A simulation model on the formation of knowledge-based collaborative networks

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Abstract

Collaborative network has been a hot topic in the related research field. This paper proposes a simulation model on the formation of knowledge-based collaborative networks mainly based on the Set theory. The paper proposes that formation process as follows: (1) find the key skills and the core members; (2) classify the organizations; (3) establish the relationship between organizations in different classifications.

Keywords: Knowledge-Based, Collaborative Networks, Set theory

1 Introduction

Collaboration between companies in collaborative networks has been widely accepted as an effective approach to cope with the challenges [1]. In order to be competitive, companies need to decrease their product's time-to-market, share information, and shift from standardization to a customization approach [2]. Rapid changes in technology often force such firms to depend on external technological knowledge and skills in addition to internal technological resources. Many firms today are relying more extensively on external linkages to acquire new technological knowledge using strategies such as technology licensing and collaborative agreements. Inter-firm collaboration is an important vehicle for the creation of technological competencies [3]. Collaborative Networks have emerged as a new and prominent paradigm to improve organizations competitiveness in a sustainable way in the increasing globalised and dynamic businesses [4]. Therefore, research on collaborative models such as collaborative networks has attracted more and more attention from experts and scholars. And also the concept of collaborative networks has risen as an organizational alternative in order to fast react to market changes and turbulences associated to the globalised economy [5].

Researchers focus on the topic of collaborative networks mainly from the perspective of motives for the collaboration, evaluation on the impact of different types of collaborative networks on product innovation performance, and value systems in collaboration networks [6-8]. However, the diffusion of knowledge and its effect on innovation is of major importance to ensure productivity growth, thus, this paper mainly talks about the formation of the collaboration networks from the perspective of knowledge, for network structure impacts the function of the community, improving or impeding the flow of information and ideas, opinion formation, and the spread of effective technologies.

2 Collaborative networks

A Collaborative network is that business entities work collaboratively to support the different processes and activities [9]. A Collaborative network are the entities which are geographically distributed or heterogeneous with respect to their operating environment, culture, social capital and goals collaborate to achieve common goals, supported by Information and Communications Technologies [10]. The collaborative network consists of heterogeneous and autonomous partners and this business model permits the rapid integration of competencies to establish an experience-centric network. Within the collaborative network each member has its own core values and the success of the collaboration network is the appropriate alignment of these values amongst the partners [11].

The purpose of building a collaboration network is to benefit from the inter-organization links that connects people and knowledge from diverse fields [12]. It is obvious that networks hold many different characteristic, which make different forms of networks suited for very different purposes and functions [13]. There is no universal network-model that fits all collaborative purpose and suitable to all situation. However, the core factors that affect the design of the collaborative project and the way it is carried out are the size of the collaborative network measured by number of active

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participants and the proximity of partners in relation to geographical and disciplinary scope [14]. The large scale and very diverse networks are especially well suited for projects with the aim of searching for new knowledge, exploring new collaborative opportunities, or creating associations [15]. However, it also needs cross-unit coordination activities to keep the network parts together, which requires strong management, and clear structures of the network. Therefore, Large scale network have the advantages of easier knowledge search for the pool of knowledge to search from is more diverse and easier exploration activities, with the disadvantages of easier for partners to violate an obligation to provide resources, management challenges, hard to get rid of non-performers. To the contrast, small scale networks have the advantages of easier to build trust, easier knowledge transfer and easier exploitation activities, with the disadvantages of redundant partner knowledge and difficult to ensure a diverse pool of knowledge [16].

Knowledge Networks is defined as [17] "A Knowledge Network signifies a number of people and resources, and the relationships between them that are able to capture, transfer and create knowledge for the purpose of creating value. An Integrated Knowledge Network spans all domains communities, and trust relationships with the goal of fostering sustainable innovation that will continue to promote the competitiveness of its users." Each member in the network will have impacts on the success of innovation projects by knowledge sharing and collaboration [18].

3 The simulation model of knowledge-based network formation

The formation of a knowledge-based collaborative network requires collaborative network members have access to both internal and external knowledge resources. So the structures of collaborative networks differ markedly according to the characteristics [9].

3.1 PROBLEM DESCRIPTION

Suppose individual or organization possess some kind of skills, but in order to complete the task or accomplish the goal, they skills they have is not enough, they need to collaborate together to form a network, so it is important to define the formulation of the network. Therefore, the problem can be described as: the input is the skills possessed by different individuals or organizations, the output is the network, and the important point is how to choose and organize these organizations to formulate an effective network.

