A Study of Tacit Knowledge Transfer Based on Complex Networks Technology in Hierarchical Organizations

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Abstract. In reality, most economic entities are hierarchical organizations. But in the hierarchical organizations tacit knowledge can be transferred across different hierarchies even across different departments. By use of complex networks technology, a hierarchical organization's framework is modeled in this paper. Through quantifying a number of technical datas we analyze and have a research on the transfer distance and the optimum tacit knowledge transfer path in hierarchy networks.

Keywords: hierarchical organization, complex networks, optimum path, tacit knowledge.

1 Introduction

The acquisition, classification and management of explicit knowledge improve enterprise's knowledge reservation and application efficiently, but tacit knowledge's acquisition and transfer flourish the information's experience exchange and accumulation in organizations. By contrast explicit knowledge can be obtained and transferred more easily. Through the means of informatization we are easy to achieve explicit knowledge's storage and access. But tacit knowledge's acquisition and transfer are relatively difficulty. Because tacit knowledge such as skills in the working, experience and personal opinion only exist in the heads of staff and in organizational culture, it is difficultly stored and transferred by computer and some other media. Furthermore it is mostly transferred only through the exchanges and collaboration between the staff. Now we all know the study of tacit knowledge's access and transfer are very useful to deliver enterprise information knowledge and exchange technical experience. During the study of the tacit knowledge's transfer and access, literature [1] studies the tacit knowledge effect in group decision making, describe three forms of tacit knowledge movement, referred a knowledge management application framework based on tacit knowledge in group decision making. Literature [2] put forward an IT

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application framework based on tacit knowledge management, which consists of three hierarchies and four subsystems; the framework provides a approach to use tacit knowledge. The literature [3] referred a switch framework to change tacit knowledge into explicit knowledge in industrial design by the analysis of some examples. Literature [4] studied what kind of way does the virtual enterprise access to the knowledge, put forward two different acquiring knowledge ways , one way in explicit knowledge transfer process and the other way in tacit knowledge transfer process, and use an example in the field of architecture to illuminate the obtaining tacit knowledge means. The literature [5] referred the way how to acquire tacit knowledge source in the hierarchical organization, referred a quantitative method of obtaining tacit knowledge which improves the efficiency and quality of the organizations.

However in traditional hierarchical structure organizations tacit knowledge is not transferred in the simple hierarchy way, for example the vertical transfer way between the superior and the subordinate and the spread way within the department group. In fact knowledge is often transferred across hierarchy and across departments. This kind of knowledge transfer way has networks properties. So the latest means of networks technology, such as modeling networks and calculating attributes related to transfer knowledge, is very useful to achieve quantitative analysis and calculation. By using the complex networks technology, such as model of hierarchy networks structure, this article makes out the distance between two networks nodes. At the same time, it gives the way how to choose the optimum path between networks nodes during the transfer knowledge.

2 Hierarchical Structure Organization and Its Tacit Knowledge Transfer

2.1 Hierarchical Organization Structure

Hierarchical structure is basic organizational structure model in actual conditions□the definition is expressed as follows:

Definition 1. Hierarchy: Hierarchy is defined as NET (N, A, R), in which N represents the node number of the hierarchy networks, A indicates the node properties, R represents the relationship between the nodes. Every node in networks must exhibit the following properties:

(1) Every node only has one father node;
(2) Every node only has one father node except the root node.

In the traditional hierarchy organization, R generally represents the relationship between the transfer between the superior and the subordinate in management process, or the relationship within the same department. Figure 1 illustrates the hierarchy structure of organization. On the graph, we describe nodes by $N_{i,j}$, i represents the node N is in the i hierarchy of the networks, j represents the node sequence in the N nodes, in the figure the networks totally exists 3 levels and 8 nodes, the second node in the third level expressed by $N_{3,2}$.

