# A Method to Evaluate the Close Degree of Cooperation in Research team

## - An Empirical Study

Pang Hongshen[1, 2], Fang Shu[1], Fu Xinjin[1,2]
1 The Chengdu Branch of the National Science Library, Chinese Academy of Sciences, Chengdu, China
2 Graduate University of Chinese Academy of Sciences Beijing, China
winsunpang@126.com

**Abstract-- This paper defines the meaning of scientific research team, and selects the WISE Laboratory in Dalian University of Technology as a research team sample. By constructing a multi-value matrix and co-operation network, this paper apply social network analysis to analyze the close degree of cooperation in research team sample. This paper uses a method which contains six indicators -- network structure, network density, compactness, average distance between points, cliques analysis and centrality analysis to evaluate the internal close degree of cooperation in research team. From the analysis results, authors find that these six indicators can better reflect and explain the close degree of cooperation in research team, and conclude the network characteristics in a research team with high internal close degree of cooperation.**

***Keywords-- Research team; Close Degree of Cooperation; Social Network Analysis; WISE Laboratory***

## I. INTRODUCTION

Nowadays with the growing trend of globalization, it is a common phenomenon that researchers cooperate with each other in scientific research. Many first-class researches are completed by different researchers with close cooperation work. With the formation of effective research team, the research team can share the scientific research resources .It can help to improve scientific productivity, promote the innovation in scientific research and maximize the effectiveness of the research team. Therefore, by measuring the close degree of cooperation in scientific research team, we can pay close attention to the cooperation within the research team, and we can give an important reference points for the research team in the optimization of the configuration

## II. RELATED WORKS

With the development of research methods in the fields of social network in recent years, a number of research monographs [1, 2] are emerging. In the field of scientometrics, many studies apply the methods of social network analysis to the phenomenon of research cooperation [3-7]. By constructing a matrix of cooperation among team members, Zhang [8] applied social network analysis (SNA) and UCINET software to evaluate the cooperation of teams. This method can evaluate the effectiveness and potential of cooperation in research team. Ming [9] analyzed the network structure, centrality, intermediary in sports research cooperation and discussed the network structure, the role of core members, and flow paths of knowledge in Chinese sports research teams. Feng[10] studied the network location and the knowledge sharing behavior of members in the university research team. Yang [11] studied the relationship among of cohesion, group structure and the overall performance of information system development team from the perspective of social network. Jesus [12] showed that members of a solid research team had more competitive advantage than those in non-solid one from experiment. Jose [13] studied how the close degree of the team of scientists and social integration affect the individual behavior and performance of scientists. The factors included the productivity, influence, prestige, cooperation model, participation in research projects, and the contribution in training of junior researchers of scientists. There are many researches in scientific cooperation, but there are few studies of members' cooperation in research team. Moreover there are no unified indicators in analyzing the network attributes of close degree of research team.

## III. THE DEFINITION OF RESEARCH TEAM

In the early days, because of the poor condition of communication, transportation and other factors, many scientific researchers studied separately. However with the expansion of scientific research activities, the human instinct for collaboration has been reflected in scientific research. Scientists and a variety of people interested in science began to study and discuss a number of scientific issues and established some scientific community and organizations [14]. Various types of scientific research team are gradually becoming the basic unit in research, so the researchers will never go it alone. They can rely on the team, and make a greater research. Jiang [15] defined the following characteristics of a team according to the definition of several scholars: (1) team members share a common commitment and goals. (2)The team is a group which is consisted of two or more members who have complementary relationship. (3) Team members cooperate and interact with each others in the process of completing organizational goals. They have a certain division of roles. (4) The team can achieve greater goal than the sum of individual members' performance. Jesus [12] defined that research team is a collection or cluster of two or more people belonging to a single research unit (department, laboratory, etc.), with common scientific interests and objectives, working on one or more common lines of research, sharing tasks and resources in order to achieve their objectives, usually publishing together, and having a certain degree of economic and decision-making autonomy.

In this research, the research team is defined as a research group consisting of two or more research members. They have a common research goal, share some of the research task and share certain resources. The team members have a relatively strong and stable relationship of cooperation. They can rely on a certain entity organizations (such as an institution, department, laboratory, etc.), or can be subordinated to some non-entity organizations (such as work together in research projects, engaged in cooperation research of a single or multiple topics, etc.).

