Visualization Analysis on 3D Printing Research Based on Web of Science

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Abstract

The distribution of time, geographic regions and institutions for the published papers regarding to 3D Printing was analyzed by making use of the newly developed information visualization methods and bibliometric, and the 3649 literature records retrieved from Web of Science. By using Cite Space draw the knowledge map of authors, cited references to analyze its intellectual structure on 3D Printing. By drawing Dual-map, discuss the journals distribution of citing literature and cited literature on 3D Printing. This paper found:①United States, China, Britain and Germany have strong international influence. Engineering, materials science and other disciplines are focused on 3D printing.②The intellectual structure of 3D Printing is made up of high cited, between centrality and burst literatures. The research hotspots of this field at present mainly are tissue engineering, selective laser and advanced titanium-based alloy et al. There are significant correlations between the citations, between centrality, burst and Sigma. ③The citing journals mainly in the areas of systems, biology and medicine, while cited journals are located in areas of chemistry, materials, physics, and computers science etc.

Keywords

3D Printing; visualization; knowledge mapping; Cite Space.

1. Introduction

In 2012, the British economist pointed out that the 3D printing and other digital production mode to promote the realization of the third industrial revolution. 3D printing, also known as rapid prototyping technology, based on the digital model file, with powder metal or plastic as the material, through the continuous printing way to generate three-dimensional entity technology step by step, integrates digital modeling technology, mechanical and electrical control technology, information technology, materials science and chemistry, and many other advanced technology knowledge, has the very high technological content[1]. At present, the 3D printing technology has become an effective means of mold manufacturing, parts and plays an important role in the aerospace, biomedical research, engineering and teaching. According to statistics, in 2012, the world's 3D printing industry output value increased by 28.3% to $2.2 billion, which is expected to reach $6 billion in 2017, to $10.8 billion in 2021[2].

In recent year, domestic scholars from different angles to study 3D printing, and has obtained certain research results, Wang xueying introduced 3D printing industry development present situation and development trend at home and abroad and its technical system, on the basis of authoritative data, she thought that 3D printing technology is facing challenges in material source, cost control, precision, speed and efficiency of [1]; Wang Zhonghong expounded the significance of the development of 3D printing industry in China, and give solution to the problems existing in the development of the technology in our country [3]; Lu bing analyzed the development status of the technology of increasing material manufacturing at home and abroad, and explained the development trend and key technology [4]; Wu Feifei, with the help of literature measurement and social network analysis method, refered the author cooperation as the research object, recognized interdisciplinary teams in the field, revealed the research status and development trend of 3D printing [5], and then they set off again from

the perspectives of citation analysis, using Histcite and Pajeck software analysis the citation chronological chart and the main path, determine the research topic and development trend of 3D printing[6].Zhang Shijia elaborated library introduction of 3D printing service to innovation significance of library service, and From the main countries of 3D printing service and library types such as point of view, analyzed the current situation of the library at home and abroad to provide 3D printing services [7].

To sum up, many domestic scholars researched from the aspects of domestic and foreign development situation and the competition situation, few through visualization method of 3D printing technology research for comprehensive analysis. Therefore, this article introduced Cite Space software into the research of 3D printing technology, in the form of scientific knowledge map display of time and Space distribution in the field of 3D printing research, on behalf of the authors and works, the research hot spot, etc., made broad scholars can more intuitively understand of the current research status of 3D printing.

2. Data sources and research tools

2.1 Data sources

Based on Web of Science database literature sources, in order to guarantee a higher recall ratio, in addition to the 3D printing in the retrieval type also increase such as 3D printing, rapid prototyping, add the manufacture of synonymous words, determine the retrieval model for "TS = (" 3D print *") OR (" three - dimensional print * ") OR (" three - dimensional print * ") OR (" rapid prototype * ") OR ("additive manufact * ") OR (" digital manufact * ") OR (" intelligent manufact * ") OR (" rapid manufact * ") OR (additive"prototype" * ") OR (" rapid prototype manufact * ") ", the time span from 2000 to 2014. To document type for the Article and Proceeding paper, refined language to English, and to deal with the weight, the last received 3649 data records. This research article 3649 citations data as data sources, citations data include: title (TI), author (AU), the (AB) and references (CR), etc. In the following analysis, the setting Time of Scaling interval is 1, will be divided into 15 times from 2000 to 2014 in segmentation processing.

