CSCanada
Management Science and Engineering
Vol. 7, No. 3, 2013, pp. 13-21
DOI:10.3968/j.mse.1913035X20130703.3246

ISSN 1913-0341 [Print]
ISSN 1913-035X [Online]
www.cscanada.net
www.cscanada.org

Research on Industry Alliance Knowledge Transfer Network Modeling and Simulation Based on Complex Networks

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Supported by National Social Science Fund (No.11BGL039), National Natural Science Fund (No. 71271119), College Philosophy and Social Sciences Key Projects in Jiangsu Province (No. 2011ZDIXM036), 2011 Doctoral Scientific Fund Project of the Ministry of Education (No. 20113223110007), and 2012 Humanities and Social Science Research Fund Project of the Ministry of Education (No. 12YJA630169).

Received 8 April 2013; accepted 12 August 2013

Abstract
The booming of the complex network research provides new avenues of research and support for various types of complex systems. And a large number of studies have shown that industrial technology innovation coalition belongs to the scope of complex system, so it is available to use the complex network theory to study it. This paper first describes the theory of complex networks. Second, the use of complex network theory in the industry alliance knowledge transfer is probed in terms of the overall network structure, network node centrality and network subgroup. Finally, the industry alliances knowledge transfer network model is constructed and the quantitative analysis of the simulation example is done with the network analysis tool, reflecting the effectiveness of analyzing knowledge transfer from a complex network perspective.

Key words: Industry technology innovation coalition; Complex network; Knowledge transfer; Network

MA Xuejun, WU Jie, ZHANG Yujie (2013). Research on Industry Alliance Knowledge Transfer Network Modeling and Simulation Based on Complex Networks. *Management Science and Engineering*, *7*(3), 13-21. Available from: URL: http://www.cscanada.net/index.php/mse/article/view/j.mse.1913035X20130703.3246
DOI: http://dx.doi.org/10.3968/j.mse.1913035X20130703.3246

INTRODUCTION
With the development of knowledge economy and the increasingly fierce market competition, the traditional enterprise due to various constraints, has not been able to adapt to the needs of the times. More and more companies have chosen Industrial Technology Innovation Alliance, I hope by the Union to achieve resource sharing, complementary capabilities, the purpose to improve their competitiveness. Industrial technology innovation alliance is a dynamic partnership to intellectual activity as the foundation, its formation and development stems from in the knowledge transfer between members. How to improve their competitiveness through the Union's knowledge transfer mechanisms become a major concern of the members of the League.

In recent years, the rise of complex networks makes the various disciplines in the field of research has been substantial breakthroughs, to re-examine the study provides a complete set of analytical methods and a unique perspective of thinking. Therefore, the use of complex network theory to guide the study of the field of knowledge management may well be a useful attempt. It will draw complex network theory to the Industrial Technology Innovation Alliance the industry alliance knowledge transfer issues from the perspective of the network, build industry alliances knowledge transfer network model and make use of relevant software simulation quantitative analysis for the Union knowledge transfer activities provides a new way of thinking.

The paper is organized as follows. Section 2 discusses an overview of the theory of complex network which include scale-free network. Section 3 contains the description of Application of complex network in alliance knowledge transfer. Section 4 introduces Industry alliance knowledge transfer network model. Section 5 is devoted to the numerical simulation and interprets the empirical results; Finally, Section 6 provides some concluding remarks and implications.

