Advance Journal of Food Science and Technology 7(8): 589-596, 2015
DOI:10.19026/ajfst.7.1364
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: September 13, 2014 Accepted: September 20, 2014 Published: March 15, 2015

Research Article

Empirical Analysis on Chinese Enterprise-enterprise Patent Cooperation in Food Industry

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Abstract: This study aims to investigate the multidisciplinary knowledge network of Chinese enterprise-enterprise patent cooperation in food industry. Multidisciplinary knowledge network which come from enterprise-enterprise patent cooperation is an important network platform to improve innovation performance and to implement multidisciplinary and multi-sectoral cooperation. The actual dynamic variation and structure characteristics of the network and the distribution characteristics of disciplines in the network besides are analyzed by the method of social network analysis based on 36731 pieces of enterprise-enterprise cooperation patent in food industry which come from State Intellectual Property Office of the People' Republic of China from 1985 to 2010. The multidisciplinary knowledge network whose structure is comparative perfect as the result shows that its carriers, the enterprises, play a positive role on knowledge flow and innovation performance in food development. At the same time, the method and the result of analysis in this study are provided both for the government and enterprises as theoretical reference and empirical material to their innovation strategy.

Keywords: Food industry, multidisciplinary knowledge network, patent cooperation, social network analysis

INTRODUCTION

In new century, the food industry has developed dramatically with new generation technologies, including the transgenosis, artificial food technique, etc. The innovation in food industry as well as other industries is now facing big challenges due to rapid development of advanced technologies. The multidisciplinary cooperation is conducive to promote innovation. Knowledge combination between disciplines has been confirmed by many scholars. Considering the references in three large data publications, Nissani (1997) examined and verified knowledge to flow between the disciplines, namely knowledge combination process by researching the reference delay. In the era of knowledge economy, it will be more frequent and rapid for knowledge to flow between disciplines. Increasing complexity of new products requires complex interdisciplinary solution; therefore, multidisciplinary team work in the multidisciplinary environment will be conducive to promoting innovation and technological progress (Ivanitskaya *et al*., 2002). Through multidisciplinary team work, a large number of tools, participants and innovative ideas from different fields gather together to open a new opportunity of the quality, variety and utility of the knowledge, which can produce the original products and skills. In this collaborative environment, effective application of knowledge increases the possibility of innovation. Moreover, Malerba (2002) believed that the innovation from the multi-disciplinary cooperation is more creative and radical and it features in obvious breakthrough. Alves *et al*. (2007) conducted case study to explain that the development of innovation thanks to a large number of creative ideas and the creative ideas come from the effective multi-disciplinary cooperation.

Diversity of knowledge, knowledge flows and knowledge network have close relationship with innovation. In the field of sociology, the diversity of knowledge has been regarded as an implicit positive influence factor of team innovation. In the field of cognition, the diversity of knowledge is considered as a key factor of realizing complex performance (Okada and Simon, 1997). Technology innovation subjects get heterogeneous knowledge by contacting with outsiders to get the inspiration of innovation. And the contact of all kinds of knowledge in different fields can integrate some complex and collaborative innovation (Dell'Era and Vergant, 2010). Theoretically, the more knowledge structures for members to use, the more creative ideas and thoughts can be generated. Knowledge flow can effectively promote cooperation performance and organizational network provides abundant resources for innovation ability and improve the knowledge transformation capacity and continuous innovation

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ability of enterprises (Breschi and Catalini, 2010). Knowledge network and knowledge management can bring many benefits for the development of food industry. The openness and richness of knowledge networks provide a good environment for generating new knowledge and complex knowledge and accelerating the pace of innovation at the same time (Adner and Kapoor, 2010). In order to take advantage of knowledge effectively, a network of knowledge and experience in food industry should be established for communication between employees and the knowledge network should be used to realize the dynamic management of knowledge. Enterprises who conduct knowledge network management should pay attention to the following three important points (Adner and Kapoor, 2010): Firstly, the knowledge network should connect knowledge of different levels, different fields and different types, including the explicit and implicit; Secondly, the knowledge network should have different levels, including individuals, groups, organizations and knowledge in different fields such as customer knowledge and research and development knowledge, etc.; Finally, enterprises should connect knowledge network with the process of the knowledge production and application. Only in this way, knowledge network can provide a sound service platform for innovation in food industry. In view of above points, most scholars believe that a network with diversity of knowledge and sufficient liquidity will greatly promote the generation of innovation in food industry.