2.2 Research tools

This article uses the visualization software Cite Space 3.8. R7 as the analytical tool, Which is based on Java platform and developed by the Institute of information science and technology, the United States Drexel University, Dr Chen Chaomei. Cite Space can be in the scientific literature to identify and show the new trend of development of the science and the new dynamic, suitable for multiple, time sharing, dynamic analysis of the complex network. Through scientific knowledge mapping, it can show the development trend of a discipline or knowledge domain in a certain period, and formed a number of research frontier in the field of research course [8].with the help of Cite Space research strength in the field of 3D printing, disciplines distribution, representative of the author and works, research hot spots and so on, this paper make a quantitative analysis and draw the corresponding visual map.

3. 3D printing research analysis of space and time

3.1 Time distribution

One of the important indices for evaluation of a certain domain development situation is the number change of the academic papers. By drawing the distribution of literature, and carrying on the multivariate statistical analysis, it is of great significance to measure the area of the status quo and development trend. Fig. 1 shows that the study of foreign 3D printing is in a stage of rapid development, especially since 2004, 3D printing number continued to rise, and reached 838 in 2014, it shows that 3D printing technology has become the industry research hot spot and will continue to get attention.

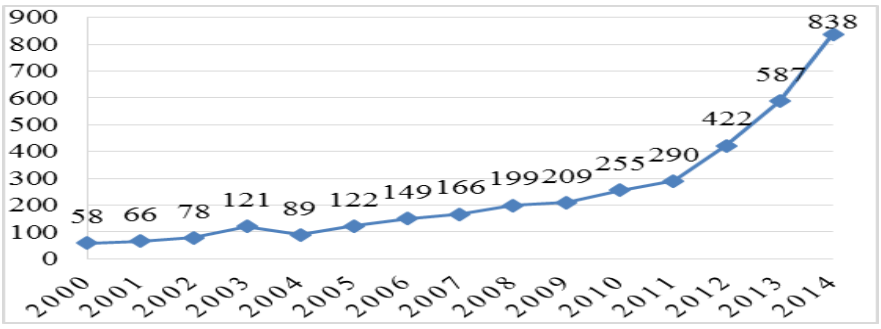

Fig. 1 3D printing literature in number

3.2 National (regional) and institutional distribution

Research on 3D printing in the field of country (region) and the study organization network analysis can learn about countries and research organizations' research strength, cooperation in the field, and so on. In Cite Space III interface, network nodes select "institution" and "country", and the threshold value is (2, 2, 20), (3, 3, 20) and (4, 3, 20).extract object is TOP50, then get a 275 nodes and 298 nation mixed with agency network, as shown in figure 2, table 1 lists the network part of the country (region) and institutions.

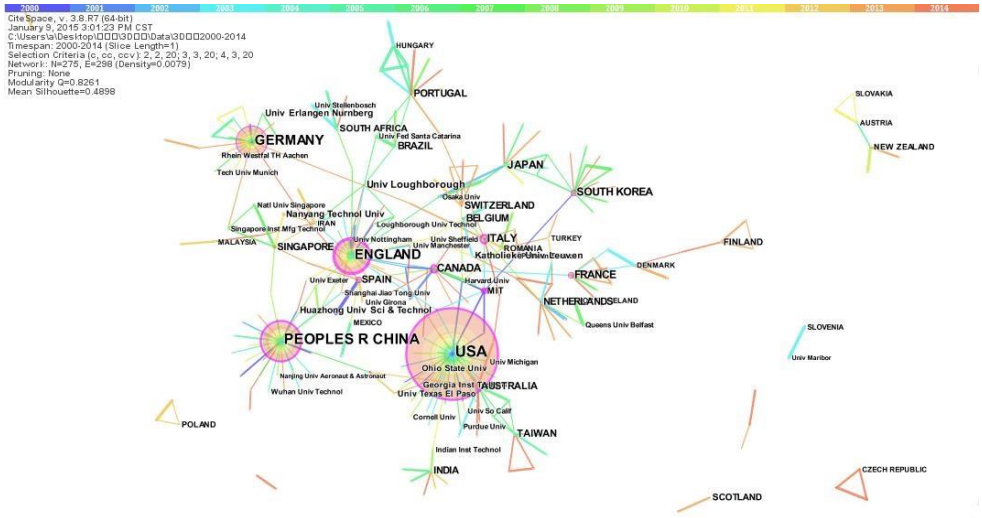

Fig. 2 Atlas of national (regional) and institution

Table 1 3D printing field research strength statistics

country (region)	Frequency	middle Central	Sudden increment	institution	Frequency	middle Central	Sudden increment
U.S.A	892	0.37	4.40	Loughborough University	80	0.09	6.32
China	429	0.24	3.80	Nanyang Technology University	49	0.00	0
Britain	356	0.47	3.17	Huazhong University of Science andTechnology	49	0.00	3.41
Germany	341	0.17	0	Massachusetts Institute of Technology	44	0.50	12.12
Italy	98	0.24	0	Katholieke	43	0.01	0