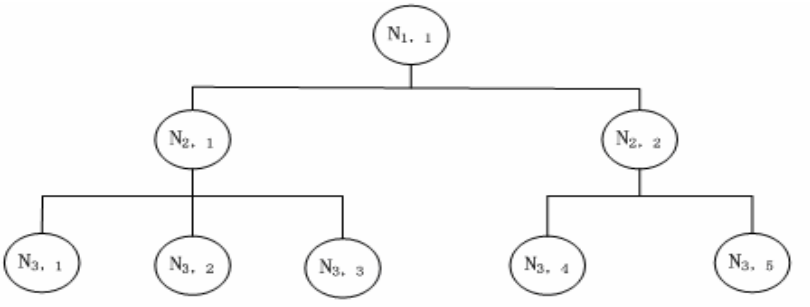

Fig. 1. The traditional hierarchical structure

However, in reality organizational management structure is not just concerned with such a mechanical hierarchy. In a hierarchical organization, there is relationship across hierarchy. For example, two members belong to the same team but not the same hierarchy and department can develop good relationship across hierarchy or across department. At the same time, learning oriental group or seminars and so on also form some different kinds of relationship across hierarchy. As a result, tacit knowledge transfer may across different hierarchies and different departments in organizations to achieve the aim of transferring knowledge.

2.2 Tacit Knowledge Transfer Channels in Hierarchical Organizations Which Have Association Degree

Knowledge transfer may across organizational level and across departments, the members of transferring knowledge mostly have some certain characteristics, such as the members belong to the same project team. To describe such a knowledge transfer hierarchical structure which is based on hierarchy and beyond the hierarchy structure, we give the definition 2, and also provide a new knowledge transfer route.

Definition 2. Association degree in hierarchy organization: in hierarchy networks NET(N,A,R), association degree is defined as a certain common characteristics among N (N>3) nodes ,we use L_i(i=1,2, .., m) represent different association degrees. In the hierarchical organizations, the N members belonging to different departments will exchange knowledge because they belong to the same project team. This relationship is beneficial to transfer tacit knowledge. This project team with N member becomes an association degree in hierarchy networks.

We use figure 2 to show the hierarchical structure with two association degrees L_1 and L_2. Because the networks has the association degree L_1, we can smoothly transfer knowledge between $N_{1,1}$ and $N_{3,4}$. In the same way we can divide all the nodes into two node sets by the association degree. $\{N_{1,1}, N_{2,1}, N_{2,2}, N_{3,4}, N_{3,5}\}$ is the sets of association degree L_1; $\{N_{1,1},N_{2,2},N_{3,1},N_{3,2}, N_{3,3}\}$ is the sets of association degree L_2. Obviously they have the same two set members $N_{1,1}$, $N_{2,2}$ by this kinds of classification.

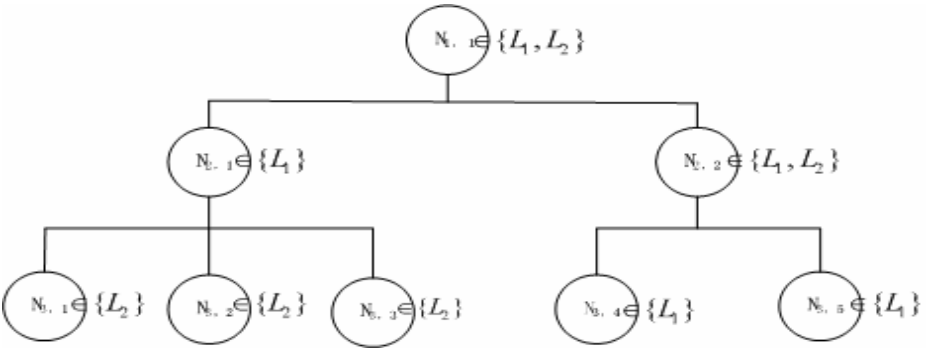

Fig. 2. A hierarchical structure with association degree

For this reason the knowledge can also be transferred between $N_{2,1}$ and $N_{3,5}$ through association degree L_1.

