Visualization Analysis of the Research on Knowledge Network in Industrial Clusters Based on CiteSpace

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***Abstract* — This paper choosed the documents on subject of knowledge network of industrial cluster included in Web of Science from 2004 to 2014 as object of research and used an information visualization analysis software CiteSpace to make visual analysis of data information in this field. Then it introduced some key indicators of knowledge map, such as frequency, centrality of knot points, burst term and so on to show the distribution of main research countries and institutions, research hotspots and research fronts in different periods.**

Keywords - Industrial cluster; Knowledge network; CiteSpace; Information visualization

I. INTRODUCTION

With the development of economy, modern society is shifting from resource economy to knowledge-based economy, and knowledge has become an important strategic resource for enterprises. In order to grasp the competitive advantage, enterprises not only need to integrate internal resources, but also make knowledge integration and innovation between different enterprises under the complex external environment.

National Science Foundation（NSF, United States of America）has made a definition of knowledge network: knowledge network is the condensates composed of academic experts, information and knowledge to analyze specific issues. Besides, knowledge network focused on integration of knowledge across time and space, the elements of which include hardware, software, people and process. On the other hand, Chinese scholars hold different views on knowledge network: Zhao Rongying believes that knowledge network is a system composed of knowledge node and chain, where knowledge node represents "knowledge element, point, unit and base", and knowledge chain represents the "edge" and "chain" of knowledge. Ma Dehui and Bao Changhuo deem knowledge network to be a kind of network in which members share the knowledge resources with different enterprises in social network, which aims at knowledge innovation and its essence is to dig the valuable tacit knowledge resources in people's mind through social network. Although starting points and definitions are distinct, the scholars' purposes are extremely similar, that's to acquire, share innovate knowledge.

Driven by economic globalization and integration, enterprises are no longer seeking independent development, but increasingly turning to enterprise alliance and clusters for competing on integral strength. Based on demand of economic globalization and market diversification, geographical connection and industrial correlation have become the main performance modes of industrial clusters, also an important topic concerned by scholars in different fields. As production specialization and product complexity increase, the demand for knowledge is inflating in enterprises. In order to maintain the competitive advantage, organizations in cluster shall reinforce collaboration with each other to learn others' superior knowledge through collaborative research, technical training, technological licensing and employee turnover. Under this condition, the different organizational units in cluster, all types of knowledge, the flow relations of knowledge in different elements and the rules embedded in the systems constitute a knowledge network of enterprise cluster. Therefore, knowledge network of enterprises cluster is critical to the survival and development of enterprises.

At present, the study of knowledge network in industrial cluster still remains in theoretical level, but seldom do scholars take scientific metrological methods to analyze research status and future development trends in the field. In order to visually display the development process of this field, this paper made a visual analysis based on CiteSpace, then study the distribution of countries (regions) and institutions, identify current research hotspots and future trends, so as to provide a valuable reference for the study of this field.

II. DATA SOURCES AND RESEARCH METHODS

In the information meteorology, citation analysis is an important index. With it, researchers can evaluate the research ability of countries, regions and institutions, as well as personal research ability, quality of journal and achievements in different fields. This paper choose Web of

Science (including SCI-EXPANDED,SSCI,CPCI-S and CPCI-SSH) as date-base, took "key word"="knowledge network" AND "key word"="industrial cluster" OR "key word"="enterprises cluster" as retrieval type, allowed literature type to be "Article" with time interval of 2004-2014 and eventually obtained 558 literature records totally.

With the help of information visualization software CiteSpace developed by Chen Chaomei team, this paper drew the knowledge map of knowledge network in industrial cluster by methods of quantitative analysis, which visually show the research hotspots and advanced field. Based on frequency and centrality, the author firstly determined the distribution of countries and institutions and then the research hotpots, and finally defined the frontier of this field based on cited literature and burst term.

III. RESULTS AND ANALYSIS

A. Distribution of Countries (Regions)

Through CiteSpace we can get the distribution of countries (regions). In CiteSpace software interface, we selected 2004 - 2014 in "time span", resulting in 11 periods. Then we chose "Title", "Abstract" and "Keywords" in option "Term source" and "country" in options "Node types". At last, it's necessary to set all threshold values to (2,2,20), and let other options keep their default selection. After running the CiteSpace software, we got the knowledge map of distribution of countries (regions).