				Universiteit LEUVEN			
France	97	0.13	0	University of Erlangen Nurnberg	38	0.00	0
Japan	96	0.07	6.71	University of Texas	32	0.08	5.72
Canada	95	0.40	4.85	Georgia Institute of Technology	31	0.00	0
korea	93	0.14	6.19	Ohio State University	30	0.00	0
Spain	86	0.14	0	University of Manchester	22	0.00	0

Fig. 2 shows that the 3D printing research in the field of countries (regions) and institutions of cooperation and communication is a universal phenomenon, of which the United States, China, Britain and Germany as in the network core node, cooperate closely with other countries and institutional. Combined with table 1, the United States is the largest contribution to the literature from the frequency of the document, far higher than other countries. China issued in the second place, but the number is less than 1/2 in the United States, the gap with the United States also is very big .Britain and Germany issued a level equivalent, respectively, in the third and fourth. The documents of the four countries accounted for 55.30% of the total amount of literature, which indicates that the research in the field of 3D printing is mainly concentrated in the United States and other countries. From the middle centricity, Britain's greatest centrality, indicate that the network in most of the countries are directly or indirectly with cooperative relationship, such as China, Spain, Singapore, Canada, the United States, China and other centricity are on top. From the point of view of the sudden increase in the document, Japan is 6.71, is the largest value-added nodes throughout the network, it shows that the amount of the document has a greater breakthrough. China's value-added is 3.80, indicating that the amount of the same there is a relatively large breakthrough . Loughborough University, Massachusetts Institute of Technology, Huazhong University of Science and Technology, Singapore's Nanyang Technology University, University of Erlangen Nurnberg, are important research institutions in the field of 3D printing.

3.3 Distribution of subject areas

Related study involved 124 subjects, figure 3 (A) shows the data of 50 or more disciplines, including engineering field in 2699 paper number well ahead of other subjects, followed by materials science (1269) and computer science (550). The results show that the 3D printing technology get greater attention in engineering, materials science, computer science and other fields. Figure 3 (B) shows that there are 14 subjects have a sudden increase in the value of the subject in 124 disciplines, namely the subject of recent changes larger in the field of 3D printing document. In 2000-2014 interval in blue line, the red line indicates a post jump phenomenon in this period. Automatic control systems in 2000-2009 has the biggest jump phenomenon, its value is 16.4681, followed by robotics (12.4504), operations research and management science(12.2102). It is worth noting that in communications (9.3045), interdisciplinary (5.3111), ecological environmental science (4.9908) and biochemical studies (3.4844) have stronger exploding since 2013, and continued until 2014Can be found that 3D printing study showed a significant interdisciplinary and integration features.