978-1-4244-8693-9/11/$26.00 ©2011 IEEE

## IV. THE INDOUCTION OF WISE LABORATORY

WISE LAB of Dalian University of Technology is an international lab established in September 21, 2005. 'WISE' is combined by four capital letters of 'Webometrics', 'Informetrics', 'Scientometrics' and 'Econometrics'.

Its basic tasks are developing basic scientometric theory, exploring creative approach in scientometrics, discovering the basic laws of development and relationship in science, technology, economy and society to be a strong support of science studies; expending the application-oriented research of scientmetrics to offer scientific evidence to national S&T policy and strategy; taking part in international academic exchange actively, strengthening international collaboration, following up research fronts in scientometrics, translating famous foreign works, being an academic bridge between world and China in the field of scientometrics and science studies; establishing the website of WISE LAB, promoting the academic exchange on line; diffusing and extending the knowledge of scientometrics, being a training center to cultivate person with abilities of scientometrics in China.

## V. METHODOLOGY AND DATA

Currently many analyzing methods of scientific collaboration networks measure the level of cooperation by constructing matrix value of researchers' paper collaboration. Most of the measurements of scientific collaboration networks analysis from the indicators including network structure, network density, cliques analysis and centrality analysis and others respectively. However the measurement methods don't integrate with each other. And the measurement indicators have no uniform standards and the meanings of indicators are explained unclearly in measuring the internal cooperation of research teams. There is still no unified method to measure the close degree of cooperation in research team at present.

From the definition of research team and the understanding of the close cooperation, a team with close cooperation has more close structure in the internal cooperation network than the team with loose cooperation. There are more cooperation connections among the members in the research team. And there are less distant relations of cooperation. By observing the relevant property in the internal network of cooperation, we can evaluate the close degree of cooperation in a research team. We consider that we can use a series of indicators such as network structure, network density, compactness, cliques analysis and centrality analysis to measure the close degree of cooperation in a research team. And we can study those indicators' actual effect in evaluation. At last we can find a good way in quantitative analysis of the cooperation in a research team. These are the main concern contents in this research.

In this research, we use the relevant properties of cooperation network to analyze the close degree of cooperation in research team by constructing the cooperation matrix and network of co-author papers. The cooperation network of research team is composed of papers' authors. Each author is defined as a point. If two authors have co-author papers, there will be a link between two points of co-author. And the number of co-author papers will mark in the cooperation matrix. The analysis method of this research is shown in Figure 1. Firstly we construct a binary matrix / multi-value matrix. Secondly we construct the cooperation network and select the indicators such as network structure, network density, compactness, Average distance between points, cliques analysis, centrality analysis and so on to analyze the close degree of cooperation in a research team. Finally, we will conclude the analyze results.

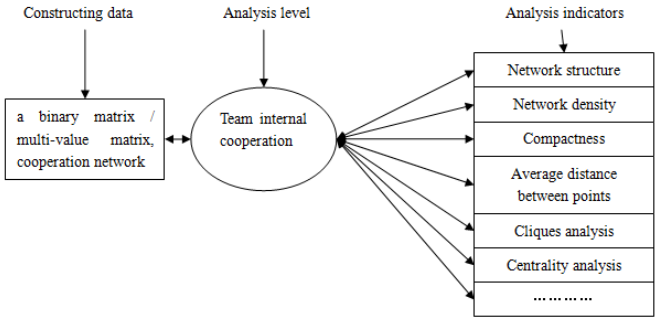


Figure 1. Analysis method of close degree of cooperation in a research team

This research selects WISE Laboratory in Dalian University of Technology as the research team's sample and uses Chinese published papers as data set. We get the team members list from the website of WISE Laboratory [16], and search the published papers of WISE Laboratory members for the Academic Literature Full-text Database in Chinese National Knowledge Infrastructure(CNKI) (search date: June 21, 2010). After that we mark the number of each member and construct co-authors matrix (a total of 23 members, sequentially numbered from P1 to P23). We also count out the number of papers of every two authors for constructing multi-value matrix A. Finally we use UCINET [17] as a tool and analyze the close degree of cooperation in WISE Laboratory through the indicators of social network analysis.