There were some discussions of the multidisciplinary research in Chinese academia, but the discussions mainly aimed at multidisciplinary research and application of specific individual technology such as mechanical design and medicine, as well as the research of multidisciplinary training in university. However, there is no literature on multidisciplinary knowledge network of Chinese enterprise-enterprise patent cooperation in food industry. Therefore, this study plays a significant role in promoting multidisciplinary development in food industry and open innovation and interdisciplinary communication for the features of multidisciplinary knowledge network between enterprise cooperation based on large-scale patent data. In the current era of open innovation, the ability of connecting to a knowledge network and managing the network will become new core strength of enterprises. Multidisciplinary network from patent cooperation between enterprises is a highly heterogeneous knowledge network and a possible sharing network. Enterprises can connect technology and business to the network to realize the dynamic management of the knowledge network: firstly, the knowledge network guides enterprises to go across organizations and technical limitation, to participate in research, development and cooperation between organizations; secondly, by contacting with the external technology sources and knowledge, the enterprises learn some tacit and explicit knowledge quickly; thirdly, enterprises constantly adjust the enterprise technology and partnership to achieve continuous or discontinuous dynamic technology progress, in order to innovate quickly and efficiently. However, we still lack understanding of the real multidisciplinary knowledge network in food industry.

The main purpose of this study lies in researching whether the knowledge network structure is conducive to innovation and can whether for provide a good network platform for food industry development and the technical development of the enterprise by understanding dynamic evolution process and network structural characteristics of multidisciplinary knowledge network of patent cooperation between enterprises since 1985. The analysis result shows that multidisciplinary knowledge network of patent cooperation plays a very important role on knowledge flow and innovation performance.

MATERIALS AND METHODS

Multidisciplinary knowledge network: In recent years with the improvement of the patent database and development of electronic patent document, some scholars developed many important indicators reflecting knowledge flow in empirical study according to information in patents (Acs and Varga, 2002). The most widely used indicators include patent reference information, co-applicants and cooperation information of inventors, which all provide foundation for the explicit and implicit flow of knowledge between research organizations. The path of knowledge flow can be reflected from the two kinds of information in the patent specification: one is the reference information recorded in the patent citation and the other is the recorded information of joint application. The method of using patent citations as an indicator of knowledge flow was put forward by Jaffe *et al*. (1993). Jaffe assumed that the patent reflected the foundation and source of innovation and took the citations between patents as the path of knowledge flow (Jaffe *et al*., 1993). The tacit knowledge flow is mainly realized by the co-applicants and the inventors. The process usually base on a potential suppose which is that the cooperative enterprises and inventors share a relatively close exchange of technical knowledge and the tactic knowledge can transit among different organizations and individuals. Sternitzke *et al*. (2008) drew technical communication network between organizations with joint inventors and combined network structure and empirical research data to demonstrate that cooperation among inventors can bring knowledge different technical fields for organizations and the inventors who have close contact with different groups of inventors apply more extensive patented technologies, because they can benefit from different knowledge sources. At present, the academia use these indicators for further

empirical analysis, such as using patent citations to analyze the relationship between geographic and social distance and knowledge flows and using patent citations and the relationship of co-applicants to analyze knowledge flow regularity in the technical fields and organizations. However, Chinese patent database basically has no patent citations. Only a handful of patent citations were added in recent years, so the flow of knowledge cannot be reflected by using patent citations in Chinese patent data. Therefore, the relationship between cooperative enterprises or co-inventors is used to analyze the knowledge flow.