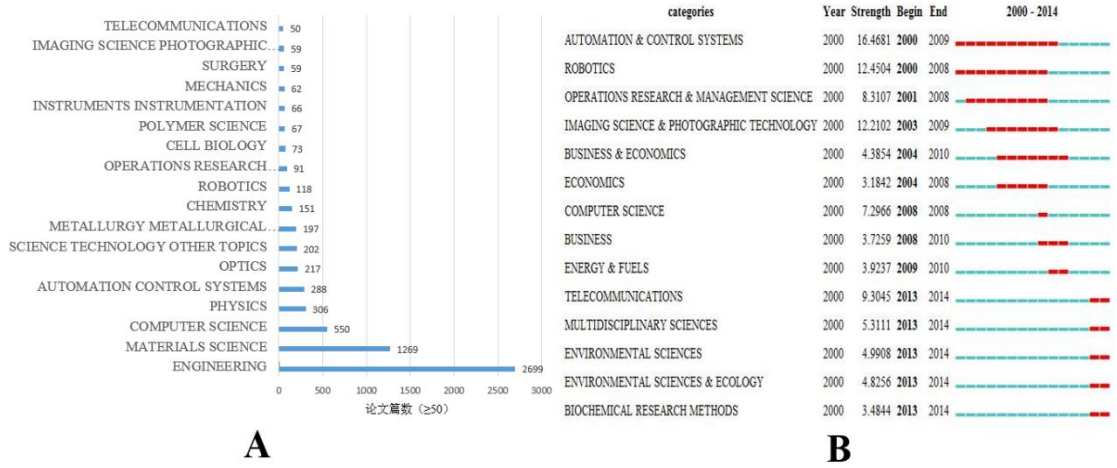

Fig. 3 3D print subject area distribution

4. Knowledge structure analysis

Using Space III 3D to draw the Cite printing field literature co citation network map, The knowledge structure in the field can be directly displayed through the analysis of the core literature and the key literature in the field of citation frequency and central height identification. Analysis of knowledge structure has immeasurable effect to refer to the forefront of research in this area and maintain its steady development[11]. Node type choose cited literature, threshold respectively (5,4,20), (5,5,20) and (5,5,20), extract object for the Top 30, and take the critical path algorithm, Finally get a literature cited network composed of 291 nodes and 291 edge as shown in figure 4. In figure 4, clustering tags (blue letters) using spectral clustering and LLR (Log likelihood thewire) algorithm, Red nodes indicates a sudden appreciation of cited literature 3.1 cluster analysis.

4.1 Clustering analysis

The average year of the cluster shows the new or old degree of the cluster, #9 (1988) is the oldest average year, suggests that the study of the clustering is the most mature. #8 (2009) and # 1 (2005) relatively new, is a hot spot in the current study. The more the class contains the nodes, the more representative it is #0 and #1 two of the largest cluster, including 38 and 36 nodes respectively. Higher clustering Silhouette value indicates that the stronger the internal consistency of the cluster, the more the better clustering effect. #7 (0.954) and #8 (0.966) two clustering effect is best, are strongly linked to internal.

The core node of the #0 (tissue engineering) is a 3D printing technology in tissue engineering applications of important documents, especially written by Seitz h et al. Three dimensional printing of porous ceramic scaffolds for bone tissue engineering and Hollister SJ: the porous scaffold design for tissue engineering. Seitz H in the paper thought that the rapid prototyping technology, in particular, 3D printing technology is very suitable for the generation of complex porous ceramic materials from the powder material. Then the paper introduces a new process chain, which is based on the above two technologies can produce custom 3D porous ceramics bone, and confirmed that the production of ceramic bone is effective and can be applied to practice.

#2（advanced titanium-based alloy）is made up of the important literatures about Ti based alloys research in 3D printing. In the clustering, the highest cited frequency and sudden appreciation is the “Three dimensional printing, rapid tooling and as directly from a CAD model”, written by Sachs E in 1992. the paper think that 3D printing technology is based on computer models, using adhesive materials such as metal or plastic, through the way of step by step a print to construct physical process. Sachs E and others by using this technology, alumina as the material, colloidal silicon dioxide as

adhesive, print out a 50 layers, each layer of 0.005 inches of three-dimensional ceramic parts [13]. Sudden appreciation in second place is Katstra WE published in 2000-Oral dosage forms fabricated by Three Dimensional Printing ™, 3D Printing is discussed in the paper what is a new type can be used in the manufacture of Oral drug technology, it can be designed with complex internal structure, different density and diffusion coefficient, and a variety of active medicines, experiments show that using this technology manufacture drug samples effect is similar to the traditional methods of drug [14].

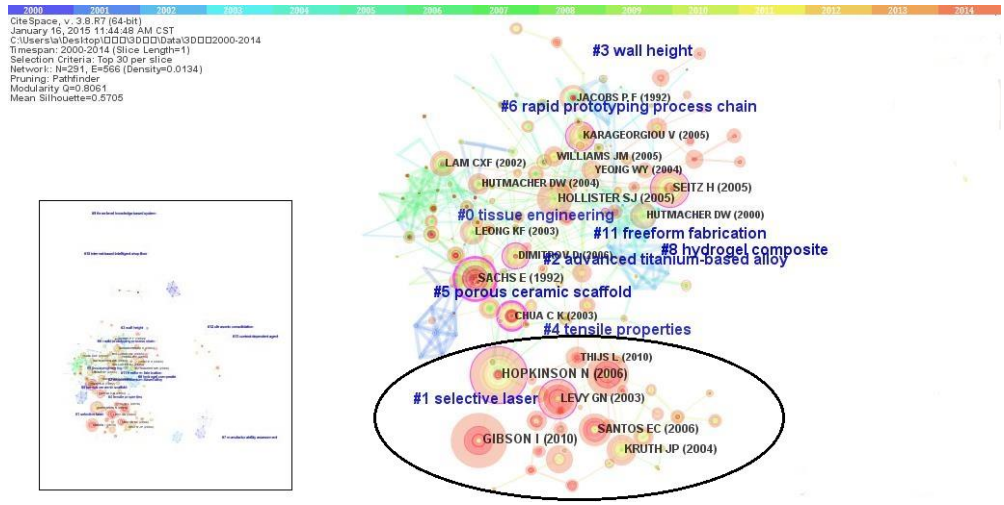

Fig. 4 Co-citation clustering map

Table 2 Cited literature clustering table (part)