## VI. ANALYSIS ON THE CLOSE DEGREE OF COOPERATION IN WISE LABORATORY RESEARCH TEAM

### A. Network Structure Analysis

Star structure and mesh structure (Figure 2 and Figure 3) are the basic types of scientific collaboration networks. We usually can see these two types in the collaboration network of various research teams. In the cooperation network of a research team, the most effective network structure is usually mesh structure (Figure 3), and no isolated point in the network. We can see that the star network is not the perfect structure for maintaining the cohesion of research teams' cooperation. If some problems were happened in the internal cooperation of a research team and the problem would lead to the disconnection points in the center of star network, the cooperation network maybe disintegrate and the close degree of cooperation will decrease rapidly in a research team. By contraries, the mesh structure network has the formation of more closely association in every network point. Once a point in the network was cut out, the other points can still connect together closely. The cutting point just has a little effect in the cooperation network of a research team. The mesh structure guarantees the cohesion of the network. In addition, the cooperation network also does not allow the existence of isolated points in a effective research team. Because according to the definition of a research team, team members must have a relatively close relationship of cooperation with each other, the isolated points can not be allowed to exist. If there is an isolated point, we can consider it as a invalid member. When restructuring the research team, the team managers should exclude the invalid members or enhance its cooperation connection with other team members. Moreover, the higher complete degree of network structure cooperation is, the higher close degree of cooperation in the research team will be.

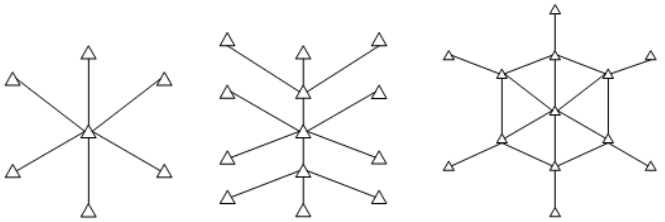

Figure 2. Various types of star network

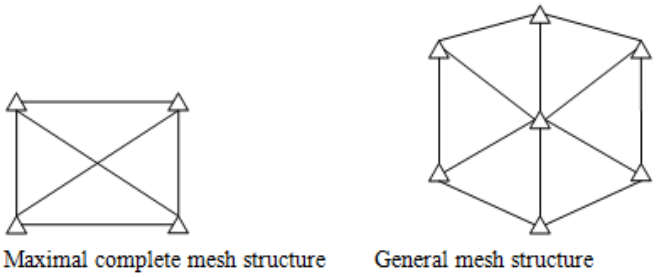

Figure 3. Mesh structure network

The cooperation network of WISE LAB team (Figure 4) is draw out by the UCINET software based on multi-value matrix A. The nodes in the network represent paper authors and the links between the nodes represent the numbers of cooperation papers. If every two authors has the cooperation papers, their nodes will have links. Meanwhile, the more two authors have cooperation papers, the thicker their nodes have the connection link. By analyzing the network structure, we can see that the network structure of cooperation in WISE LAB is mesh structure. The left side in network graph has higher degree of interleaving, and the right side was looked like star structure locally. However, the thick links in the right side show the high cooperation strength among few author nodes, and there is no isolated node in the network. Therefore, we can consider that WISE LAB team is established based on a relatively close relationship of mutual cooperation and this research team has higher close degree of cooperation .

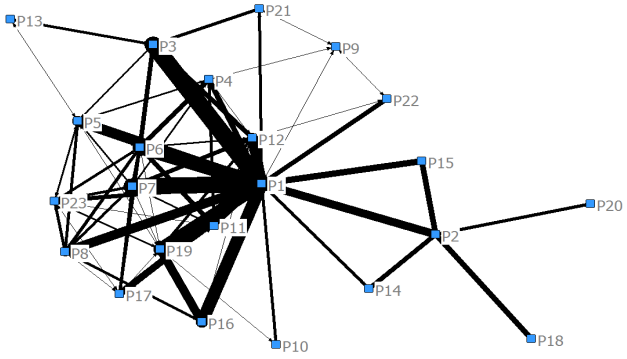

Figure 4: Cooperation network of WISE LAB team

B. Network Density Analysis

The density of a network is the ratio of actual numbers lines to the maximum number of lines theoretically in the network. The density is an important variable in the structure of a group. There are more cooperation behaviors in the teams with cohesion cooperation. Meanwhile, the knowledge is communicated more easily and the performance can be better in these teams. Contrarily, the teams with loose cooperation have less information communication, less emotional support and lower satisfaction of the job [9]. By analyzing the network of multi-value matrix A we get the following results in table 1.