Fig.1 Distribution of Countries (Regions)

In Fig.(1), the size of circle indicates the quantity of literatures. The bigger the circle is, the higher the frequency is, and the lager its contributions are.The color of annual ring indicates citation time; the deeper the color of most periphery ring is, the closer the time is. It can be seen from the table I that, USA leads the world's top place for research capability in this field with frequency of literature of 99; China ranks second in the world with frequency of literature of 71. Apart from this, some other countries (regions) like England, Spain, Taiwan, Italy, Germany, Australia, Canada and Netherlands also make great contributions to this field, whose frequencies are all above 17. However, from the view of centrality, England owns the highest degree of 0.42, USA 0.30, China 0.04 and Taiwan merely 0.00.

TABLE I. EACH COUNTRY'S (REGION'S)RESEARCH CAPABILITIES (FREQUENCY >17)

Country	Frequency	Centrality	Year
USA	99	0.30	2004
PEOPLES R CHINA	71	0.04	2004
ENGLAND	46	0.42	2004
SPAIN	42	0.14	2005
TAIWAN	36	0.00	2004
ITALY	29	0.12	2004
GERMANY	25	0.11	2006
AUSTRILIA	21	0.13	2006
CANADA	18	0.16	2004
NETHERLANDS	18	0.07	2004

B. Distribution of Institutions

Similar to visual operation for distribution of countries(regions), in CiteSpace interface, we Chose "institution" in "Node types", but other options stayed the same with that of the countries(regions). After running the CiteSpace, we acquired a knowledge map of distribution of all institutions. Just like Fig.(1), all circles in this figure stand for institutions. The bigger the circles are, the great contributions the institutions have made. In Fig.(2), the connection lines between different institutions exhibit their working relationship.

Fig.2 The Distribution of Institutions

According to table II, from the view of frequency, Univ Politecn Valencia ranks first in the world. Professor Hervas-Oliver (Univ Politecn Valencia) holds the view that firm-specific characteristics should be considered as central to the explanation of innovation, and he has been exploring the role of combining internal and relational resources to explain innovation in clusters [1]. IBM Corp and Georgia Inst Technol are both American institutions with frequencies of 9 and 6 respectively. Taylor and Mollie (Georgia Inst Technol) argued that unless a local high-technology industry could develop abundant multiple and locally centered social networks to embed companies in the region, or the development of cluster development will stagnate [2]. Zhejiang Univ, Univ Hong Kong and Chinese Acad Sci are Chinese institutions which also hold leading position in this field. Guo Bin(Zhejiang Univ)holds the view that for emerging countries, the following four factors are decisive for technological learning opportunities within the knowledge networks of industrial clusters: the underlying complexity of technology in clusters, the inter-connectedness between product and process, path dependency in knowledge searching, and the incremental nature of a cluster's technological development [3].

TABLE II. EACH INSTITUTION'S RESEARCH CAPABILITIES

Institution	Frequency	Centrality	Year
Univ Politecn Valencia	10	0.00	2008
IBM Corp	9	0.01	2005
Zhejiang Univ	7	0.00	2011
Georgia Inst Technol	6	0.01	2009
Univ Jaume 1	6	0.00	2012
Univ Hong Kong	5	0.00	2008
Fdn Adv Studies Int Dev	5	0.00	2006
Univ Belgrade	5	0.00	2011
Univ Antwerp	5	0.00	2009
Chinese Acad Sci	4	0.00	2013

C. The Research Hotspot

High-frequency keywords and subject headings are often used to identify the hot issues in the research field. Although each paper only have a few keywords, they are the essence of the literature [4]. By analyzing keywords and subject headings of literatures, we can grasp the research hotspot in related fields. In the CiteSpace interface, the paper chose both "Noun Phrases"and "Keyword", and other options kept the default selection. After running the CiteSpace, we obtained the knowledge map of the research hotspot. In Fig.(3), there are 494 nodes and 841 lines, which stand for 494 keywords and 841 connections.