1. OVERVIEW OF COMPLEX NETWORK THEORY

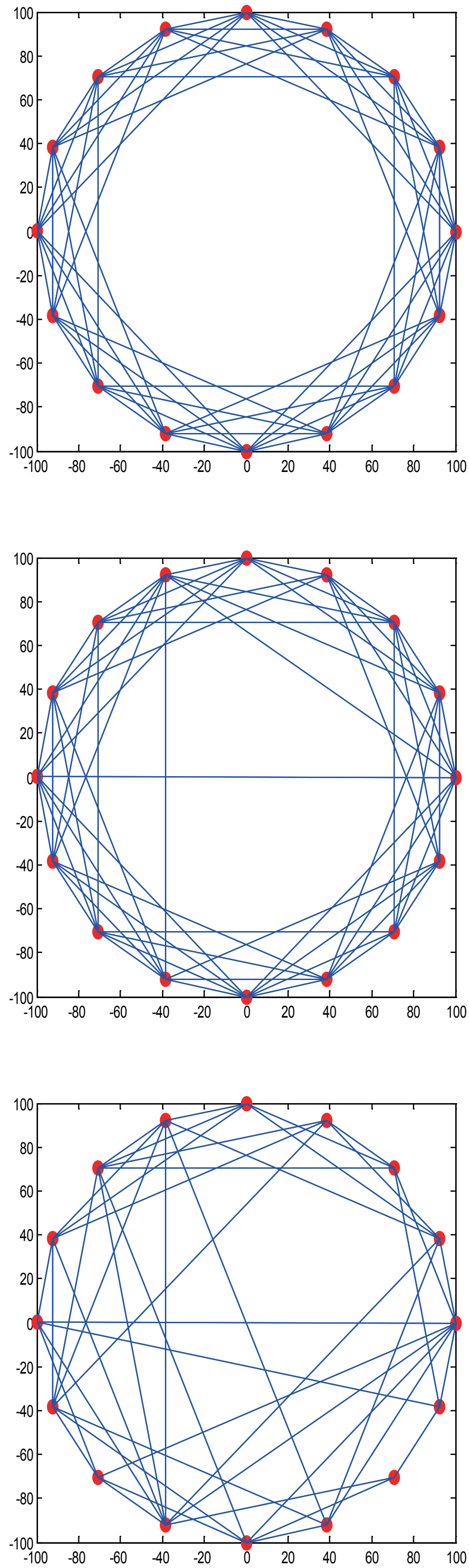
In 1736 the German mathematician Euler of famous "Königsberg Bridge Problem" marked the use of the network's point of view to describe the beginning of the objective world, to create a branch of mathematics - graph theory. Abstract figure shows the abstract point of nodes in the network to represent the connection between the nodes in the network connection between the nodes. In 1960, the mathematician Erdos and Renyi proposed topology analysis of complexity of the network with random graph theory, the research model is called the "ER model", opened a new era for the study of complex networks. Many of the results obtained in recent years, scientists have a lot of real network computing research deviates from the random graph theory, therefore, the need for new and more rational complex network model to describe the characteristics apparent in the actual network. In 1998, Watts and Strogatz published paper in Nature entitled "Collective dynamics of small-world networks" (Wstts & Strogatz, 1998), a well-known WS small world network model to construct a range of regular networks and random networks between the networks—small-world networks. Scholars subsequent studies have shown that real network almost all small-world effect, but the model does not portray the actual network found that the prevalence of the "rich get richer" phenomenon. In 1999, Albert and Barabási in Science pointed out that many practical complex network connectivity distributions with a power-law function type, no significant measurable characteristics of the power-law distribution of such network is also known as scale-free networks. Both studies caused huge concern in the scientific community, the subsequent set off a craze of the study of complex networks in the world.

Small-world networks is a transition which from a completely random network to completely regular network, the network has a high degree of aggregation and random networks of the regular network short path characteristics. WS small-world network model construction algorithm (Li, 2009) is as follows:

(a) Starting from the regular graph: Consider a nearest neighbor coupling network with N points, they are surrounded by a ring, wherein each node and its left and right adjacent to each of K / 2 connected to the node, K is even.

(b) Randomized reconnection: Cycle through all of the rim, reconnect with probability p to a randomly chosen node, the edge of one of the endpoints remain unchanged, while the other endpoint is taken as the random selection of a node in the network which states that only one connection between nodes and each node does not allow self-join.

In the above model, p = 0 corresponds to completely rule network, p = 1 corresponds to a completely random network, the transition from a completely regular network to a completely random network, as shown in Figure 1 can be controlled by adjusting the value of p:



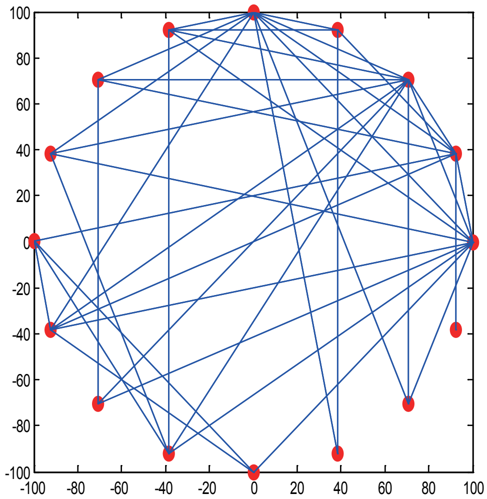


Figure 1
WS Diagram (N = 20, K = 4, p = 0.001, 0.1, 0.5, 0.999)