Cluster ID	Size	Silhouette	Average year	Lable by LLR	Representative Author
0	38	0.766	2004	tissue engineering	Chua CK
1	36	0.874	2005	selective laser	Gu DD
2	27	0.895	1997	advanced titanium-based alloy	Hong SB
3	26	0.909	1991	wall height	Pinkerton AJ
4	21	0.820	2002	tensile properties	Goodridge RD
5	21	0.935	2000	porous ceramic scaffold	Seitz H
6	17	0.870	1997	rapid prototyping process chain	Knitter R
7	12	0.954	1992	manufacturability assessment	ShiauJY
8	9	0.966	2009	hydrogel composite	Bakarich SE
9	9	0.899	1988	three-level knowledge-based system	Castillo L

#1 and #8 is the relatively new research hotspot, because the #8 contains fewer nodes, so no longer detailed analysis. Nodes #1 contains the most citations spurted (red), analysis to understand the latest 3D printing technology development is of great significance. Table 4 lists the top 10 citation rates and 10 references cited literature in #1. Consolidation phenomena in laser and powder - bed -based layered manufacturing, written by Kruth JP in 2007, is cited frequency and the highest value. In this paper, it think that selective laser sintering/melting (SLS/SLM, selective laser sintering/melting) in layered manufacturing (LM, layered manufacturing) technology plays an important role, combined with solid phase sintering, the liquid phase sintering, partial melting mechanism, SLS (SLM) can make metal, ceramic and other materials into composite materials. The use of SLS (SLM) process manufacturing composites, JP Kruth think that liquid phase sintering matrix can promote SLS processing, and the combination of different materials can get the performance that single material

can not be achieved. JP Kruth finally pointed out that the layered manufacturing technology only to constantly adjust the manufacturing process and expand the source of the material can be extended to its applicability [15]. Cited frequency in second place is Rapid manufacturing and Rapid tooling with layer manufacturing (LM) technologies, the state of the art and future perspectives, published by the Levy GN in 2003, Levy GN make a clear definition for rapid manufacturing and rapid tooling, and based on this, advances layered manufacturing and Process oriented metal parts manufacturing technology classification [16]. Published in 2004 by Kruth, JP Selective laser melting of iron - -based powder is cited in third place, he think the SLS technology can handle any type of material, is an ideal method to produce high density metal parts, but SLM technology can produce nearly 100% density, mechanical properties and forging process components. its material sources is wide, such as single metal powder, metal ceramics powder, etc., the manufacturing process is not limited by complex structure parts, and the manufacturing process is simple. Compared to SLS, SLM technology is difficult to control because of the need to provide greater energy, the complete melting of metal powder and residual stress. Finally, through the experiment this paper describes the importance of using SLM method to obtain 100% density metal parts process parameter setting, and considered that the faster scanning speed is helpful to reduce the spheroidzing to get smooth surface forming [17].

#1 contains 36 cited papers, 10 cited papers of the table 3 published in 2010, and they cited references of 68%-95% in #1. Selective laser melting W-10 wt.% Cu composite powders ,written by Li RUID et al, is the most widely citing literature (95%) that cite reference in #1 , The author creatively introduces the selective laser sintering technology to the manufacturing technology of W-Cu alloy parts., and determine the remake stage of w particles and liquid phase sintering matrix of powder system through experimental study[18]. Other papers have also studied the selective laser technology, which has promoted the development of 3D printing technology to the selective laser.

Table 3 #1 cited literature and citing literature statistics

Cluster #1 selective laser			
Cited references		Citing references	
Cites	Author(Year) Journal, Volume, Page	Coverage	Author(Year) Title
73	Kruth JP(2007) CIRP ANN-MANUF TECHN, V56, P730	95%	Li Ruidi(2010)**selective laser** melting w-10wt.% cu composite powders
63	Levy GN(2003) CIRP ANN-MANUF TECHN, V52, P589	90%	Yadroitsev I(2010) **selective laser** melting technology: from the single selective laser
56	Kruth JP(2004)J MATER PROCESS TECH, V149, P616	88%	Gu Dongdong(2010) hardmetals prepared by **selective laser** melting
55	Santos EC(2006) INT J MACH TOOL MANU, V46, P1459	87%	Yadroitsev I(2010) single track formation in **selective laser** melting of metal powders
45	Chua CK(2010)[Book]	83%	Laoui, Tahar (2010) develop a rapid manufacturing knowledge-based environment
38	Thijs L(2010) ACTA MATER, V58, P3303	80%	Chua, CK (2010) l approach on temperature variation in **selective laser** melting
35	Murr LE(2009)J MECH BEHAV BIOMED,V2,P20	76%	Facchini, Luca (2010) ductility of a ti-6al-4v alloy produced by **selective laser** melting
34	Yadroitsev I(2007) APPL SURF SCI,V253,P8064	73%	Ghosh, Subrata Kumar (2010) influence of size and volume fraction of sic particulates
33	Kruth JP(2005) RAPID PROTOTYPING J,V11,P26	73%	Kerninon, J. (2010) global approach to design and manufacture direct parts
29	Simchi A(2003)MAT SCI ENG A-STRUCT,V359,P119	68%	Li, Ruidi. (2010) RM 90w-7ni-3fe parts via **selective laser** melting