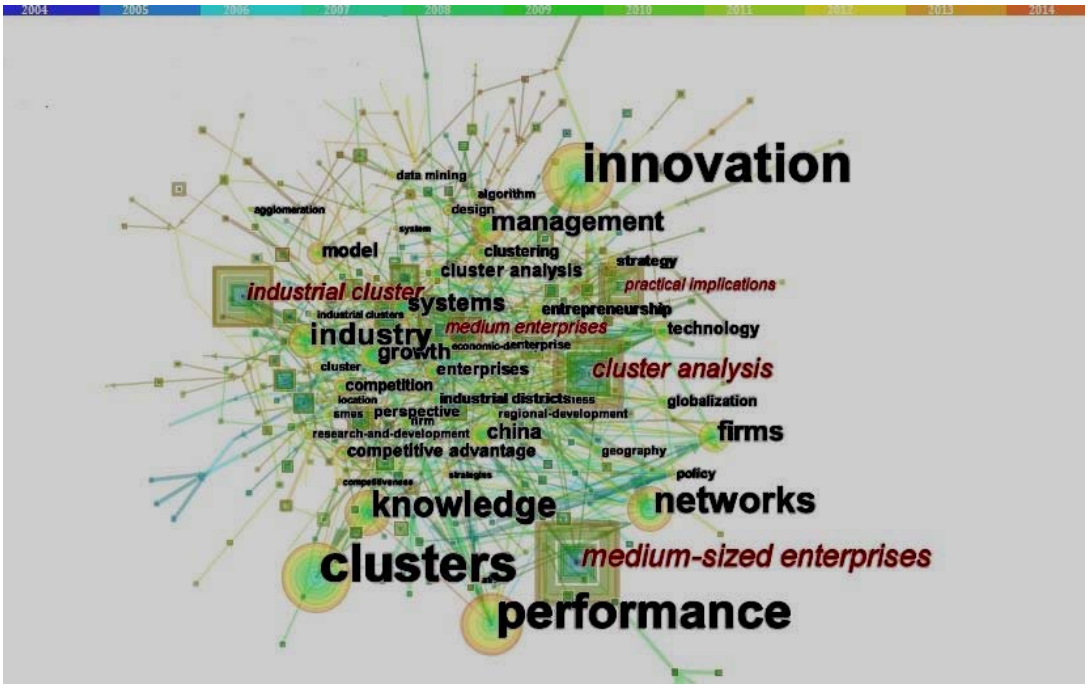

Fig.3 The Research Hotspot

In Fig.(3), the circled nodes refer to the keywords of literature, and the size of nodes refer to frequency of keywords. The bigger the nodes are, the more frequent they appear. Likewise, the square nodes stand for subject headings and their sizes indicate the frequency of them. Where, Keywords are printed in black font and subject heading by red font, both of which jointly exhibit the research hotspots in this field. It can be seen from table III that some terms like industry, firms, enterprises, cluster and knowledge network appear relatively more frequently throughout the whole stage of such research.

In addition, we found that research directions were slightly different in these years.

In 2004, studies in this field mainly focused on clusters and partnerships, Mytelka, LK (2004) examined the relationship between clustering and long distance partnering from the perspective of evolutionary economics and innovation systems literature [5].

In 2005, the theme mainly focused on evolution of knowledge network and supply chain. Vila, C (2005) presented a solution for cooperation between companies that belong to a supply chain in the ceramic sector, where it requires constant innovation in product design to maintain competitiveness. The main contribution of his research work lies in the definition of collaborative infrastructure for cooperative design that enhances interaction and knowledge management among different firms through information, technology tools and, particularly, PLM solutions[6].

In 2006, the research focused on innovation, performance, management and communication technology. In 2007, it transferred to competitive advantage, entrepreneurship and globalization, Lorentzen, Anne (2007) hold a view that the firms were capable of sourcing knowledge in a flexible and complex way, and that the division of labor exists in regional, global and national knowledge sources. Global sources have been regarded as the most important sources of innovation, while the regional level basically provides a labor market and entrepreneurship [7].

In the year of 2008 and 2009, the research focused on design, strategy and perspective. Arikan, Andac T(2009) viewed clusters as venues of enhanced knowledge creation and introduced the concept of a cluster's knowledge creation capability, then developed a model that outlined the antecedents of this concept. The model concentrates on factors that create opportunities to enable and increase the effectiveness of inter-firm knowledge exchanges among clustered firms [8].