$X = \{x_1, x_2, \dots \dots, x_N\}$ denotes the set of the individuals or the organizations, and $i=\{1, 2, 3, \dots \dots, N\}$ means the i^th^ individual or organization. $S=\{s_1, s_2, \dots \dots, s_M\}$ denotes the finite set of all skills. An individual i's skill set is the subset of those skills she possesses, $Si \subseteq S$. Each individual or organization is endowed with a copy of a problem requiring a subset of the skills.

3.2 SKILL REDUCTION AND CORE MEMBER

The organizations and the skills they possessed can be seen as a whole knowledge system, the organizations are the objects in the system, and the skills that are needed to complete the task are the attributes.

Definition 1: (U, A, F, V) is a knowledge system, U means the object

$U= X = \{x_1, x_2; \dots \dots, x_N\}$ denotes the set of the individuals or the organization;

A is the attribute set, $A=\{a_1, a_2, a_3, \dots \dots, a_m\} \subseteq S$ means that in order to complete the task, the skills that are needed. F is the information function set;

$F=\{f_{a1}, f_{a2}, f_{a3}, \dots \dots, f_{am}\}$,for each $ai \in A$, fai is a mapping function from U to V_{ai}, that is, $f_{ai} : U \rightarrow V_{ai}$

V_{ai} is the range of attribute a_i $(1 \le i \le m)$, $V=\{(v_{a1}, v_{a2}, v_{a3}, \dots \dots, v_{am}) \mid v_{ai} \in V_{ai}, 1 \le i \le m \}$, here we define that $v_{ai}=\{0, 1\}$.

Therefore, actually a knowledge system is a data table, in which columns are labelled by attributes while rows are labelled by objects. For example, suppose a task need a_1, a_2, a_3, a_4, a_5 five kind of skills, and $x_1 \sim x_6$ organizations are going to collaborate so that to complete the task, if x_i owns the skill a_j, then the value in the convergence of the x_i row and the a_j column will be 1, otherwise 0, as shown in table 1.

TABLE 1 A knowledge system

U	a_1	a_2	a_3	a_4	a_5
x_1	1	0	0	1	0
x_2	0	1	0	0	1
x_3	1	0	1	0	1
x_4	1	0	0	1	0
x_5	0	1	1	1	0
x_6	0	1	0	0	1

Base on the knowledge system, in order to get the key skills, algorithm as follows is taken use of.

The reduction algorithm:

Step 1: calculate the matrix M_{n*n}

$M_{n*n} = (cij)_{n*n} = \{\alpha \mid (\alpha \in A) \wedge (f_\alpha(xi) \neq f_\alpha(xj)\}, \forall i, j = 1, 2, 3, \dots \dots, n$

n is the total number of objects in U, that is, $n = |U|$;

Step 2: for all $cij \neq \Phi$, get the disjunctive normal form $L_{\wedge(\vee)} = \bigwedge_{\forall c_{ij}=\alpha(x_i,x_j)\neq\varphi\in M_{n*n}} \alpha(x_i, x_j)$

Step 3: convert the disjunctive normal form to conjunctive normal form $L_{\vee(\wedge)} = \bigvee_{L_k \neq \varphi} L_k$

Step 4: get the RED(C)={ $L_k \mid \forall L_k \in L_{\vee(\wedge)}$ }

From the algorithm above, we can get the key skills in the knowledge system, and the organizations who own the key skills will be the core numbers in the network.

3.3 NODE CLASSIFICATION

Each organization can be seen as a node in the network. The paper classified the organizations according to their attributes which mean the skills.

Definition 2: Assume R is a equivalence relation on the non-empty finite set U, for $\forall$ x∈U, $[x]_R=\{y \mid yRx\}$, $[x]_R$ is a classification of U according to relation R.

Definition 3: | S | means the number of elements in the set S.