Table 4 High centrality degree literature statistic

B-Centrality	References	Cluster
0.24	Sachs E,1992, J ENG IND-T ASME, V114, P481	# 2
0.22	Chua CK,2003 [Book]	# 0
0.16	Seitz H,2005, J BIOMED MATER RES B, V74B, P782	# 0
0.15	Hopkinson N, 2006 [Book]	# 4
0.15	Dimitrov D,2006, RAPID PROTOTYPING J, V12, P136	# 2
0.13	Karageorgiou V,2005, BIOMATERIALS, V26, P5474	# 0
0.12	Hofmeister W, 2001,JOM-J MIN MET MAT S, V53, P30	# 3
0.11	Levy GN, 2003,CIRP ANN-MANUF TECHN, V52, P589	# 1
0.10	Kruth JP, 2007,CIRP ANN-MANUF TECHN, V56, P730	# 1
0.10	Lewis GK, 2000,MATER DESIGN, V21, P417	# 3

4.2 Intermediate center analysis

Intermediate centrality is a index to measure of the importance of nodes in the network, as the "bridge" between different sub networks, which usually indicates the emergence of new research trends [19]. Table 5 lists the ten important pieces of literature that Intermediate centrality is more than or equal to 0.10, the importance of these literature lies not only to connect different nodes, but also to link different Subject groups. In the ten papers, three papers belong to #0, #1, #2, and #3 each have two, #4 only has one, these documents is the important literature to make #0 and #1 development for the popular research branch. In the Hopkinson n, Hague R, who co -authored the rapid manufacturing: an industrial revolution for the digital age, defined rapid manufacturing that: on the basis of computer aided design (CAD), through the accumulation of the automatic manufacturing process, construct can directly use the final products or components, is to disperse / deposition manufacturing mode to realize the reproduction of three-dimensional computer aided design data. The book gives a detailed and comprehensive introduction to the emerging rapid manufacturing technology, provides a wealth of theoretical knowledge for product design, materials science, other manufacturing industry practitioners and related researchers [20]

Table 5 High cited literature statistics

Frequency	References	Cluster
92	Hopkinson N, 2006, John Wiley & Sons[Book]	# 4
92	Gibson I,2010, [Book]	# 4
73	Sachs E,1992, J ENG IND-T ASME, V114, P481	# 2
73	Kruth JP,2007, CIRP ANN-MANUF TECHN, V56, P730	# 1
63	Levy GN,2003, CIRP ANN-MANUF TECHN, V52, P589	# 1
62	Seitz H,2005, J BIOMED MATER RES B, V74B, P782	# 0
60	Hollister SJ,2005, NAT MATER, V4, P518	# 0
56	Kruth JP,2004, J MATER PROCESS TECH, V149, P616	# 1
55	Santos EC,2006, INT J MACH TOOL MANU, V46, P1459	# 1
51	Karageorgiou V,2005, BIOMATERIALS, V26, P5474	# 0

4.3 Citation frequency analysis

The core literature with high citation frequency is often used because of its theory or method innovation. In the 10 high cited papers in Table 6, #1 contains four, #0 contains 3, #4 and #2, respectively, two and one. This also shows that #1 is one of the hot spots of research. Hopkinson N

(2006) and Gibson I (2010) tied for first with cited 92 times, followed by the Sachs E(1992) and Kruth JP (2007) with cited 72 times, fifth to six of the tenth papers belonging to #0 and #1. Ten articles, in addition to the Sachs E (1992), the remaining nine were all published in 2003, suggesting that they have an important role in promoting the development of 3D printing technology to the field of tissue engineering and selective laser.. Gibson I published a book additive manufacturing technologies, in which summarized manufacturing (AM, additive manufacturing) process into the following eight steps: Computer Aided Design (CAD), go to the STL (standard tessellation language), go to the AM machine and the STL file processing, set machinery, construction, remove, post processing, application, it Provides effective guidance for subsequent practical applications [21]