Table 1. Network density indicators of multi-value matrix A

| Avg Value | Std Dev | Density | No. of Ties |
|---|---|---|---|
| 1.2016 | 2.8774 | 0.2767 | 140.0000 |

The average value of cooperation in WISE Laboratory team (Avg Value) is 1.2016. It means that every two members in the team have 1.2016 cooperation papers averagely. The standard deviation value (Std Dev) is 2.8774. It represents the fluctuations of the numbers of cooperation papers in every two members. The more different in the numbers of cooperation papers in every two members, the higher Std Dev values is. The network density value (Density) is 0.2767, representing that every two network nodes has 0.13835 connect lines averagely. it also means that there is 1.3835 pairs of cooperation relationship in every 10 pairs of members. The number of relationship (No. of Ties) is 140, representing that there are 70 lines in the network. It also means that 70 pairs of members have the co-author relationship in the teams (there are 253 pairs of network nodes, so the cooperation pairs of members account for 27.67% of the total pairs of members.)

Among these four indicators, Avg Value, Density and No. of Ties have positive correlation with the close degree of cooperation in a research team. The higher these three indicators value, the higher close degree of cooperation in a research team. When the value of Density is higher, Std Dev has negative correlation with the close degree of cooperation in a research team. Because the higher value of Std Dev, the more centralized cooperation in several members. While cutting off the several core members, the close degree of cooperation will be decrease sharply. Contrarily, if the value of Std Dev is lower, the value of the network density will only have a little change when removing each of the member in the team. Generally speaking, a research team with higher close degree of cooperation should have higher value of Avg Value, Density, No. of Ties and lower value of Std Dev.

C. Network Compactness Analysis and Average Distance between Points

Widmeyer [18] defined the cohesion as that: "In the process of pursuing goals, the cohesion reflects that the members of a group find staying together to be in mutual interest." they described cohesion as a dynamic process, not static cohesion. In UCINET, there is a analysis indicator of cohesion (Compactness). Its value is between 0-1. The larger this indicator, the more cohesion of the overall network [19].

Firstly we analyze the Compactness of multi-value matrix A .we find out that the value of Compactness is 0.609 and the average distance between points is 1.901 based on the Adjacency distance calculating. In this calculating type, UCINET software will automatically change the multi-value matrix into a binary matrix for processing. Secondly we try to remove the P1 which is the central point in the network out of the multi-value matrix A, and we analyze the results again. We find that the Compactness decreases to 0.405. The value decreasing sharply proves that P1 has an important role in the cohesion of the team. Meanwhile, the WISE cooperation network divides into two sub-networks when the P1 has moved out, so we can not calculate the average distance between points. Thirdly, we try to remove the P18 which is the edge point in the network out of the multi-value matrix A. We find that the Compactness increases to 0.630. The increasing value proves that the edge point of the network has negative effect on the cohesion of the research team. Moreover, the average distance between points increases to 1.818, which proves that the cooperation path of the network has shortened when removing out the edge points. We can see the change when some points were removed in Table2.Therefore, the Compactness and the average distance

between points in the network can be indicators of measuring the close degree of cooperation in a research team. These two indicators means that when we construct or reconstruct a research team we should consider that keep the members who have positive effect value and move out the members with negative effect value, or take action to change the members with negative effect value into positive ones. By improving the value of these indicators, we can improve the cohesion of a research team, shorten the path of cooperation and increase the close degree of cooperation.

Table 2. The Compactness and Average distance between points in WISE LAB team cooperation network

| | **WISE LAB cooperation network (multi-value matrix A)** | **P1 was removed in WISE LAB cooperation network** | **P18 was removed in WISE LAB cooperation network** |
|---|---|---|---|
| **Compactness** | 0.609 | 0.405 | 0.630. |
| **Average distance between points** | 1.901 | the network was divided into two sub-network | 1.818 |

D. Network Cliques Analysis

One of the major concerns of social network analysis is identification of cohesive subgroups of actors within a network. Cohesive subgroups are subsets of actors among whom there are relatively strong, direct, intense, frequent, or positive tie [20]. In UCINET, we can measure the close degree of cohesive subgroups in a research team by using the cliques analysis. At present, there are many ways in analyzing the cohesive subgroups, however Liu [21] think that: In analyzing the cohesive subgroups, we should firstly analyze cohesive subgroups with strict definition. After that, we can analyze cohesive subgroups in loose definition. For example, we can analyze the cliques firstly. if there is no cliques in the network, we should further analyze the n-cliques, n-clans, k-plex, k-core, component, Lambda set and so on.

The research team generally has close relationship of cooperation, so we can find the cohesive subgroups easily through the cliques analysis. In this research we select the cliques analysis to analyze the cohesive subgroups. In the cliques analysis of multi-value matrix A, we set the minimum size of cliques members into 3. We find 20 Cliques in this network (Table 3).