ER random graph and WS small-world networks are a common feature of the model is the network connection distribution can be approximated using the Poisson distribution, such networks also known as homogeneous networks or exponential networks. In recent years, the study found that node degree of many complex networks follows a power law distribution. In order to explain the mechanism of the power-law distribution, Barabási and Albert proposed BA scale-free network model. Scale-free networks generated by the model are two basic mechanisms of growth and preferential attachment (Liu & Chen, 2010), "growth" means the total number of nodes is not fixed, but a growing dynamic process; "Preferential attachment" indicates that the connection between the nodes in the network is a preference, which characterizes the "rich get richer" phenomenon prevalent in the real network. The construction algorithm is as follows:

(a) Growth: a small amount of m_0 nodes in the initial network, each time step, the introduction of a new node is connected to the m node already exists, where m $\leq m_0$;

(b) Preferred choice: in the choice of m nodes connected, follow the principle of preferential attachment. The probability Π_i is connected to the probability of a new node with existing nodes i, which satisfies the following relationship with the degree k_i of node, i:

$$\prod i = \frac{k_i}{\Sigma k_j}$$

In the above formula, the denominator is taken over the existing network of each of the connecting nodes of degree. After t time step, the network evolved into an existing $N = m_0 + t$ nodes, MT edges of the network, and the network's degree distribution follows a power law distribution of $P(k) \sim k^{-\gamma}$, γ value is typically between 2~3. Most of the node has only a few connections, while a few nodes have a large number of connections. If the node degree distribution logarithmic painting in the double logarithmic coordinates, the results will be a straight line, as shown in Figure 2:

The probability distribution of node degrees in the network diagram

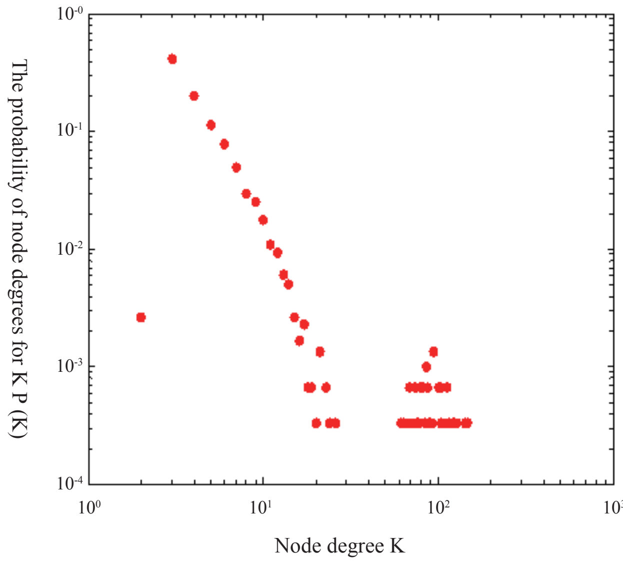


Figure 2
BA Scale-Free Network Node Degree Distribution

2. APPLICATION OF COMPLEX NETWORK IN ALLIANCE KNOWLEDGE TRANSFER

Industry Alliance is a complex system in the economic field, the Union separate open complex systems linked through knowledge transfer between alliance members learn from each other and exchange between them constitute a complex knowledge transfer network. Industry alliance knowledge transfer networks with complex network characteristics, so we can apply complex network analysis method combined with the corresponding software tools, measurement and analysis of knowledge transfer network structure, which helps members of the Alliance to implement management measures to quantify evaluation. Complex network structure features (Ding, Chen, & Han, 2008) include: The overall structural characteristics of the network, including network density, the average path length, network-centric and the degree distribution; the individual structural features of the network, including node centrality, node degree, structural holes; structural characteristics of the network subgroup. In order to meet the research needs, will collect some related metrics analysis.