Based on the above thoughts, this study also argues that in the process of cooperation, enterprises have the opportunity to contact with different knowledge resources to bring different useful information, so as to allow the technologies which are applied for patents more extensive.

In addition, this study also adopts the hypothesis of tacit knowledge flow, which means that there exists knowledge flow between cooperative enterprises. This study base on two underlying assumptions: firstly, if there is a same enterprise between two disciplines and the enterprise has certain degree of contact with both disciplines, knowledge flow happens between the two disciplines; secondly, when an enterprise join the network by cooperating with other enterprises, the multidisciplinary knowledge and the combination process of the knowledge which the enterprise contacts will spread in the network. Therefore, this study aims to research whether the cooperative network structure is conducive to effective collision of interdisciplinary heterogeneous knowledge, connection between enterprises and different knowledge resources and whether is advantageous to the enterprise into different knowledge and cooperative innovation between enterprises with multidisciplinary knowledge backgrounds. The study gives a definition of knowledge flow between the organizations as the interdisciplinary knowledge flow which is contained in the patent classification numbers. Figure 1 shows the path of the multidisciplinary knowledge network.

Assumption: Enterprise A and enterprise B cooperate for patent I and the patent I involves disciplines or subjects S1 and S2; Enterprise B and C cooperate for patent II and patent II relates S3 patents. There are three possible paths of knowledge flow among three subjects. Firstly, the direct knowledge flow path: if two subjects belong to one patent classification number, then cooperative enterprises of the patent are the carriers of knowledge flows between disciplines or subjects, for example, enterprise A and enterprise B are the carriers of knowledge flow between S1 and S2. Secondly, the indirect knowledge flow path: the technical knowledge contacted by enterprise B involves S1, S2 and S3. However, S1 and S3, as well as S2 and S3 are not in a same patented technology field. The assumption is that

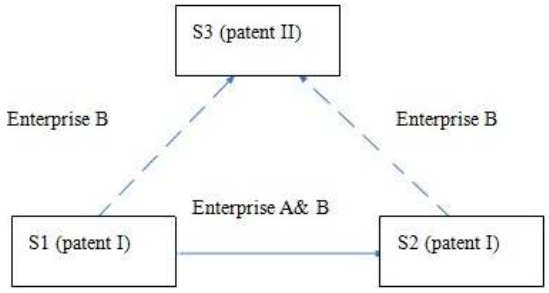

Fig. 1: The path of the multidisciplinary knowledge network

because of a same enterprise B involved, the knowledge flow happened between S1 and S3, as well as S2 and S3. Thirdly, overflow path between enterprises in the cooperative patent network: for example, enterprise B is regarded as the diffusion node and all the enterprises who conduct cooperation with enterprise B are the overflow paths. They spread the multidisciplinary knowledge of enterprise B, i.e., S1, S2 and S3 as well as the application knowledge of the combination of the three, to other cooperative enterprises, such as enterprise C.

Therefore, construction of multidisciplinary knowledge network can be divided into two steps:

- To extract first three umbers which show the disciplines of the sub-classification numbers of each cooperative patent document, including the patents with a single classification number, for example the number A61N5/067 is extracted into A61, which means medical or veterinary medicine or hygiene and to extract the corresponding patent applicants at the same time.
- To collect the information of enterprises of corresponding disciplines.

The specific methods of network construction:

- To assume that the number of subjects is i and the number of applicants is p; to match subjects and enterprises into the subjects of $i \times p$-the enterprise matrix A_{ij}, in which $A_{ipj} = 1$ means i enterprises have p_j inventors.
- To conduct multiplication of the matrix A_{ip} and its transposed matrix to get a common enterprise matrix A_{ij}. If $A_{ij} = m$ represents the subject i and subject j have the common enterprises and the number of the common enterprises is m, thus the conclusion could be drawn that it can process multi-value matrix.