TABLE III. MAIN KEYWORDS AND THEME WORDS (FREQUENCY >15)

Number	Node	Frequency	Year	Number	Node	Frequency	Year
1	innovation	76	2006	18	technology	24	2006
2	clusters	74	2006	19	enterprises	24	2006
3	performance	69	2006	20	Competitive advantage	23	2007
4	networks	51	2006	21	clustering	22	2006
5	knowledge	50	2006	22	competition	22	2007
6	Medium-sized enterprises	42	2004	23	Practical implications	22	2008
7	industry	42	2006	24	entrepreneurship	21	2007
8	management	39	2006	25	perspective	20	2009
9	firms	38	2007	26	Industrial districts	20	2006
10	Cluster analysis	36	2006	27	globalization	20	2007
11	systems	33	2004	28	strategy	20	2009
12	Industrial cluster	32	2006	29	design	17	2009
13	growth	31	2005	30	Communication technology	17	2006
14	china	29	2006	31	Supply chain	17	2005
15	model	28	2009	32	policy	17	2006
16	Cluster analysis	26	2007	33	business	16	2006
17	Medium enterprises	25	2007	34	Research and development	16	2008

D. The Research Frontier

Dr.Chen Chaomei defined the research frontier as a dynamic concept of a group of emergent and potential issues, while the intellectual base of research frontier was the trajectory of scientific literature and its citation network. By examining the time distribution of keywords, we can detect high frequency change rate of vocabulary. According to the change trend of word frequency, we can determine the frontiers of knowledge network in industrial cluster. In the CiteSpace interface, select “burst term” in “term type”, and choose “Cite Reference” as network node, while other options keep the default selection, once running the CiteSpace, we can get the knowledge map of the research frontier.

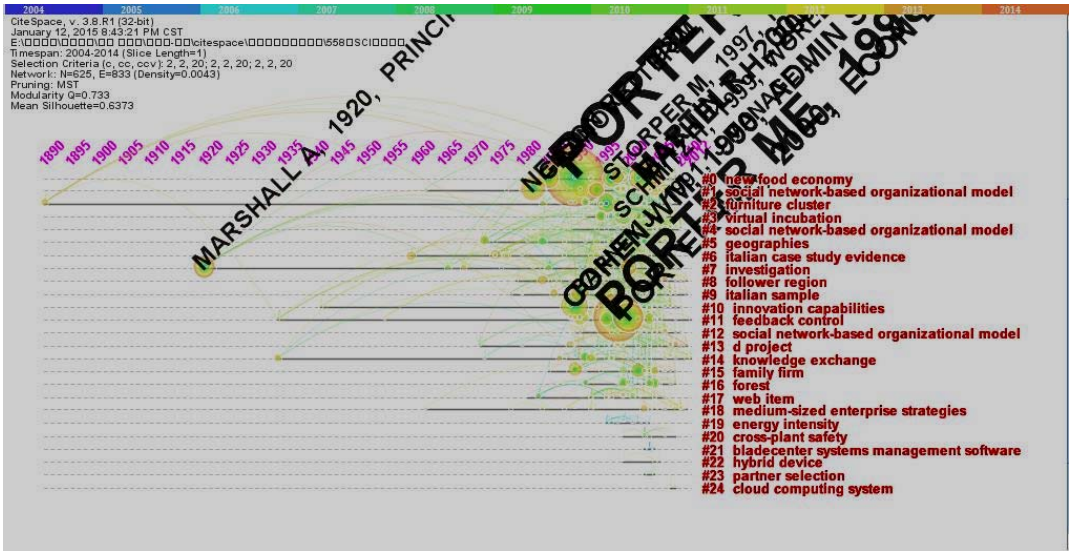

Fig.4 The Research Frontier

In Fig.(4), the node literatures are all arranged in chronological order. By clicking "Link Walk-through", we can see the evolution path of each literature from 2004 to 2014.The red words on the right side of time axis are burst terms calculated by CiteSpace, which, just as the map shows, cover 25 burst terms in this field. Black fonts represent some important literatures, which spread out the map in accordance with the relationship between time and cluster. By means of reading the related literature through Google scholar, removing redundant clusters and generalizing the burst terms, research frontiers are discovered mainly focusing on following four aspects.