2.1 To Analysis Knowledge Transfer from the Overall Structure of the Network

The overall structural characteristics of the network

(Ca, 2010), including network density, network average distance etc, different structural characteristics of the network have different effects on the alliance knowledge transfer. The network density is a common language in the knowledge network analysis used to measure the close connection between each node in a network. In an undirected graph, which is calculated as $e = 2L/ [n (n-1)]$, where L is the actual number of connections in the network, n is the number of nodes in the range of [0, 1]. Moderate connected network facilitates the transfer and diffusion of knowledge, the network density is too low will limit the effective communication between network nodes, but the density is too high will result in increased opportunity costs and the reduction of the efficiency of knowledge transfer. Therefore, alliance members to grasp the overall network density, to minimize the cost to get the maximum knowledge transfer, to avoid redundant network density. The shortest distance d_{ij} between nodes i and j is defined as the number of edges of the shortest path connecting two nodes in the network. Network average distance *D* is defined as the average of the shortest distance of any two nodes, it indicates that the degree of separation between the nodes in the network, i.e. the network how small, reflecting the global characteristics of the network. N is the number of nodes in the network, the $D=\Sigma d_{ij} / [n(n-1)]$, $i\neq j$. The average path length of the network determines the smoothness of this parameter is smaller, indicating that the shorter the time to reach the target position, the smaller the distortion.

2.2 To Analysis Knowledge Transfer from the Individual Networks Structure

Node centrality in the network of individual structural features is an important indicator, a measure of the central tendency of a single node in the network. Node centrality in three indicators: degree centrality, betweenness centrality and closeness centrality. Centrality analysis will help prevent the loss of knowledge to improve the ability of the alliance as a whole knowledge transfer. Degree centrality can be measured from two aspects, the first is the absolute degree centrality, is the direct number and the related points; the other is the relative degree centrality, is absolutely central numerical node and degree in the graph limit value ratio, namely $C(i)$ and $C(i) = k_i /(n-1)$. In the network, the node's degree centrality is higher, more contact with other nodes, living in the central position of the whole network, have greater "power" and influence in the network. Degree centrality is too high or too low is not conducive to the transfer and dissemination of knowledge. For the high degree centrality, actors will be stressful because of excessive dependence. Once the actors exit the organization or fails, the entire network knowledge transfer will be affected and even lead to the collapse and fragmentation of the network. Therefore, the industry alliance analyzes the knowledge transfer from the node centrality network, you should identify the key nodes, and to take measures to protect and improve it. At the same time, focus on improving the level of knowledge and cooperation of the key nodes, to better play the role of connectivity. On the other hand, the low degree centrality will lead to excessive fragmentation of the network, the lack of authority figures; the same is not conducive to the transfer of knowledge. In addition, the analysis also can find the marginalized in the network edge. These marginalized members may feel the lack of attention, enthusiasm frustrated, it may be in firm alliance does not get to play and participation of member companies. The alliance should pay more attention to the cultivation of these members, establish relevant system to promote the key nodes with the alliance of exchanges, expand the edge nodes in knowledge transfer pathway.

Betweenness centrality (Jiang, 2011) is used to measure the ability to control other nodes a node. In the network, if a node in the path between many of the other two nodes, then the betweenness centrality of this node is high, living an important position in the network, because of its ability to control the other two actors shared. In alliance knowledge transfer network, betweenness centrality high members can contact more members of the network, there are more opportunities to acquire knowledge from different channels and promote knowledge exchange between the different members, thus promoting the knowledge transfer network. Closeness centrality (Jiang, 2011) used to measure the distance of a node with other nodes, the shorter means that the node can be connected to many other nodes through a short path, so closeness centrality of this node is smaller, and the node plays a more crucial role in the network. Correspondingly, members with higher closeness centrality access to other members of the path is the longer, more difficult access to knowledge and information, the higher the cost of the exchange of knowledge. Such members are usually in a non-core status, must rely on the specific contact object to access and transfer of knowledge within the organization, which is not conducive to the spread of knowledge throughout the network. At the same time, members with lower closeness centrality more easily with other members to exchange knowledge, and can bring the other members of the communication distance is shortened, thereby shortening the entire network of communication distance, to maximize the shortest connection between members.

2.3 Analysis of Alliance Knowledge Transfer from the Network Subgroup

With the in-depth study on the physical meaning of the nature of the network and the mathematical properties, find many practical network structure often exhibit a certain degree of aggregation, a particularly close relationship of partial knowledge node, increasing the similarity of knowledge between the node will formed several networks subgroup. Connections between nodes of each group within the relatively very closely, but the connection between each group looks relatively sparse. Nodes connected incoherent network subgroup called bridging. In reality, the alliance knowledge transfer network is more complex, one of the actors may come from the same company, or it may come from different organizations. You should increase the knowledge transfer of network bridge connection, the positive development of persons responsible for all members of the organization into a network of subgroups of bridge, in order to promote the exchange and dissemination of knowledge within the alliance. At the same time, be good at discovering existing bridging in the alliance, actively encourage other members to exchange knowledge, optimize the knowledge transfer path, expand channels and scope of knowledge transfer. Daily exchange mechanism should be established within the alliance, and create a culture conducive to knowledge transfer, such as increasing the seminars regularly work interviews, group project groups, informal organization, formed to promote the alliance network subgroup.