4.4 Citation burst analysis

There are two aspects in the process of citation burst: the intensity of the citation burst and the duration of the citation. Table 6 listed 10 highest value-added articles between 2000 and 2014, three paper in #8, #1 and #2 are 2, #3, #4and#5 are one. It is worth noting that the three papers in #8 are published in 2012, indicating that #8 received a more prominent concern in recent years, and may become an important research area in 3D printing technology in the future. In addition, #2, #3, #4 and #5 ,that have the phenomenon of citation burst ,are also not ruled out the possibility of becoming hot research in the future.

Table 6 High burst value literature Statistics

Burst	References	Cluster
13.53	Sachs E,1992, J ENG IND-T ASME, V114, P481	# 2
13.45	Gibson I,2010, [Book]	# 4
9.25	Symes MD,2012, NAT CHEM, V4, P349	# 8
8.33	Kitson PJ,2012, LAB CHIP, V12, P3267	# 8
6.76	Wu BM,1996, J CONTROL RELEASE, V40, P77	# 5
6.72	Melchels FPW,2012, PROG POLYM SCI, V37, P1079	# 8
6.4	Vrancken B,2012, J ALLOY COMPD, V541, P177	# 1
6.39	Mazumder J,1997, JOM-J MIN MET MAT S, V49, P55	# 3
6.38	Levy GN, 2003,CIRP ANN-MANUF TECHN, V52, P589	# 1
6.16	Katstra WE, 2000, J CONTROL RELEASE, V66, P1	# 2

4.5 Sigma value analysis

Sigma value is used to measure the intermediate center of the node and the index of citation spurt, if a citation in the middle of the center and the sudden increase in value is very large, it must have a higher Sigma value. In 291 citation node, Sachs E (1992) of Sigma value 17.8 row in the first place, indicating that he play an irreplaceable role in the network structure and the citation process increased; in second place is the book written by Chua CK et al in 2003, rapid prototyping: principles and applications, The book published in 1997, and has been reprinted many times so far, the book detailed introduce the rapid prototyping development process, different types of manufacturing systems and a variety of manufacturing technology content [22]

Table 7 Correlation analysis of cited frequency, middle degree of centrality, sudden increment of value and Sigma

index		Frequency	Burst	B-Centrality	Sigma
Frequency	correlation coefficient	1.000	0.467**	0.506**	0.394**
	Sig.（bilateral）	.	0.000	0.000	0.000
Burst	correlation	0.467**	1.000	0.220**	0.679**

	coefficient				
	Sig. (bilateral)	0.000	.	0.000	0.000
B-Centrality	correlation coefficient	0.506**	0.220**	1.000	0.567**
	Sig. (bilateral)	0.000	0.000	. 0.000	0.000
Sigma	correlation coefficient	0.394**	0.679**	0.567**	1.000
	Sig. (bilateral)	0.000	0.000	0.000	.
**. Correlation was significant at 0.01 of confidence (bilateral)					

4.6 Correlation analysis

What is the relationship between betweenness, citation frequency, citation spurt, and Sigma in co-citation literature? For this, This paper uses SPSS to carry on the Spearman correlation analysis, the result as shown in table 7. As you can see, between the four sig was less than 0.01, shows that between them there is correlation: ①citation frequency and betweenness centrality degree of correlation as high as 0.506, indicating that cited frequency of higher literature plays an important role in connecting different nodes or sub networks in the network. ②The correlation coefficient between the quotation and the Sigma value is 0.679, higher than the correlation between the frequency (0.467) and the betweenness centrality (0.220), which indicates that the higher value of the node is more likely to produce high Sigma value. ③The correlation coefficient between the betweenness centrality and the Sigma value is as higher, as 0.567, which indicates that the high Sigma value of the nodes always with its high betweenness centrality.

5. Dual-map overlays analysis

Overlays Dual-map is a new method to reveal the relationship between journals and the trend of movement. The map of the Dual-map is divided into left and right two subgraphs, left as citing and right as cited literature periodicals, according the Subject similarity to cluster, and identify in different colors. The 10000 periodical source of Dual-map is the 2011 periodical citation report published by Thomsen Reuters.. The curve between the two figure is left to right, and distinguished by different colors[23-24].