Sample data: Patents contain three categories: patent for invention, patent for utility models, patent for design. Patent for invention shows greater creativity than other two categories. The patent in this study only refers to the patent for invention patent. Patent cooperation between enterprises discussed in this study

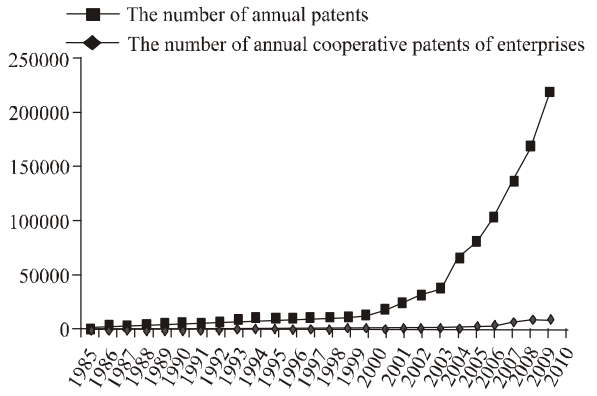

Fig. 2: Annual growth of cooperative patents of enterprises and announcement of patents

only refers to one form which is joint application for patents of enterprises. The data retrieval was conducted on the net of State Intellectual Property Office. The research targets include the joint application of enterprises, including companies, groups and factories, which belong to patents for invention in mainland China, excluding Hong Kong, Taiwan and Macao. The date of data retrieval was September 5, 2011. The authors searched the patents from January 1985 to December 2010 and got 39351 items of original data. Each patent item shows the information of the publication number, application number, publication date, applicants, classification number and inventor. After processed with above standards, the sample date account for 36731 items.

The annual growth of cooperative patents of enterprises and announcement of patents are shown in Fig. 2. The sample data are divided into seven stages: from 1985 to 2004 every 5 years is a stage with a total of four stages: 1985-1989, 1990-1994, 1995-1999 and 2000-2004; and the rapid development phase is from 2005 to 2010, which is divided into three stages including 2005-2006, 2007-2008 and 2009-2010, respectively.

Seen from the Fig. 2, the data show that from 1985 to 2000 witnessed a slow growth; the starting phase of rapid growth is for 2000 to 2004; and the boost phase began with 2005. The proportion of cooperative patents of enterprises in the announcement patents was 0.5 to 0.6% before 1997; the percentage has a rapid increase from 1998 to 2001, which reached 2.45% in 2001; the data in 2005 keep a stable number of 2.55%. The percentage has a rapid growth starting in 2006 and it is 4.55% in 2010. In general, the proportion of cooperative patents of enterprises in the annual announcement of patents is very small.

RESULTS AND DISCUSSION

The phase evolution of the network and overall structure characteristics: The indicators of overall structure characteristics of social network include scale, average connections, average degree, centralization and network density. These indicators reflect the different aspects of network structure characteristic. And in general, these indicators should be combined to analyze the structure characteristics of network. In the multidisciplinary knowledge network, the sides between discipline nodes are enterprises. The more connections between two nodes, the more enterprises joining the knowledge flow between disciplines. And the more connections of a single node, the more enterprises becoming the carriers of knowledge flow between disciplines and the more important of the disciplines in multidisciplinary knowledge flow, combination and application. The average connections mean the average of the number of connections of all nodes in the network. Average degree indicates the link level between discipline nodes and other nodes and the greater of the average degrees, the more extensive links between disciplines. Network centralization describes the central tendency of network and network density reflects the tightness of links between nodes.

The phase structure characteristics of multidisciplinary knowledge network produced by Patent cooperative patent of enterprises are shown in Table 1 and the network revolution is shown as Fig. 3.