3. INDUSTRY ALLIANCE KNOWLEDGE TRANSFER NETWORK MODEL

The formation and development of the industry alliance stems from the knowledge transfer activities between members, you can abstract the industry alliance knowledge transfer activities of the network as a complex network, and then the application of complex network theory and methods to study. In reality, with the increasingly fierce market competition and the advantages of industry alliance emerge constantly, more and more enterprises will choose to join the industry alliance. Therefore, the number of members of the alliance is growing, that the alliance is open, dynamic growth, from time to time, there will be new members to join the alliance; In the real industry alliance, the propagation process of a specific knowledge, where exists knowledge sender and receiver in the communication between members of knowledge, industry alliance knowledge transfer network is a directed network; Furthermore, since each member's knowledge similarity, level of knowledge and ability to absorb knowledge of different and cause the differences exist among the members of closer relations, so the knowledge exchanges frequently vary, the efficiency of knowledge transfer is different (Zhao & Zhang, 2010).

According to the above situation, 3 hypotheses are put forward to construct the model:

(a) Assuming that the knowledge transfer network is open, dynamic growth, i.e the number of nodes in the network will increase over time.

(b) Assuming that the knowledge transfer network in the industry alliance is a directed network, that is, for a particular knowledge which has an ordered relationship between nodes;

(c) Assuming that the knowledge transfer network in the industry alliance is a weighted network, the weights represent the number of knowledge transfer in this direction, the greater the value of the right, which means that knowledge transfer between the two exchanges more frequently.

According to the description based on the of the network graph theory, industrial alliance knowledge transfer network is abstracted as graph $G = (N, E, W)$, where $N = \{ n_1, n_2, n_3 ,,n_n \}$ represents knowledge transfer network node set. $E = \{e_1, e_2, e_3, , e_k\}$ represents the set of relations of the knowledge transfer network, where e_{ij} represents a directed edge which connected n_i and n_j, which means that the node n_i knowledge transfer to n_j.

When $e_{ij} = 1$, suggesting that the knowledge transfer can be found between the node n_i and n_j, that there is a connection side;

When $e_{ij} = 0$, suggesting that without knowledge transfer can be found between the node n_i and n_j, there is no connection side.

$W=\{w_1, w_2, w_3, , w_n\}$ represents the set of the weights of relations of the knowledge transfer network, where w_{ij} represents the weight of knowledge transfer relationship between n_i and n_j, which means that the frequency and of knowledge transfer in this direction, as shown in Figure 3:

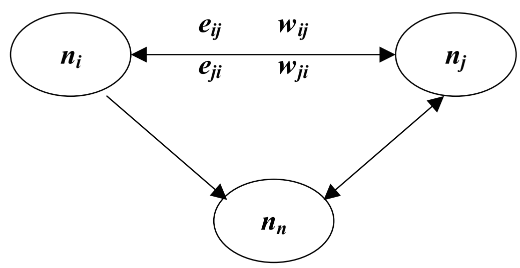


Figure 3
Knowledge Transfer Network of Local Demonstration

Figure 3 indicates that our sample only represents a local simplified model of knowledge transfer network of Industry Alliance, but in the real knowledge transfer network would involve much more complex factors than the above figure, including more nodes, more sides of the connecting edges between nodes and more hierarchies. In the knowledge communication process of industry alliance, the specific path of knowledge transfer as shown above, the knowledge among the nodes are connected through the transfer path. According to the actual situation, we can define the weight values of connection path, and then the adjacency matrix $\{e_{ij}\}$ and the weighting matrix $\{w_{ij}\}$ can be calculated.