3 The Analysis of Networks Model and Knowledge Transfer in Hierarchical Organizations

3.1 Complex Networks and Its Technical Analysis

From traffic problems to the society relationship networks, networks have a closer contact with our lives than ever. The research of complex networks began at the 18th century, at that time the regular networks provide a means to establish and simulate some relations; in the mid-19th century the random networks becomes a more exact description of a random variable networks structure; at the end of the 20th century small-world theory found by Watts and Strogatz as well as Barabási and Albert's scale-free networks model create a new research way of complex networks [6]. In 1998, Watts and Strogatz in their "small-world" theory find a small world networks not only have a big cluster coefficient C but also have short average distance L [7]. WS small world theory truly demonstrates the characteristics of the networks, such as interpersonal networks and the disease spread networks. They all have the typical characteristics of small world networks - a big cluster coefficient and a short average distance. Small-world theory is good at explaining a large class of life problems in practice. Such as the "Six Degrees of Separation" in Stanley Milgram's postman problem experiment can be well explained as following: WS network's high clustering characteristic and short average path characteristic. In 1999, Barabási and Albert model a scale-free networks - BA model, put forward a kind of networks in which connected nodes satisfy degree power probability distribution, therefore the BA's model can illustrate a lot of the actual situation very well [8], such as the internet, WWW, as well as metabolic network's degree distribution.

3.2 Construct Hierarchical Structure Model Based on Complex Networks Technology

Hierarchical structure is basic relations in the real organizational structure. But in the hierarchical structure exists a great deal of relations across hierarchy, such as cooperation Symposium, study group across hierarchy across different departments, the freedom discussions and so on. The anti-hierarchical structure of the organization leads to a complex hierarchical organization structure. It is difficult to study the knowledge transfer in the hierarchical organization by using statically traditional relationship, and it is also very difficult to make out a reasonable conclusion. By using the complex networks research findings, we establish a hierarchy networks model, study transfer knowledge questions in hierarchical organizations through the complex network's characters. we also refer a knowledge transfer idea for path selection and its optimization.

Definition 3. Hierarchical networks: in the hierarchical organization structure, the relations between the organization members will form a network, we sign G = (V, E) as a network, V represents the node set of all organization members, E indicates all relationships between the Organization members. The network construct (V, E) only have two elements nodes and edges, nodes represent the hierarchical organization members, edges represent the relationship between the hierarchical organization members. This kind of relationship can be relationship between direct leader and the subordinate employee, or the relationship in the same department, also the relationship among the same association degree.

Definition 4. Relational association: in the hierarchy network the node sets in which they have direct relationship, we call it relational association. In the hierarchical network, the people in the same department constitute a relational association. Unquestionably the parent node and its nearest t nodes also constitute a relational association, because they can transfer information and knowledge when they meat each other.

Relational association can be defined as the following form:

$$V_T \subseteq V \wedge \quad V_T = \bigcup_{i=1}^{m} V_i \ \wedge \forall V_i, V_j \in V_T \rightarrow P(V_i, A_T), P(V_j, A_T) \quad (i \in 1, 2, ...m)$$

In the formula $P(V_i, A_T)$ represents V_i has the property A_T , that is to say V_i belong to the same department or belong to the same association degree. So V_T may constitute a relational association.

Within a relational association, the nodes have a strong connection characteristic, the distance between two nodes all are 1. At the same time, we can calculate

$C_i = \dfrac{2E_i}{k_i(k_i - 1)}$ the cluster coefficient of each node i, E_i is the number of connection

relationship between all nodes. Because the member of relational association V_T may belong to the same project team or the same department, they will have relationship and their exchange has no distance. For the reason E_i equal to $C_{k_i}^2$, we can get C_i =1. The nodes in relational association are all connected with a high cluster coefficient. This kind of character ensures the relationship in the relational association is very tight, so the knowledge and information is spread fast.

