy is also improving. Therefore, the application scope of 3D printing technology has been further expanded. At present, the research on 3D printing technology in Europe, America and other countries is relatively mature, which is applied to aerospace, automobile manufacturing, medical treatment, industry, construction, biotechnology and other fields, and large-scale marketization has formed the corresponding industrial chain. Although the research on 3D printing technology in China started late, the great potential of 3D printing technology has been valued by a large number of researchers, and China's 3D printing technology has developed rapidly. There are many researches on the key technologies and development status of 3D printing applied in various fields at home and abroad, but there are few researches on the analysis of international 3D printing technology from the perspective of journal papers. Therefore, based on bibliometrics, this paper studies and analyzes the journal papers of international 3D printing technology from different angles, analyzes the publication of papers, author cooperation, countries, institutions and discipline distribution, especially studies the hot spots and trends of 3D

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printing technology according to the keyword co-occurrence analysis, so as to provide some basis and reference for the research work of scientific researchers.

2 MATERIALS AND METHODS

2.1 Data Collection

In this study, we took the Web of Science Sore Collection as the data source, selected advanced retrieval. The theme for retrieval was set as"3D print" or "three dimension print". The retrieval time range was set from 2011 to 2020, the language was set to “English”, the document type was set to "article". The articles retrieved from the database were exported to the local database in the format of txt. The irrelevant articles were manually eliminated, and then we merged these articles and removed duplicates. Finally, 24082 articles are determined.

2.2 Statistical Methods

Based on bibliometrics, this research made statistical analysis and visual analysis of all articles on the theme of "3D printing" from 2011 to 2020, so as to reveal the research theme, development trend and frontier in the research of 3D printing technology. Statistical analysis mainly presented the number of articles published, authors and countries. Visual analysis used the software “CiteSpace” to analysis the author cooperation, institutional cooperation, national cooperation, keyword co-occurrence and other analysis and finally formed visual maps.

3 RESULTS AND DISCUSSION

3.1 Analysis of Papers’ Annual Amount

The number of published papers within a certain time range can be used as a measure of the development trend of a field, and intuitively show the development level, development speed and activity of research in this field. Figure 1 shows the output of global 3D printing core papers from 2011 to 2020, with a total number of 24082, showing a continuous upward trend as a whole. From 2011 to 2014, the average development level of global 3D printing technology was in the embryonic stage. Although the number of papers was small, the technology received attention and developed rapidly. From 2015 to 2020, with the upsurge of research enthusiasm, global 3D printing research developed rapidly. Although the annual amount of papers growth rate decreased slightly since 2017, the number of published papers was still growing steadily. It can be seen that in the future, the steady development trend of 3D printing technology research will continue, and the technology is becoming more and more mature.

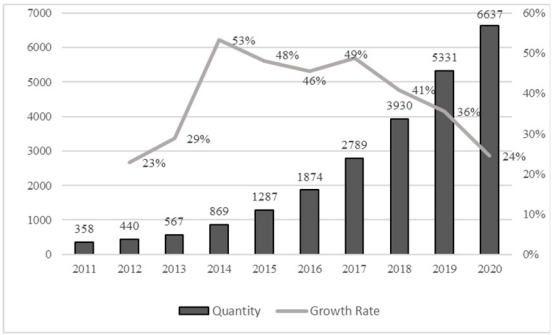

Figure 1: Number and types of papers published from 2011 to 2020.

3.2 Analysis of Discipline Layout

Table 1: WoS Categories of “3D print” research papers from 2011 to 2020.

SN	WoS Categories	Quantity	Proportion
1	Engineering	8426	34.99%
2	Materials Science	8100	33.64%
3	Chemistry	3911	16.24%
4	Science & Technology	3631	15.08%
5	Physics	3281	13.62%
6	Electrical & Electronic	3084	12.81%
7	Physics Applied	2857	11.86%
8	Computer Science	2468	10.25%
9	Nanoscience & Nanotechnology	2437	10.12%
10	Biomedical	1714	7.12%

Based on the classification of web of science, the scientific layout of papers on the research theme of "3D printing" is analyzed. Table 1 shows the top 10 disciplines in the global paper category in the field of 3D printing technology from 2011 to 2020. The two disciplines with the largest proportion are engineering and materials science, with 8426 and 8100 relevant literatures respectively, covering 34.99% and 33.64% of the papers issued in the field

of 3D printing technology, followed by Chemistry (16.24%) and science and Technology (15.08%).

3.3 Core Authors Analysis

The research on the structural network between high-yield authors in a field is helpful to understand the cooperative relationship between core authors and provide reference basis for academic exchange, international cooperation and talent introduction (White H D 2003). Figure 2 display the network map with the author as the node. The larger the node, the higher the frequency of the authors in the research field. The thicker the line, the higher the frequency of cooperation. As shown in Fig. 2 and table 2, there are 15 high-frequency authors in the field of 3D printing technology (frequency ≥ 35), including Ianzhong Fu (64) published the research on 3D bioprinting methods for the first time in 2015 (Gao, He, Fu, 2015), and the formed a strong cooperative research team with Yong He (46) and others. Dongwoo CHO (62) has been cited 902 times at most, and his team is good at physics, chemistry, bioengineering and other fields; Dichen Li (60) the paper was first published in 2013, and the highest number of citations reached 402. These high-frequency authors are basically in the center of the network, and the cooperative relationship between high-frequency authors is closer.