Table 3. WISE LAB team Cliques

| **Cliques No.** | **Memebers** |
|---|---|
| 1 | P1 P6 P7 P11 P17 P19 P23 |
| 2 | P1 P6 P7 P11 P12 P19 |
| 3 | P1 P4 P6 P7 P11 P12 |
| 4 | P1 P5 P6 P7 P19 P23 |
| 5 | P1 P5 P6 P7 P8 P23 |
| 6 | P1 P4 P5 P6 P7 |
| 7 | P1 P6 P7 P8 P17 P23 |
| 8 | P1 P3 P5 P6 |
| 9 | P1 P3 P6 P12 |
| 10 | P1 P2 P14 |
| 11 | P1 P2 P15 |
| 12 | P1 P4 P9 |
| 13 | P1 P9 P21 |
| 14 | P1 P9 P22 |
| 15 | P1 P10 P19 |
| 16 | P1 P12 P16 P19 |
| 17 | P1 P8 P16 |
| 18 | P1 P3 P21 |
| 19 | P1 P12 P22 |
| 20 | P3 P5 P13 |

In a network, a clique is a maximal complete sub-network which includes at least three points. It means that every two points in the cliques connect with each other. Therefore, if we find fewer cliques in a network, but the cliques include many members, we can consider that there is close cohesion in the network. In addition, if we find many cliques in a network, but the cliques include several members, we can also consider that there is close cohesion in the network. Contrarily, if we find fewer cliques in a network and fewer members in the cliques, we can consider that the network structure is loose. According to the cliques in Table 2, we can see that there are many cliques in the WISE LAB team network and fewer members in the cliques. We believe there is higher close degree of cooperation in WISE LAB team.

Meanwhile, we find that P1 has close cooperation relationships in 19 cliques. We believe P1 is the core member in the team and P1 play an important role of cooperation and exchanging information among cliques. We also find that two members (P18, P20) are not included in any of the cliques .it means that anyone of these two members hasn't effective cooperation with each other two members, and they has loose cooperation relationship with the team. So they should strengthen the cooperation research with the others members in the team.

E. Network Centrality Analysis

Centrality analysis is one of the key issues in the research of social network analysis. It can measure the central status of individuals or organizations in the social networks. We can analysis the close degree of cooperation in a research team from point centrality, betweenness centrality and closeness centrality of members or the whole team. These three types include centrality of every point and centralization of a graph. We can find the core members in the team through the analyzing of centrality of every point. in the meaning of sociology, these core members is the people of the highest social status and have the most power in the organizational behavior. The ones who has high value of centrality has an important status in the team. Centralization of a graph doesn't like the network density. It represents the focus of power in groups. Just like that the team interaction or cooperation focused on the minority members. The higher the value of Centralization in a graph, the more difficult share and communicate the knowledge in the team.

We analyze the point centrality, betweenness centrality and closeness centrality of multi-value matrix A and conclude three centralizations of the WISE LAB team network (Table 4). We also add the value of centralizations of star network and ring network/ complete network in table 4 so that we can easily compare the centralizations.

The values of centralization of the star network is 100% and the values of ring network / complete network is 0%, so we can see that the WISE LAB team cooperation network is not exactly a form of star network or ring network / complete network from the data of table 4. The structure of WISE network just like the aforementioned analysis is mesh structure and does not fully meet the condition of complete network. We believe that the values of centralization in table 4 can reflect the interleaving degree of the network. We consider that as a research team, its values of centralization of cooperation network should not be too high. If the values of

centralization are too high, the power, resource and achievement of the team will more concentrate into several members in the team. The higher centralization may do harm to the development of the whole team, and affect the close degree of cooperation in the team. Therefore, a research team with higher close degree of cooperation should try to lower the values of centralization.

Table 4. Values of centralization

| types of network / centralization of a graph | WISE LAB team cooperation network (multi-value matrix A) | star network | ring network/ complete network |
|---|---|---|---|
| **point centrality** | 38.60% | 100% | 0% |
| **betweenness centrality** | 54.49% | 100% | 0% |
| **closeness centrality** | 71.95% | 100% | 0% |

## V. CONCLUSION

This research use six indicators including network structure, network density, compactness, average distance between points, cliques analysis and centrality analysis to analyze the internal close degree of cooperation in a research team. However it is not limited to these six indicators when we measure the internal close degree of cooperation. Besides these six indicators maybe measure other aspects in the team's cooperation network. In the analysis above, these six indicators can better explain and reflect the internal close degree of cooperation in a research team. Moreover, we conclude the network characteristics in a research team with high internal close degree of cooperation through the analysis of these indicators: (1) mesh network structure; (2) higher value of Avg Value, Density, No. of Ties and lower values of Std Dev in the analysis of network density; (3) higher value of compactness and lower value of average distance between points in the analysis of cohesion; (4) shorter average distance between points; (5)in the cliques analysis, there are several cliques with more members in the cliques or more cliques with several members in the cliques (6)lower values in every centralization of the network.