Definition 4: Suppose S is the object set including n subsets which are represent by C_1, C_2, C_3, … …, C_n, then the entropy of S is

$$entropy(S) = -\sum_{i=1}^{n} p_i \log_2 p_i \,, \tag{1}$$

p_i means the probability of C_i, that is $p_i = \frac{|C_i|}{|S|}$

Definition 5: Suppose S is partitioned into m subsets by attribute A, then

$$entropy(S,A) = \sum_{i=1}^{m} \frac{|S_i|}{|S|} entropy(S_i) \,, \tag{2}$$

$$entropy(S_i) = -\sum_{i=1}^{n} \frac{|S_i \cap C_j|}{|S_i|} \log_2 \frac{|S_i \cap C_j|}{|S_i|} \,, \tag{3}$$

$$gain(S,A) = entropy(S) - entropy(S,A) \,, \tag{4}$$

S_i is the i^{th} partition subset of set S.

Therefore, the larger gain(S, A) is, the more important attribute A is.

Then the paper classified the organizations by the following steps:

Step 1: For all the a_i∈A, each a_i is seen as a set A, and calculate gain(U, A) according to definition 5 so that to get the relative importance of the skill, and arrange A in descending order according to the relative importance, that is, after rearrangement, for A={a1, a2, a3, … …, am}, gain(U, a1)≥gain(U, a2)≥gain(U, a3)……≥gain(U, am) ;

Step 2: According to the skill reduction algorithm introduced in 3.2, get the key skills set K={k_1, k_2, … …, k_s}, $K \subseteq A$;

Step 3: Get the partition of U according to attribute K, PU={SPU_1, SPU_2, SPU_3,… SPU_h}, SPU_i is the i^{th} partition subset of set U;

Step 4: Calculate SKN(SPU_i), which is the number of skills owned by the members in SPU_1~SPU_h, arrange SPU_1~SPU_h in descending order according to SKN(SPU_i), that is, if the members in PUi own skill more than PUj, then i<j. For example, according to table 1, if key skill set K={a_1, a_4}, then SPU1={x_1, x_4} because x_1 and x_4 owns both a1 and a4 skill, SKN(SPU1)=2, | K | =2;

Step 5: A'=A-K, and A'={A_1', A_2', … … A_f'}, A' is also in descending order according to the relative importance of skills. Let A_0'= K, then | A_i'| =| A_{i-1} | + k, k is a constant set by people, and $\sum_{i=1}^{f} |A_i| = |A-K|$.

Step 6: Get each partition of U according to A_1', A_2', … … A_f', that is according to A_1' get a partition PU_1'of U, according to A_2' get a partition PU_2'of U,… …, total get *f* partition.

3.4 NODE DISTANCE

The paper adopts Euclidian distance to calculate the node distance. For the m dimensional space, the Euclidian distance is

$$d(x,y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2} \,. \tag{5}$$

For the organizations as the objects, each object can be seen as a vector, and the attributes can be seen as its dimensions. So each organization is a m dimensional vector, the i^{th} organization in the form of vector is $x_i=[a_{1i}, a_{2i}, a_{3i}, \dots a_{mi}]$, and the distance between x_i and x_j is

$$d(x_i,x_j) = \sqrt{(a_{1i}-a_{1j})^2 + (a_{2i}-a_{2j})^2 + \dots + (a_{mi}-a_{mj})^2} \,. \tag{6}$$

Obviously, from the Euclidian distance, we can see that the more different skill owned by the two organizations, the larger Euclidian distance is.

3.5 EDGE GENERATION

The relationship between the organizations can be represented by edges between nodes. So how to establish the relationship between the organizations so that to form the network is a quite important issue.

The core members in the network who own the key skills should first establish some relationship with other members who own the skills the core member don't have. Actually, the core members may in the same classification, so the relation establishment is between the members in different classification, as shown in figure 1.

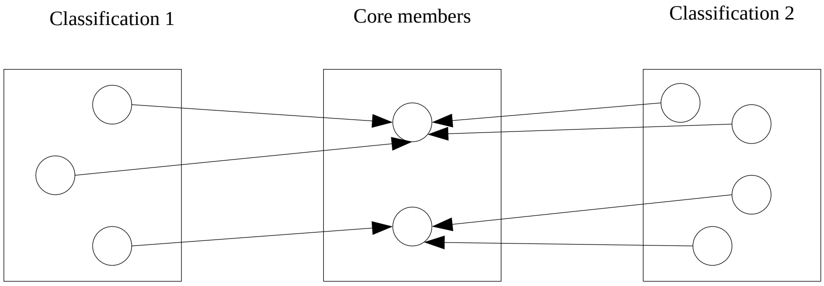

FIGURE 1 Relationship establishment

The relationship establishment between organizations, in other words, the edge generation between nodes, follows the steps below:

Step 1: Get all the node classification PU, PU_1', PU_2', PU_3', … …., according to the algorithm introduced in 3.3.