Definition 5. Relational association degree: We hypothesize that two relational associations V_{Ti} and V_{Tj}, if the potency of $V_{Ti} \cap V_{Tj}$ is k, we will call k the relational association degree. The relational association degree reflects the intersection number between the two relational associations, the bigger the k value, the closer link relationship in the corporation.

Definition 6. Distance of relational association: What if two relational associations V_{Ti} and V_{Tj}, they satisfy $V_{Ti} = V_{Ti}^{1} \cup V_{Ti}^{2}$, $V_{Tj} = V_{Tj}^{1} \cup V_{Tj}^{2}$ and $V_{Ti} \cap V_{Tj} = V_{Ti}^{1} = V_{Tj}^{1}$, we define the distance between V_{Ti} and V_{Tj} is 1. So we know two rational associations share some member but not the same, the distance between the two relational associations is 1.

What if two relational associations V_{Ti} and V_{Tj},they have the relationship $V_{Ti} \cap V_{Tj} = \phi$,and we have another relational association V_{Tk} satisfy both $V_{Ti} \cap V_{Tk} \neq \phi$ and $V_{Tj} \cap V_{Tk} \neq \phi$, so we define the distance between V_{Ti} and V_{Tj} is 2. Have a recursion like above, we may get all the distance of two relational associations.

Distance of relational association algorithm:

1) If a association with N members has a strong connection, then we draw a conclusion the N nodes form a relational association. Next we can easily make out the relational association number.

2) We use a point represents each relational association, what if two associations share the same member, we draw a line between the two associations, this indicators the two association have a connection.

For example the relational associations in figure 3 we can use the node structure graph figure 4 to express the relation in figure 3. In figure 4 it is easy to see that the

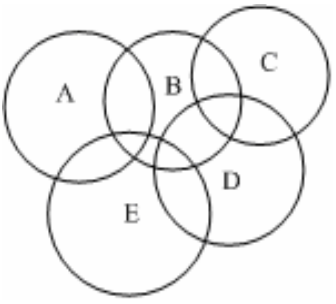

Fig. 3. Relational association structure

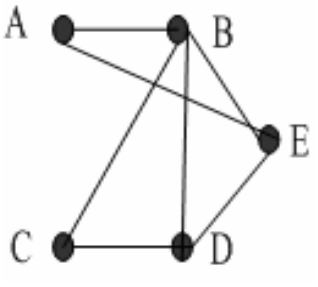

Fig. 4. Topological structure of relational association

distance between A and B is 1, between A and C is 2, between A and E is 1, between A and D is 2.

3) We use Dijkstra's algorithm to search the shortest path in figure 4, establish the optimum path from the primary node to all the other nodes. Figure 5 show the optimum path of figure 4.

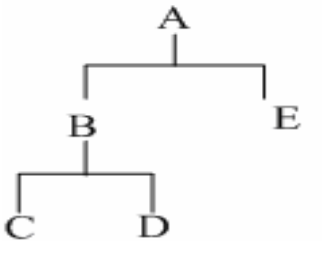

Fig. 5. Tree topology structure of relational association

It is easy for us to determine the distance between any two relational associations within the hierarchy corporation using the distance of relational association algorithm.

Definition 7. High tightening organization structure.

If an organization exists N associations totally, and the distance between any two associations is 1, then we say the organization is a high tightening organization structure.

3.3 Analysis of Tacit Knowledge Transfer Path

In the hierarchical structure network, tacit knowledge is transferred through the node's relations. The node distance within one relational association is 1, but the node distance between the intersecting relational associations has two possibilities:

1. $V_i \in V_{Ti}$, $V_j \in V_{Tj}$, if $V_i \in V_{Ti} \cap V_{Tj}$ or $V_j \in V_{Ti} \cap V_{Tj}$, then V_i and V_j belong to the same relational association, the distance between V_i and V_j equal to 1;