(1) Constitution of subject. #2 Furniture cluster, #6 Italian case study evidence, #9 Italian sample, #15 Family firm and #23 Partner selection. Among them, Italian case study evidence mainly refers to the knowledge network of Italy Modena Bio Valley cluster, which bio-medical industry has become the most important sterilized products center of extra-corporeal blood circulation in Europe. In this cluster, it includes not only universities and research institutions, but also some financial institutions, intermediary agencies and governments, these subjects mutually connect to construct a complex knowledge network. #0 New food economy, #19 Energy intensity and #20 Cross-plant safety are important factors affecting subjects. Among them, new food economy represents external environment which bleeds industry cluster; energy intensity significantly impacts on the formation of industrial clusters; cross-plant safety is an important guarantee for knowledge sharing and exchange between different enterprises.

(2) Evolutionary process. #3 Virtual incubation is a kind of business model of virtual alliance which emerges due to influence of economic and political changes under external macro-environment. Virtual incubation is a key topic of knowledge network in industrial cluster, which sets up a bridge among enterprises, universities, research institutions and financing mechanism; furthermore, establishes division of labor and cooperative relation in different areas and combines the trans-regional local relation through coordination; finally, speeds up the spread share and innovation of knowledge.

(3) System. #11 Feedback control. From the perspective of specialization, the division and cooperation promote the development of cluster, which simultaneously require transaction network to expand. #24 Cloud computing systems. With continuous expansion of industrial cluster, the flow of knowledge and resource among companies becomes increasingly huge. Cloud computing systems can store huge distributed data and handle and use them effectively. What's more, the system provides a collaborative management platform for subjects in cluster, and enables knowledge sharing to come true.

(4) Knowledge Innovation. #10 Innovation capability. Knowledge network in industrial cluster can not only realize the knowledge sharing, dissemination and diffusion between different enterprises, but also promote knowledge appreciation and innovation. By using the effect of knowledge spillover, a subject in cluster can absorb heterogeneous knowledge from other enterprises in order to realize innovation of its own technological ability and enhance competitive advantage of enterprises.

IV. CONCLUSIONS

From the perspective of country (regional) distribution, it can be seen that USA ranked first in the world, followed by China, England and Spain, etc. But on the other hand, the centrality of PEOPLES R CHINA and TAIWAN were obviously lower than other countries. From the perspective of institutional distribution, Univ Politecn Valencia ranked first in the world, followed by IBM Corp and Georgia Inst Technol. Some institutions of China ranked in the third group, including Zhejiang Univ, Univ Hong Kong and Chinese Acad Sci.

From the perspective of research hotspot, it can be seen that some high frequency terms include industry, firms, enterprises, cluster and knowledge network, which consist with the substance of research and exist across all stages of research. In addition, research directions of each year were slightly different. In 2004, studies in this field mainly focused on clusters and partnerships; in 2005, the theme mainly focused on evolution of knowledge network and supply chain; in 2006, the research focused on innovation, performance, management and communication technology; in 2007, it shifted to competitive advantage, entrepreneurship and globalization; in the year of 2008 and 2009, it focused on design, strategy and perspective.

From the perspective of research frontier, it can be seen that the research frontier primarily behaves in four aspects: firstly, Constitution of Subject, the main subject includes not only enterprises, but also financing institutions and government; secondly, Evolutionary Process, business model of virtual alliance emerges due to stimulation of comprehensive factors like economy, politics and technology, which speed up the pace of knowledge sharing; thirdly, the System, basically expressed by feedback control and cloud computing systems; fourthly, Knowledge Innovation, enterprise cluster is established not only for the sharing of knowledge but also for absorbing heterogeneous knowledge from other enterprises and then converting into their own technical capacity so that enterprises can maintain competitive advantage in market competition.

Overall, this research remains at exploratory stage yet with a number of deficiencies to be improved. As regard to

threshold, the author selected threshold relied on subjective experience. In addition, this paper failed to analyze each key node in detail for lack of experiences. In future research, the author will make a further study on these problems.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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