PU={SPU_1, SPU_2, SPU_3,… SPU_h},

PU_1'={SPU_{11}', SPU_{12}', SPU_{13}',… …'},

PU_2'={SPU_{21}', SPU_{22}', SPU_{23}',… …},

… …

Step 2: Set PUM=PU, PUM={PUM_1, PUM_2, PUM_3,… …}

If the classifications in PUM cannot cover all the skills, for j=1, 2, 3, ……., once at a time, $PUM = \bigcup (PUM_i \cap SPU_j^{'})$.

NOTES:

1. the skill of each classification is the least skills owned by the members in the classification, for example, classification 1 have x_1, x_2 two members, x_1 owns a_1, a_2, a_3, x_2 owns a_1, a_2, then the skills owned by this classification are a1 and a2);
2. "once at a time" means that if PUM=PU cannot cover all the skills, $PUM = \bigcup (PUM_i \cap SPU_1^{'})$, and if PUM still can't cover all the skills, $PUM = \bigcup (PUM_i \cap SPU_2^{'})$, just like this, until classifications in PUM can cover all the skills.

Step 3: Get the final PUM set, arrange the subsets in PUM in descending order according to the relative importance, PUM={PUM_1, PUM_2, PUM_3,… …}, that skills owned by PUM_1 is more important than skills owned by PUM_2, and each subset PUM_i in PUM is actually a classification,

Step 4: Calculate the each node distance between every two classifications.

Step 5: For each node xi, find the node x_j that is most far away from it, establish the relationship from x_i in PUM_i to x_j in PUM_j if i<j, or establish the relationship from x_j in PUM_j to x_i in PUM_i if i>j.

3.6 THE SIMULATION PROCESS OF NETWORK FORMULATION

So the process of the network formation is shown in figure 2.

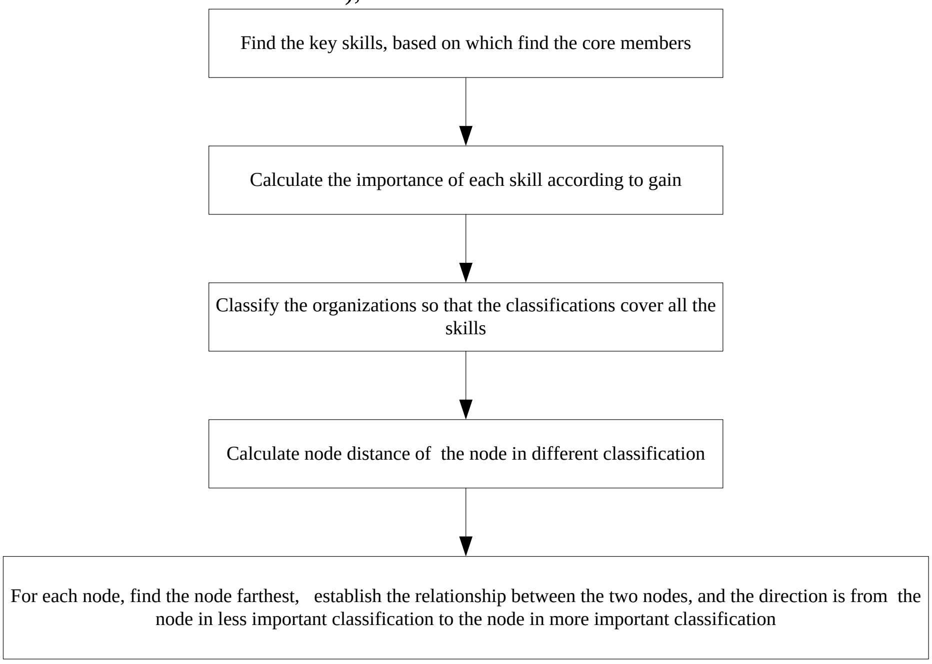

FIGURE 2 Network formation process

4 Conclusions

Recently, the research topics on collaborative networks are mainly on the motives for the collaboration, evaluation on the impact of different types of collaborative networks on product innovation performance, and value systems in collaboration networks. However, there are few researches on the formation of the network. Therefore, this paper mainly talks about the network formation and proposes the simulation model on the formation process based on the set theory.

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