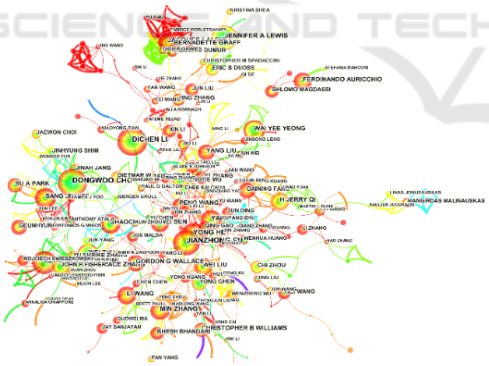

Figure 2: Author Cooperation Network Map.

Table 2: TOP 5 Key Authors.

F	Centrality	Author	Year	Highest Citations
64	0.02	IANZHONG FU	2015	285
62	0.03	DONGWOO CHO	2014	902
60	0.01	DICHEN LI	2013	402
46	0.02	YONG HE	2015	285
46	0.01	JACQUES LALEVEE	2017	75

3.4 Research Institutions Analysis

This paper took the research institution of the first author as the object to make statistics on the top 20 research institutions in the field of 3D printing technology (Table 3). In terms of the number of papers published, China's research institutions account for a large proportion. The Chinese Academy of Sciences accounts for 2.3% of the world's total number of papers. Institutions with a large number of papers published in other countries mainly include Nanyang Technological University, Massachusetts Institute of technology, Georgia Institute of technology, etc. We used CiteSpace to processes all data to form a cooperative relationship network between research institutions, as shown in Figure 3.

There is less cooperation between research institutions in China, and more tend to inter agency internal cooperation or small group cooperation. The relationship between research institutions in other countries is relatively close, with more partners and a wider range of cooperation. The cooperation centers of the research institute network mainly include Harvard University, North Polytech University, Chinese Academy of Sciences, University Western Australia, King Abdulaziz University, etc.

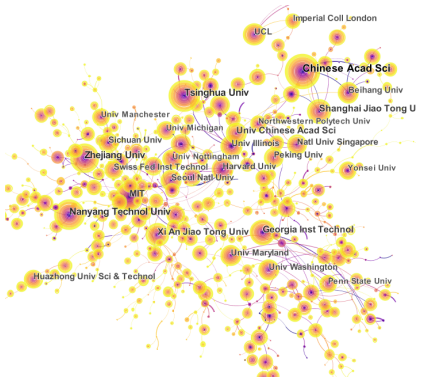

Figure 3: Institution Cooperation Network Map.

Table 3: Top 20 Research Institutions.

SN	Quantity	Institution	SN	Quantity	Institution
1	559	Chinese Academy of Sciences	11	173	University of Illinois
2	325	Tsinghua University	12	172	Huazhong University of Science and Technology
3	306	Nanyang Technological University	13	172	Harvard University
4	303	Zhejiang University	14	167	Sichuan University
5	274	Shanghai Jiao Tong University	15	163	University College London
6	243	Xi An Jiao Tong University	16	159	University of Maryland
7	240	Massachusetts Institute of Technology	17	147	Seoul National University
8	239	Georgia Institute of Technology	18	145	Beihang University
9	187	Peking University	19	145	Swiss Fed Inst Technol
10	183	National University of Singapore	20	135	Imperial College London

3.5 National Layout Analysis

Use quantitative analysis to explore the productivity and influence of relevant countries in the field of 3D printing technology. After searching and processing, 24082 papers come from 153 countries, and there are 461 cooperative relationships. Table 4 shows the top ten countries in the total number of papers issued in the field of 3D printing technology in the world, and Figure 4 shows the national cooperation network. In terms of productivity, the top three in the total number of papers issued are the United States, China and the United Kingdom. The number of papers issued by the United States and China far exceeds that of other countries, accounting for 26.82% and 23.94% of the world respectively, more than three times that of the United Kingdom and Germany. They are the main force of research in this field. In terms of influence (centrality and total number of other citations). The centrality and total number of other citations in the United States, Britain and Germany are high, which obviously has a great influence and plays a central role in the national cooperation network. China's total number of other citations is high, but its centrality is low, reflecting that China has a low global influence in the research field of 3D printing technology, tends to domestic cooperation or small group cooperation, which needs to be improved Further deepen cooperation.

Table 4: Top 10 Countries.