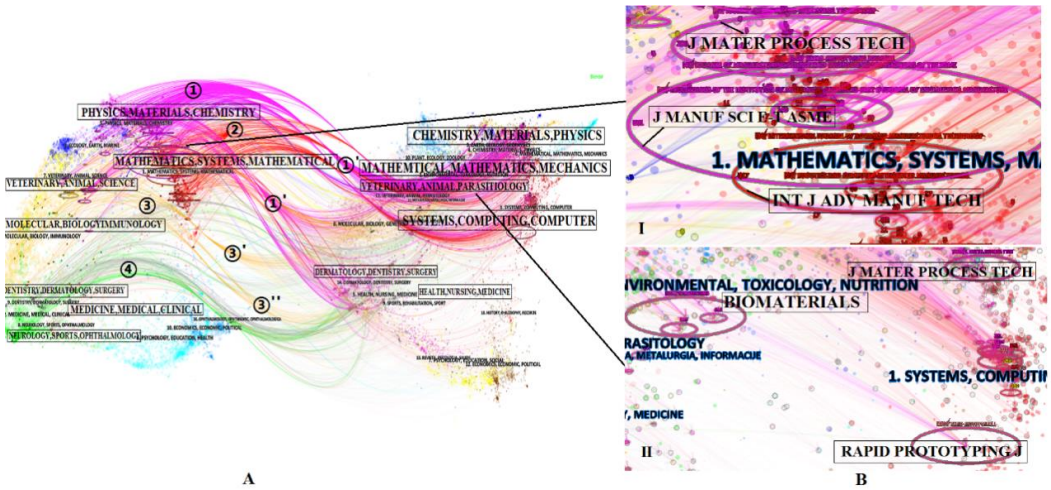

Fig. 5 3D print research area Dual-map overlays

it can be seen from figure 5 (a) that citing literature periodicals in the field of 3D printing are mainly distributed in the following areas: (1) physics / Materials Science / chemistry With red logo; (2) mathematics/systematics with red logo; (3) molecular / Biology / immunology field with yellow markings; (4) medical field with green and grey identification, such as: dentistry, dermatology, surgery, and other. From the four areas of reference curve point to the right of the periodical reference

group: the purple reference curve is divided into two streams (curve①', ①'), shows that citing journals of physics, materials science and chemistry is mainly comes from chemical / Materials Science / Physics/systematics / computing and medical area; red reference curve refers to chemical / Materials Science / Physics and systematics / computer science and other fields; yellow curve also divided into two data flow (curve③', ③) ', pointing to the medicine and Molecular Science / Biology / genetics; green and gray curve is pointing to the medical field.

Figure 5(B) shows the number more journals(figure I) and papers cited rate higher journals (figure II) In figure I, J MANUF SCI E - T ASME, INT J ADV MANUF TECH and J MATER PROCESS TECH aperture area is larger, indicating that these three journals are published more journals in the field of 3D printing, respectively, 501, 317, 285. In figure II, BIOMATERIALS, RAPID PROTOTYPING and J J MATER PROCESS TECH , the three journals are cited higher, followed by 2026 times, 1839 times, 1261 times, indicating that these journals are more focus on 3D printing technology. the above analysis again shows that the 3D printing is an interdisciplinary and multi-disciplinary research field.

6. Conclusion

With the help of CiteSpace software, this paper makes visual analysis to the 3D printing research collection in Web of Science database. Through the above analysis, the following conclusions are drawn:

First, Under the international field of vision, the research of 3D printing field shows the growth trend in general, and will continue to be received extensive attention of scholars; The United States, China, Britain and Germany has strong influence in the field, loughborough university, Massachusetts institute of technology, huazhong university of science and technology, are the important research institutions in the field of 3D printing; Engineering, materials science, computer science are the major concern discipline in 3D printing.

Second, through the literature and literature co-citation clustering analysis, get that the knowledge structure of the field of 3D printing is composed of a group of highly cited, high centrality, high value-added literature, this group includes literature “Rapid manufacturing: an industrial revolution for the digital age” written by Hopkinson N, and “Three dimensional printing: rapid tooling and prototypes directly from a CAD model” ,which is written by Sachs E.; by means of CiteSpace spectral clustering, it is concluded multiple research hotspots: tissue engineering , selective laser, Ti based alloy and so on.; By means of correlation analysis, we can find that there is a significant correlation between citation frequency, intermediate center, sudden increment and Sigma value.

Third, by Dual-map overlays in CiteSpace software, it can be found that in the field of 3D printing citing literature periodicals have math, systematics, molecular, biology, immunity and medical field. the cited literature periodicals mainly distribute in chemical, Materials ,Physics, systematics and computer science and medical area. J, MANUF, SCI, E-T and ASME Journal published more papers and BIOMATERIALS and other journals were cited higher.

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