It is not enough to entirely measure the close degree of cooperation in research team only using these six indicators mentioned above. Therefore in the further study, we can also extend this research from the following aspects: such as comparison of members cooperation between inside and outside of the team; comparison of team members' papers between personal and co-author papers; further study of the measurement indicators and the adjustment the indicators to enhance the measurement system; selecting more research teams and expanding the range of data sets to verify the rationality of indicators.

## REFERENCES


[1]Luo Jiade. Social Network Analysis [M].Beijing: Social Sciences Academic Press,2005:11

[2]Liu Jun. Lectures on Whole Network Approach[M].Shanghai: Shanghai People's Publishing House,2009:4-7

[3]Zhu Qinghua,Li Liang. Social Network Analysis Method & Its Application in Information Science[J]. Information Studies:Theory & Application,2008(2):179-183

[4]Wang Fusheng, Yang Hongyong. Author Collaboration Network Model and Demonstration Study[J]. Library and Information Service,2007,51(10):68-71

[5]Zhang Peng. The Community Structure of Scientific Collaboration Network[J]. Complex Systems and Complexity Science,2005,2(2):30-34.

[6]Zhang Xiumei, Wu Wei. Visualization of Scientific Collaboration Networks and Its Application in Bibliographical Retrieval Service[J]. Journal of the China Society for Scientific and Technical Information,2006,25(2):9-15

[7]Liu Jie, Lu Junan. A Small Scientific Collaboration Complex Networks and Its Analysis[J]. Complex Systems and Complexity Science,2004,1(3):56-61

[8]Zhang Haiyan,Liuna,Chen Shijun.etc. Evaluation on the Collaboration of Teams Based on SNA Technology[J]. Higher Vocational Education(Journal of Tianjin Professional College),2008(1):83-85.

[9]Ming yu,Si Huke,Su Yanfeng. The Study of Performance of Sport Research Team Impacted by Team Network Structure[J]. Journal of Nanjing Institute of Physical Education(Social Science),2009(4):72-76.

[10]Feng Bo,Liu Jia. Social network analysis of knowledge sharing in research teams of universities[J]. Studies in Science of Science,2007(6):1156-1163.

[11]Yang Heng-Li, Tang Jih-Hsin. Team structure and team performance in IS development: a social network perspective[J]. Information & Management, 2004, 41(3): 335-349.

[12]Jesus Rey-Rocha, Belen Garzon-Garcia, Jose Martin-Sempere. Scientists' performance and consolidation of research teams in Biology and Biomedicine at the Spanish Council for Scientific Research[J]. Scientometrics,2006,69(2)：183-212.

[13]Jose Martin-Sempere, Belen Garzon-Garcia,Jesus Rey-Rocha. Team consolidation, social integration and scientists' research performance An empirical study in the Biology and Biomedicine field[J]. Scientometrics,2008,76(3): 457-482.

[14]Zhou Jizhong.Innovation Management of Science and Technology[M].Beijing: Economic Science Press,2002:57.

[15]Jiang Rifu,Huo Guoqing,Tang Hongjun.etc. Investigation on the situations of scientific research teams in Chinese state-owned scientific institutions[J]. Studies in Science of Science,2007(2):364-372.

[16]Webometrics, Informetrics, Scientometrics and Econometrics La[EB/OL].[2010-6-22].http://www.wiselab.cn

[17]UCINET[EB/OL].[2010-6-22]. http://www.analytictech.com/ucinet/

[18]Widmeyer W. N.，Canon A. V., Brawley R. Group Cohesion in Sport and Exercise. Handbook of Research on Sport Psychology,1993:672-679.

[19]Liu Jun. Lectures on Whole Network Approach[M].Shanghai: Shanghai People's Publishing House,2009:15

[20]Wasserman S., Faust K. Social Network Analysis: Methods and Applications[M]. Cambridge : Cambridge University Press,1994：249.

[21]Liu Jun. Lectures on Whole Network Approach[M].Shanghai: Shanghai People's Publishing House,2009:154