SN	Quantity	Centrality	Country	Year	All Citations
1	6458	0.13	USA	2011	245949
2	5765	0.02	CHINA.	2011	135517
3	1692	0.09	ENGLAND	2011	46521
4	1687	0.12	GERMANY	2011	51765
5	1581	0.04	SOUTH KOREA	2011	36287
6	1007	0.02	AUSTRALIA	2011	37510
7	951	0.12	ITALY	2011	26192
8	906	0.10	FRANCE	2011	21818
9	860	0.05	CANADA	2011	21362
10	752	0.07	JAPAN	2011	13078

3.6 Keywords Analysis

Keywords are the author's highly concentrated and summarized research content and core ideas of the article, reflecting the research direction and value of the article. High frequency keywords are often used to explore hot issues in a research field. In this paper, the word frequency statistics of keywords in the research field of 3D printing technology are carried out, and the keyword co-occurrence analysis is

carried out through CiteSpace software to generate the keyword co-occurrence map of 3D printing technology research. Keywords with high frequency at home and abroad include "3D printing", "fabric", "additional manufacturing", "design", "mechanical property", "model", "scaffold", "behavior", "composite", "system", etc. it can be seen that 3D printing technology has been widely used in manufacturing engineering, especially in aerospace (Tan, Fang 2016), biotechnology (Mao, Gu, 2018) and other fields with high requirements for mechanical properties.

Figure 4: Country Cooperation Network Map.

Figure 5: Keywords Clustering Map.

The keyword clustering map shows the main research hotspot in the research field of global 3D printing technology. As shown in Figure 5, at this stage, the research in the field of 3D printing technology is roughly summarized into 26 clustering labels. It can be seen that the research categories involved in 3D printing technology are rich and cover a wide range of fields. This paper can be roughly summarized into 3D printing technology (such as melt deposition modeling, selective laser, accuracy), 3D bioprinting (such as bone tissue engineering, cardiovascular tissue, biological cells, etc.), 3D printing materials (such as graphene, polylactic acid, carbon nanotubes), 3D printing performance (such as mechanical properties, mechanical properties, process parameters).

Table 5: Distribution of Research Hotspots in Each Stage.

Keywords	Strength	Begin-End	2011 - 2020
face recognition	43.17	2011-2015	
rapid prototyping	41.84	2011-2016	
image	25.52	2011-2014	
lithography	20.28	2011-2017	
fabrication	19.13	2011-2013	
cell	14.30	2011-2015	
nanostructure	8.82	2011-2015	
biological property	6.15	2013-2015	
tissue	14.24	2014-2016	
chemical synthesis	11.77	2014-2017	
tissue engineering	8.37	2014-2016	
biology	7.29	2014-2016	
extracellular matrix	7.45	2015-2016	
electrochemical detection	6.10	2016-2017	
fused deposition	6.02	2016-2018	
fluid	4.90	2016-2018	
marrow stromal cell	4.61	2016-2018	
transistor	5.56	2017-2018	
ultrasound	5.56	2017-2018	
gelation	3.49	2017-2018	
porous material	3.30	2017-2018	
aerogel	6.07	2018-2020	
energy harvesting	4.69	2018-2020	
polymer-matrix composites (pmcs)	4.41	2018-2020	
architected material	4.14	2018-2020	
nanomaterial	3.01	2018-2020	

Keyword emergence analysis refers to the analysis of words with high frequency of change or more times in the published literature in a research field in a certain period of time. It is often used to identify the research frontier or predict the development trend. In this paper, 26 emergent words

with high emergent value are obtained by CiteSpace software. Combined with the further analysis of emergent intensity and duration, this paper explored the frontier problems and evolution trend of 3D printing technology research. According to table 5, the development of 3D printing from 2011 to 2020 is divided into three stages. From 2011 to 2013, the research of this stage mainly focuses on 3D printing technology, including stereo lithography, rapid prototyping, image processing. From 2013 to 2018, the research focusing on bioscience, tissue engineering and other hot spots began to appear; Since 2018, 3D printing materials such as hydrogels, carbon nanotubes and polymers have become the mainstream of research.

4 CONCLUSIONS

With the help of the bibliometric analysis software CiteSpaces, this paper analyzed the articles related to 3D printing included in the web of science core collection from 2011 to 2020. This paper systematically and comprehensively expounded from the six perspectives of annual document volume, discipline layout, core authors, research institutions, national distribution and keywords, explored the hot spots and overall situation in the field of 3D printing through keyword cluster analysis and keyword emergence analysis. To sum up, in the past decade, 3D printing technology has been booming at an amazing speed, mainly used in engineering, materials and chemistry. The research countries are widely distributed and the overall international cooperation relationship is close.

The visual situation analysis of 3D printing technology research can provide reference for the development of 3D printing in China in the aspects of introducing talents, carrying out international cooperation and focusing on research hotspots. Compared with other advanced countries, the overall level of 3D printing research in China needs to be improved, which is mainly reflected in the large number of articles published in China but few highly cited articles, the degree of international cooperation is low and China is not at the center of the national cooperation network. Therefore, China needs to enhance the national strategic position of innovative technologies such as 3D printing, strengthen the R & D of key technologies, deepen international cooperation, grasp research hotspots and future trends, optimize the industrial chain, provide assistance for talent training and rapid and high-quality development of 3D printing technology, and move forward to deeper research.

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