Before 1999, the linking discipline nodes are few and the network relations are relatively sparse; beginning with 2000, the nodes, average connections, average degree and density witnessed a great increase. Compared with the phase before 1999, the network relations and nodes have a great improvement and linking scope of disciplines was broadened. Network nodes, degree and density showed a trend of rapid increase from 2005. Up to the phase of 2009-2010, there were 116 nodes and there were 129 major categories in International Patent Classification (IPC), 2010. The average connections of nodes account for 710.51, which explained that averagely 710 companies

Table 1: The characteristics of multidisciplinary knowledge network

Phase	85-89	90-94	95-99	00-04	05-06	07-08	09-10
Effective samples	53	176	527	3051	4151.0000	9949.0000	18725.0000
Scale	32	49	52	86.0000	103.0000	117.0000	116.0000
Average connections	16.3750	30.4900	20.2690	96.7210	150.8160	334.0680	710.5170
Average degree	12.2500	22.2400	9.3100	36.5800	47.3800	66.4800	79.8600
Partial cluster coefficient	1.1610	1.3560	1.7950	2.9310	3.37600	6.0980	11.4380
Centralization	11.2500%	5.6000%	8.6600%	6.2500%	6.1800%	9.8600%	12.1300%
Density	0.5282	0.6352	0.3974	1.1379	1.4786	2.8799	6.1784