4. NUMERICAL SIMULATION

In order to better analyze the practical significance of alliance enterprise knowledge transfer from the perspective of complex network, through a simple hypothetical example combined with the constructed model in Section 4, we can simulate knowledge transfer networks of industry alliance with network analysis software UCINET. In order to facilitate the interpretation and calculation, we will simplify the reality of a typical Industry Alliance, omitted some actual nodes and links, and assuming that the knowledge network is a non-weighted network. In this simulation example, to seize the market opportunities for improving their own competitiveness, assuming that there are 4 members respectively A, B, C, D building up industry alliance. Participation in their respective knowledge transfer, respectively, A (a_1, a_2, a_3, a_4); B (b_1, b_2, b_3); C (c_1, c_2, c_3); D (d_1, d_2). Table 1 shows the adjacency matrix of knowledge transfer network between alliance members by investigating and arranging the data information of nodes in the network.

Table 1
Knowledge Transfer Network Adjacency Matrix

	a_1	a_2	a_3	a_4	b_1	b_2	b_3	c_1	c_2	c_3	d_1	d_2
a_1	0	1	1	0	1	0	0	1	0	0	0	1
a_2	0	0	1	1	1	0	0	1	0	1	1	0
a_3	1	1	0	1	0	0	0	0	0	0	0	0
a_4	1	1	1	0	0	0	0	0	0	0	0	0
b_1	1	1	0	0	0	0	1	0	0	0	0	0
b_2	0	0	0	0	1	0	1	0	0	0	0	0
b_3	0	0	0	0	1	0	0	0	0	0	0	0
c_1	0	1	0	0	0	0	0	0	0	0	0	0
c_2	0	0	1	0	0	0	0	0	0	0	0	1
c_3	0	1	0	0	0	0	0	0	0	0	0	0
d_1	0	1	0	0	0	0	0	0	0	0	0	1
d_2	1	0	0	0	0	0	0	0	1	0	0	0

Figure 4 is drawn using Netdraw software, to describe the knowledge transfer network of industry alliance.