2. $V_i \in V_{Ti}$, $V_j \in V_{Tj}$, if $V_i \notin V_{Ti} \cap V_{Tj}$ and $V_j \notin V_{Ti} \cap V_{Tj}$, then the distance between V_i and V_j equal to 1;

Simple verify: the first case, we may set up $V_i \in V_{Ti} \cap V_{Tj}$, if $V_j \in V_{Tj}$, then V_i and V_j necessarily belong to the same relational association V_{Tj}, thus their distance is 1;the second case, $V_i \notin V_{Ti} \cap V_{Tj}$ and $V_j \notin V_{Ti} \cap V_{Tj}$, then the relationship from V_i to V_j certainly not belong to the two relational associations intersection region. What if V_{Ti} and V_{Tj} have intersection, then it must exist a node V_k which satisfy $V_k \in V_{Ti} \cap V_{Tj}$, the distance between V_i and V_k is 1, the distance between V_k and V_j is 1.So the distance between V_i and V_j is 2.

In the hierarchical structure, the knowledge transfer distance algorithm between the nodes are as following in which $V_i \in V_{Ti}$, $V_j \in V_{Tj}$.

1. By utilizing the hierarchical organization structure and the association degree we can determine V_i and V_j belong to which two relational association's intersection. For example $V_i \in \bigcap_{V_i \in V_{Ti}} V_{Ti}$, but $V_j \in \bigcap_{V_j \in V_{Tj}} V_{Tj}$;
2. Determine the relational associations that have the elements V_i and V_j : $A_{V_i} = \left\{ V_{Ti} \middle| A \in \bigcap_{A \in V_{Ti}} V_{Ti} \right\}$ and $A_{V_j} = \left\{ V_{Tj} \middle| B \in \bigcap_{A \in V_{Tj}} V_{Tj} \right\}$. If there is a intersection between A_{V_i} and A_{V_j}, then the distance between node V_i and node V_j is 1. If there is not intersection, the algorithm skips to the step 3.

3. If $A_{V_i} \cap A_{V_j} = \phi$, then by the relational association distance algorithm we can find two relational associations V_{Ti}^{x} and V_{Tj}^{y} which make the path between A_{V_i} and A_{V_j} is shortest (the process may be repeated), of course $V_{Ti}^{x} \in A_{V_i}$ and $V_{Tj}^{y} \in A_{V_j}$. Then we can get that the distance between V_{Ti}^{x} and V_{Tj}^{y} is K。 So the distance between V_i and V_j is K+1。

During the same knowledge transfer course, the transfer path algorithm between V_i and V_j is defined as follow:

1. Find the relational association's set which have the element V_i or V_j : A_{V_i} and A_{V_j} ;

2. If $A_{V_i} \cap A_{V_j} \neq \phi$, we select out the node B $B \in A_{V_i} \cap A_{V_j}$, then we can draw a conclusion not only $V_i \in B$ but also $V_j \in B$, it is obviously that the tie line between V_i and V_j is the knowledge transfer path.

3. If $A_{V_i} \cap A_{V_j} = \phi$, we can find two relational associations V_{Ti}^{x} and V_{Tj}^{y} which have the shortest distance, through the relational association distance algorithm we can determine the path between V_{Ti}^{x} and V_{Tj}^{y}, then the path between node V_i and V_j can be determined easily.

4 Summary and Outlook

Because the hierarchy structure has variety kinds of relationships, its knowledge transfer is complex. In this paper we construct a network model in the hierarchy organization, use the relational associations structure to simulate a kind of very tight relationship between the nodes in the hierarchy organizations. The nods within the relational associations are strongly connected. Through analyzing the technical data and the algorithm we successfully pick out the optimum path and make out the precise

distance in the tacit knowledge transfer. This idea provides a reasonable route selecting way in knowledge transfer within organizational entities. However the network structure optimization of knowledge transfer in the whole organization, as well as relocation issue of the optimal path brought about by the optimization has not yet discussed. This in the future will be my research directions.

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