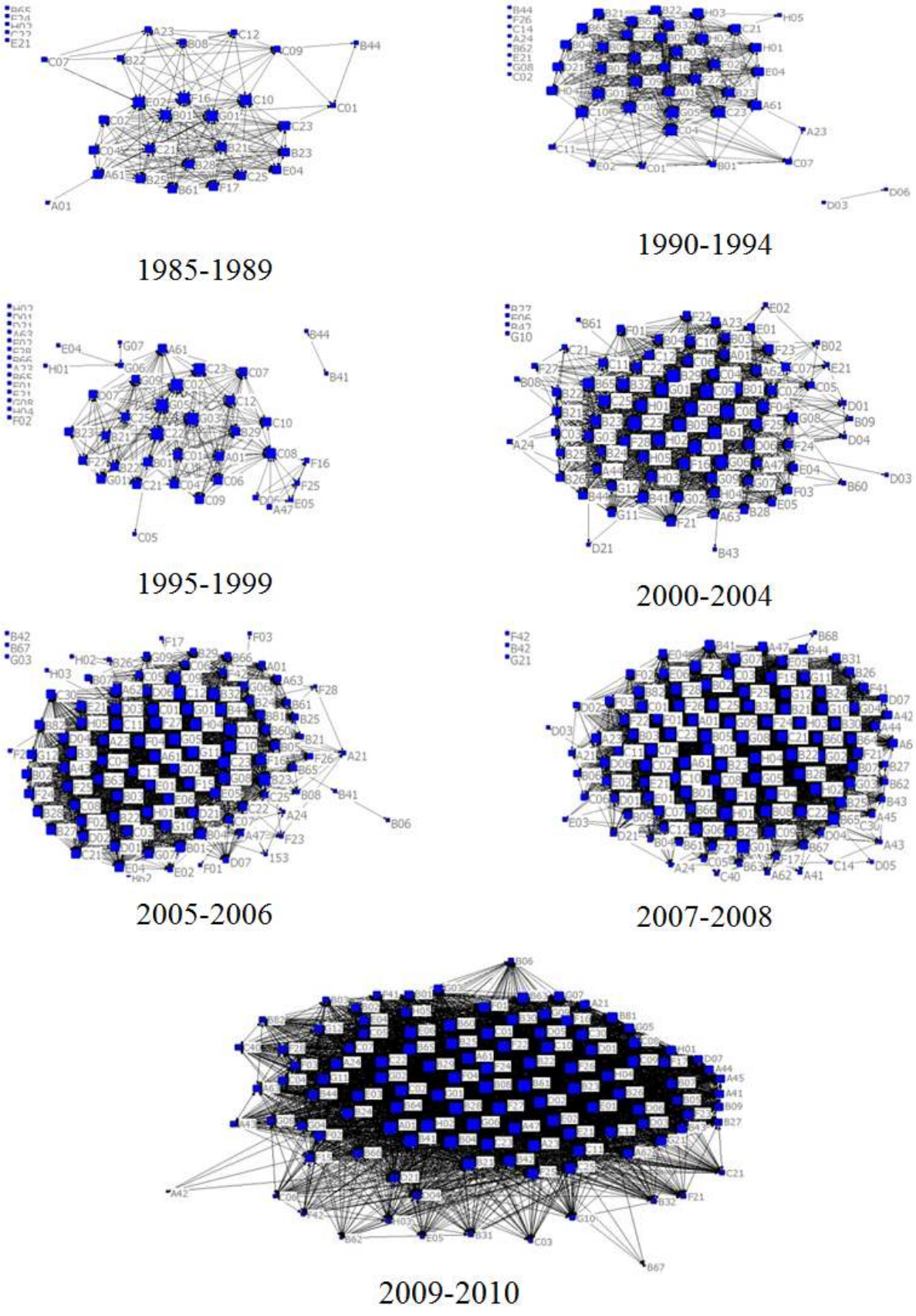

Fig. 3: Network revolution from 1985 to 2010

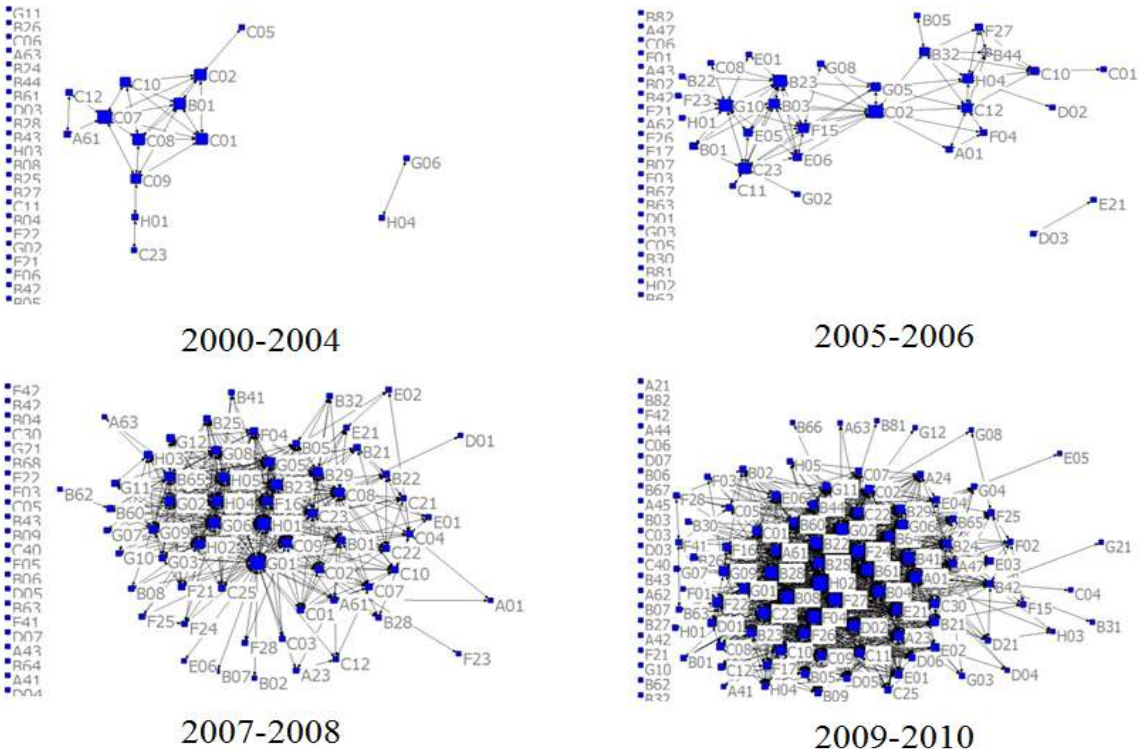

Fig. 4: Strong ties of multidisciplinary knowledge network

acted as the carriers of knowledge flow between discipline nodes. The average degree of nodes is 79.86, which means a discipline has knowledge connection with other 79 disciplines. Network density cannot be compared in different size of network. In general, the density would be higher in smaller network. But starting with 2005, despite its growing size, the network density value is rapidly rising, which shows that the link between nodes get strengthened continuously. Network centralization has also been growing since 2005. The growth of centralization implies some central nodes were appeared to increase the speed of information communication. In general, multidisciplinary knowledge network has developed into a network with close link and certain centralization by the phase from 2009 to 2010. From the view of degree, there exist no extraordinarily outstanding disciplines, but many disciplines with similar degree. And in the process of development of the network, some important nodes undergo big changes in each stage.

Strong ties of network: This study assumes that there are more than 10 enterprises as carriers of knowledge flow between two disciplines. Therefore, because of the existence of these enterprises, knowledge features in flow, combination and application between two subjects with certain intensity. Take 10 as the threshold value, which means at least 10 enterprises between nodes and get the adjacency matrix and this matrix is the strong tie matrix. Figure 4 shows strong ties of multidisciplinary knowledge network.

Cross and Prusak (2002) believed that the ideal network structure is a network including some small groups with high internal density and at the same time, there is a certain "intermediary" between each group, which helps complementary and transmission of knowledge between teams and improve knowledge performance management in organizations. Therefore, the internal groups with strong ties play a very important role in knowledge flow and application in network. The status of strong ties is presented as Fig. 4. There were no strong ties of network before 1999. From 2000 to 2006, with the continuous increase of other disciplines nodes, the number and link of nodes with strong ties are increasing, but the network was still rather sparse with low network density. However, starting with the phase from 2007 to 2008, the number of discipline nodes and degree increased rapidly and network density has a big