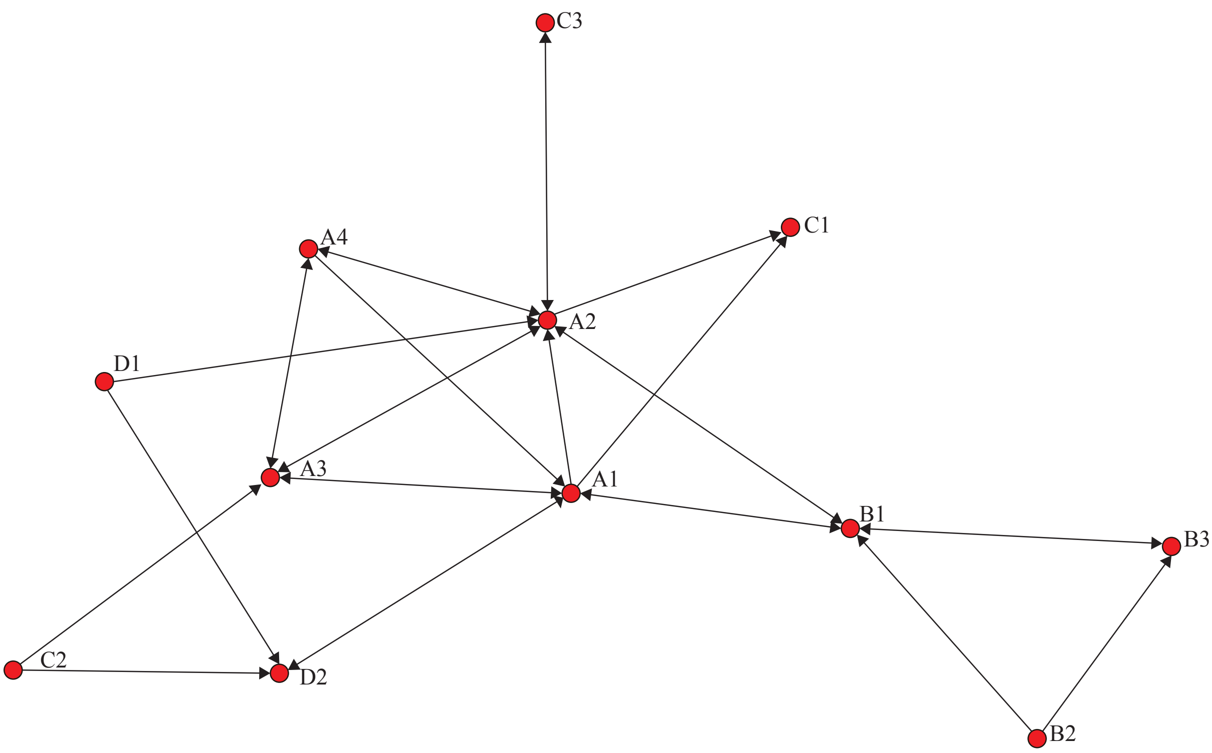


Figure 4
Industry Alliance Knowledge Transfer Network Structure

5. DISCUSSION OF RESULTS

5.1 Overall Structure of the Network Analysis Making

We can calculate the average density of knowledge transfer network with UCINET software, Density = 0.2348, the value is low, which means that will limit the efficiency of the exchange of knowledge between nodes. By observing any two nodes, it is found that they are up to, but requires more media, which will affect the overall level of knowledge transfer. This indicates that the density of exchange of knowledge of the alliance members need to be further improved. The network average distance is used to measure the number of links between any two nodes which need to communicate in the network. In our example, the value of network's average distance is equal to 2.099 which suggest that any node who wants to achieve knowledge transfer in the network needs averagely two media.

5.2 Analysis of Network Centrality

Measuring network centrality with the software, and the results are shown in Table 2:

Table 2
The Centrality of Each Node in Knowledge Transfer Network

	Degree	Between	Closeness
a_1	6	14.667	28.000
a_2	7	23.333	27.000
a_3	4	6.167	32.000
a_4	3	0.000	33.000
b_1	4	18.000	31.000
b_2	2	0.000	40.000
b_3	2	0.000	40.000
c_1	2	0.000	35.000
c_2	2	0.500	39.000
c_3	1	0.000	37.000
d_1	2	1.000	34.000
d_2	3	3.333	34.000

Overall Table 3 shows members A of the League plays an important role in the knowledge network, especially the a_1 degree centrality (Degree) reached 70%, 60% for a_2, that plays a positive role in the entire league, indicating that the actors a_1, a_2 in the flow of knowledge, they should pay attention to the protection of the core, give full play to its influence in the network. While only a few nodes of the other members in knowledge transfer networks have played a positive role, such as b_1, c_2, d_1 respectively become a key node of the members. Members of the A can take advantage of the key nodes of the other members; to enhance each other's knowledge transfer B, C and D members should develop incentive system to encourage internal members to carry out the exchange and transfer of knowledge with other members. In the process of acquiring knowledge resources, we can focus on contact with the actor a_1, a_2, thereby expanding the scope of knowledge transfer in the shortest distance, promote the whole network knowledge exchange. We can also find in Table 3, the degree centrality of c_3 is lowest, so it became the edge of the network nodes, not to play an adequate role in the alliance knowledge transfer, likely to cause the loss of knowledge. The C members cope with the actors c_3 take some incentives to enhance the exchange of knowledge with other nodes.

Besides that, given the Closeness Centrality data in Table 3, although d_1 is not the key node in the knowledge transfer network, but its closeness centrality has a relatively small advantage, has the potential to develop into a key node. d_1 can be regarded as a potential key nodes, and Members D should take corresponding measures and means to optimize the path of the exchange of knowledge, and promote their development to become a key node of the network as a whole.

5.3 Analysis of Network Subgroup

According to the K-plex method defined subgroups, and with the help of software for the judge, when K =1 and the number of nodes of the network subgroup is not less than 3, the network consists of four network Subgroups: a_1, a_2, a_3, a_4; a_1, a_2, b_1; a_1, a_2, c_1; b_1, b_2, b_3. Notably, a_1, a_2 between the different subgroups plays a role of bridge connection. In the internal knowledge transfers of the A, B are in close communication, is conducive to the promotion of their own knowledge level. In the subgroup contained b_1, does not involve b_2, b_3, indicating knowledge transfer between B members b_2, b_3 with other members lack of knowledge transfer, the knowledge exchange to be enhanced. Subgroup contains c_1 there is no c_2, c_3 participation, indicating that internal actors of the C with other external members are in rare communication, which for the complete knowledge transfer task, improve the competitive advantage of the members is very unfavorable.