enhancement with closely strong ties between disciplines, just as the points of view of Cross and Prusak (2002), the multidisciplinary knowledge network is conducive to knowledge flow, spread, combination and application. On the other hand, in the process of network development, strong ties within groups has a big change and the relations between important nodes in different phases are not stable, which explains that links between disciplines would change along with the development of economy and technology as well as the change of cooperative

companies and their technical development. Therefore, strong ties between disciplines will change as time goes on, which is not a steady state.

From 2007 to 2008, the nodes with high extent and intensity include B23, B22, B25, B05, B60, B28, G08 H03 C09 and F02, respectively. From 2009 to 2010, the nodes with high extent and intensity are G07, G08, G02, H02, G01, E04, B23, B22, E06 and E05, respectively. In development of multidisciplinary knowledge network, the nodes with high extent and intensity in each phase experience larger changes than other nodes.

Discussion: In general, knowledge flow shares a close link with disciplines in the knowledge network. And the network can provide an important platform for the innovation of enterprises. In order to utilize multidisciplinary knowledge networks in food industry to improve innovation performance, the author gives two pieces of suggestions for construction of patent cooperation network in China:

- Enterprises should make full use of multidisciplinary knowledge network to enhance innovation speed and performance in food industry. Firstly, enterprises can utilize disciplinary links in the network to analyze the connection between the disciplines to pursue the space of technology expending and the cooperative enterprises. The network can help enterprises find technologies of other disciplines to improve their own technology to realize open innovation, complex technology innovation and multidisciplinary research and development innovation.

  Secondly, enterprises should focus on technology tendency associated with the field the enterprises involved in the network, especially some dynamic changes of the effect on the society from some discontinuous progress of the science and technology and the emerging of new networks such as business networks and enterprise cooperation network. Enterprises must keep sharp observation for the dynamic development of networks, continually adjust strategies and utilize dynamic evolution of multidisciplinary knowledge network to realize the dynamic development of the enterprise innovation.