5.4 Selection of the Optimal Path of Knowledge Transfer (Zhang, Guo, & Cai, 2010)

The use of software can quickly find out the trajectory of the optimal path from the source node to the destination node, so as to promote the efficiency of knowledge transfer across the network, reduce the cost of the exchange of knowledge. For example, when the actor b_3 want to get the knowledge originally belonged to c_2, with UCINET6.0 may find the three transfer paths: c_2-a_3-a_1-b_1-b_3, c_2-a_3-a_2-b_1-b_3, and c_2-d_2-a_1-b_1-b_3. At this time, the b_3 should be preferred route 1 or route 2. Although the path 3 has the same distance (4 steps) as the other two transfer paths, but need to go through the members of the D and A, and the path 1 or 2 only after members of the A. Typically, the difficulty of knowledge transfer between the alliance members is far greater than the exchange of knowledge among members of actors. Meanwhile, in the paths 1 and 2, we can also compare the knowledge transfer capacity of a_1 to a_2, to select the most beneficial knowledge transfer object as pathways node, in order to improve the efficiency of knowledge acquisition.

6. SUGGESTIONS

Based on the above analysis, it puts forward the corresponding suggestions on the network optimization:

(a) Accurately identify the key nodes (a_1, a_2) in the network. These two nodes to communicate frequently with other nodes, they are in the core of the network status, have a greater influence in the network. A member should protect and make the most of the central position of actors a_2, a_1, the fully authorized to give full play to its value. The key nodes in the knowledge transfer network plays an important role, the alliance should analyze the knowledge and relationships of key nodes on the status and role of dominance, to ensure its position and influence in the formal organization structure in the network in the same position and influence; At the same time , the alliance need to enhance the identity of the key nodes in the eyes of other members , the other members want to focus on connecting with the key nodes in order to expand their effective knowledge transfer paths.

(b) Vigorously develop the potential critical node d1. When we analyze the network nodes, we should pay attention to the potential ability of development, most to play and promote each node of the knowledge transfer level. Potential key nodes usually occupy the location of the key links between the nodes in the knowledge transfer network and play a role of intermediary or bridge. Therefore, performance evaluation, incentive system and other measures are applied to expand the breadth and scope of knowledge transfer relationship, and developed it into a key node of the entire network. For the d_1, we can take targeted strategies to maintain and develop, to ensure their own ability and the other node's contribution.

(c) We should devote more efforts to improve network density and foster more network subgroup. If the density of knowledge communication in the network is too low, making the exchange of knowledge between the members of the League hampered by the lack of effective communication channels, and even lead to lower knowledge transfer efficiency of the entire network. Especially for the members of the C, D, lacking of internal knowledge exchange, it will not help to complete the knowledge transfer task and improve their competitive advantage, where network centricity of c_1, c_3, d_1 is all low, they become the edge nodes of the network which tends to cause loss of knowledge. For the reality of the industry alliance, the leader of the members should be developed to become the bridge of the network, and establish daily contact mechanism in the alliance to focus on the relevant issues, in order to increase the number of bridge in the whole network; Accordingly in each member inside, we should strive to create a culture atmosphere conducive to knowledge transfer, increase the internal channels of communication (formal or informal) in the work to promote more network subgroup formed inside the members as well as with other members.

(d) Correctly select the optimal path to obtain the target knowledge. It is necessary to consider the length of the distance but also consider the special nature of the organization and the transfer ability of actors. For instance, such as members of the internal knowledge transfer more easily among the members of the knowledge transfer, transfer the actors ability will influence the results of knowledge transfer and transfer time consumption. For example, the knowledge transfer activities between the internal nodes of each member are easier than that among the alliance's own members to carry out, because the transfer capacity of the actors will influence the results of knowledge transfer and transfer time consumption. All the actors to consider the difficulty of knowledge transfer path, select the optimal path, reduce the knowledge exchange cost, and maximally improve efficiency and effectiveness of knowledge transfer.

CONCLUDING REMARKS

The present work could be extended in at least three directions. First, one could investigate the inherent mechanism and evolution of the industry alliance knowledge transfer more in-depth. The new model construction is based on the industry alliance knowledge transfer, which is the simplification of the real network. So its evolution algorithm should be further improved. Analyzing the actual situation of the industry alliance can provide a realistic basis for the theoretical model building. Second, enhance the applicability of the model in the industry alliance complex networks. At present, the use of complex network theory into the industry alliance is still in the trial stage, especially the weighted network research. How to make the complex network theory more effectively guide the industry alliance knowledge transfer activities is worthy of further study. Finally, increase empirical research and analysis. One could extend our model by conducting empirical research combined with case studies. Through analysis of a typical case, one could get a combination of qualitative analysis and quantitative analysis, which will become further research objectives of this study.

ACKNOWLEDGEMENTS

We would like to thank my advisor Jie Wu for offering the helps on my paper.

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