  Finally, enterprises should participate in and make full use of the network platform resources to get more multidisciplinary creative information and other business information and to create more creativity and ideas. The analysis targets of this study are the networks in mainland China and enterprises could according to the actual needs conduct similar analysis of the industries the enterprise involved or interested in, in order to provide some clues for innovation.

- The government should fully analyze multidisciplinary knowledge network in food industry and guide and regulate the utilization.

  Firstly, the government should pay attention to the network of enterprises which associated closely with the multidisciplinary knowledge networks, especially the structural holes which exist in the business cooperation groups. The government also should organize the cooperative enterprises to participate in various communication activities, increase the number of “intermediary" and try to realize the negotiability of the innovation of multidisciplinary knowledge network. The foundation of cooperation of multidiscipline and multi-organization is the effective collision of heterogeneous knowledge. If more and more participants of multidisciplinary projects can join a same communication network, which is equivalent to set many “intermediary” between each small group, the multidisciplinary and heterogeneous information resources cannot be left aside in small groups and a large number of novel and non-redundant knowledge for other groups will spread to the position to exert the potential value. As a result, flow, spread and application scope of multidisciplinary and heterogeneous knowledge will broaden rapidly. At, present, multidisciplinary research and development cooperation still have many difficulties and obstacles. The government should focus on the importance of the construction of multidisciplinary knowledge network. The proportion of patent cooperation in the total patents as well as the number of enterprise participating in is small. In the phase from 2009 to 2010, the number of enterprises accounted for 4,400. The government should encourage the enterprises in the network to consolidate and strengthen cooperation relationship and inspire more enterprises to participate in the network. Once the implicit and explicit multidisciplinary knowledge get effective transformation and collision, the creativity and ideas will be more and more. In that way, the multidisciplinary knowledge network platform can improve individual and overall innovation performance to provide technical support and organization support for open innovation.

  Secondly, the government should focus on the global development of science and technology as well as the development of multidisciplinary research and development, get aware of the technologies which are urgently needed for the development of economy and the society and pay attention to the nodes in the network with high extent and intensity as well as the intermediary nodes. On the other hand, the government should introduce advanced and core technology into the important nodes or indirectly to make them become

the central nodes or intermediary nodes in the network. The government should make full use of the important nodes with high extent and intensity to allow advanced technology of these disciplines spread more quickly to other fields, strengthen the effect of the intermediary nodes in the multidisciplinary knowledge network to promote collision and communication of disciplines and support and guide technology innovation of the enterprises who involved many disciplines to encourage more enterprises with good communication ability of disciplines and rich cooperation experience to enter the network. Only in that way, multidisciplinary knowledge network will accelerate integration of knowledge in practical application to further enhance the original innovation ability and to promote the function of innovation network platform.

CONCLUSION

Since 1985, the multidisciplinary knowledge network in food industry has been formed by patent cooperation between enterprises and the overall structure gets improved continuously. To the phase from 2009 to 2010, the International Patent Classification had a total of 129 categories, among which there are 116 categories of networks. The overall network structure features in strong ties group with numerous nodes and close link spreading multidisciplinary knowledge to wide extent by the connection of weak ties, to realize information accessibility of networks. Close multidisciplinary links in networks indicate that in the current development of technology, the knowledge flow is frequent. The multidisciplinary knowledge network in food industry is conducive to knowledge flow and innovation. However, in the process of network evolution, the multi-disciplinary knowledge network and important disciplines in the strong tie network have rather big changes. Links between some disciplines experience change with the development of economic and technology, as well as cooperation between the members, so it is not in a steady state. Multidisciplinary knowledge networks in food industry do not have small-world effect and the extent and intensity have positive correlation from a certain degree.

ACKNOWLEDGMENT

This project is supported by the grant of the Philosophy and Social Sciences Planning Project in Zhejiang Province (No. 12JCGL25) and the National Natural Science Foundation of China (No. 71072033).

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