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Multi-source Knowledge Acquisition Model based on Rough Set

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Abstract: Knowledge acquisition is the key function of knowledge management system, as well as the base for improving absorption capability and innovation performance in Open Innovation Alliances (OIAs). Firstly, this study analyzes characteristic of knowledge acquisition in open innovation alliances. In addition, this study targets incomplete rough decisional information system and explores deeply the knowledge acquisition method based on rough set theory. Then, this study develops the multi-source knowledge acquisition model of open innovation alliances. This research could serve as a well basis on which enterprise can further build knowledge management system of open innovation alliances.

Key words: Knowledge acquisition, open innovation alliances, rough sets

INTRODUCTION

Open Innovation Alliances (OIAs) have emerged as a new collaborative paradigm and industrial organization in multiform settings in recent years, which are inherently knowledge alliances. OIAs transform dynamically over time as new members join and adopt open innovation paradigm, in which collaborators and competitors integrate in the pursuit of the co-development of technological innovations (Han *et al.*, 2012). In practice, some firms have participated in OIAs to acquire external knowledge widely and integrate key resources in industry make use of alliance and generate aggregations effect of innovative resources. There are many open collaborative paradigms which are driven by innovation in high-tech industry (e.g., Open Handset alliance, Open Mobile Alliance, Liberty Alliance, MIPI Alliance etc.). Meanwhile, the research on theory of OIAs has just begun. Existing research have proved the impact of openness on acquisition of both new technology and specialized complementary assets, as well as impact of openness on innovation performance, are inverted U curves (Chen and Wu, 2012). So, firms need find the right level openness that can facilitate the pooling of complementary skills and resources without incurring excessive coordination cost (Han *et al.*, 2012). OIAs integrate key resources in industry make use of alliance and generate aggregations effect of innovative resources. On the other hand, OIAs acquire external knowledge widely by members and their networks. That is why firms take part in an OIA meanwhile they adopt open innovation paradigm. This study explored deeply the open innovation alliances knowledge acquisition model by virtue of rough set theory to help members find the right openness.

In general, the importance of knowledge and knowledge management has been highlighted throughout the related literature. Some researches have proposed different knowledge management system architectures in various industries and areas (Hung *et al.*, 2005; King and Marks, 2008; Tornøe *et al.*, 2011). Knowledge acquisition is not only one of key functions of knowledge management system, but also one of critical processes to arrive at an integrative view of managing knowledge (Abd-Elaziz *et al.*, 2012). Knowledge acquisition is the base for improving absorption capability and innovation performance in alliances (Lichtenthaler and Lichtenthaler, 2009). Therefore, in order to improve knowledge management of OIAs, knowledge acquisition model is essential. During planning and programming of knowledge management, various artificial intelligence systems are used to realize knowledge acquisition, such as rough set which is a new mathematics tool and is commonly used to analyze the inconsistent or ambiguous description of objects (Barnes, 2002; Pawlak, 2002).

Rough Set theory is a valid method of mining data and is able to derive rules of decision or classify by means of knowledge reduction (Pawlak, 1997). In recent decades, rough set theory has been put into many interesting applications, such as in the areas of knowledge acquisition (Pawlak, 1997). Zhou (2003) put forward a knowledge model based on rough set theory. Leung *et al.* (2006) raised a method of knowledge acquisition taking advantage of rough set theory in incomplete information systems. Imai *et al.* (2008) analyzed knowledge acquisition to achieving good performance of human resource management making use of rough sets. Based on previous achievement, rough set showed obvious advantage over other data mining technologies. Therefore, This

study, firstly, analyzed characteristics of open innovation alliances knowledge acquisition from the perspective of system application and then proposed a method of rough set algorithm for open innovation alliances knowledge acquisition.

OPEN INNOVATION ALLIANCES

OIAs is a new collaborative paradigm, which is composed by enterprises, rivals, suppliers, users, innovation intermediary, private research institute, university and higher research institute, government and public research institute, etc.; The main goal of OIAs is in pursuit of open standard and co-development of technological innovation; It is clear that OIAs differ substantially from traditional, interfirm innovation alliances, such as technological innovation strategic alliance (Table 1). OIAs are formed and maintained based on several unique governing principles, such as openness, transparency, self-regulation and self-monitoring, all of which rarely occur in traditional alliances (Han *et al.*, 2012).

Openness and transparency: OIAs adopt open innovation paradigm, the driver of which are openness. In open innovation alliances, new technology may access alliances in any phase of R and D and commercialize in any manners. For example, Open Handset Alliance (OHA) is based on an open source license and has unveiled Android since 2007. Android, which is an open source mobile phone platform, allow any mobile terminals to join OHA and have enough developers. Therefore android soon developed into the largest smart phone operating system in the world. Comparing to traditional technological alliances, the openness of OIAs also reflect that rivals easily explore and exploit technological innovation of alliances. The openness of alliance extensively expands market demand. The transparency of OIAs embody the functioning and governance related activities within OIAs, including knowledge exchange and strategic decision making, are known to participants and the public (Han *et al.*, 2012). In other word, the openness of OIAs brings the transparency.

Self-regulation and self-monitoring: An OIA can be thought of as a dynamic “adaptive system” (Han *et al.*, 2012). Members of an OIA are regarded adaptive agents. The society can be thought of as the simulated environment in which actions taken by one agent may have an effect on the resulting actions of another agent. Agents interact with each other and with their environment, which study and accumulate experience continuously. According to the experience and rule, agents supervise and adjust their behaviors and structures. Also, agents can self-regulate in terms of change of other agents or environment. In OIAs, members interact with each other and with their environment, which is the main driving force of alliance evolution. The member acquire knowledge interacting with other members and environment; Members response to stimulation from environment.

KNOWLEDGE ACQUISITION OF KMS IN OPEN INNOVATION ALLIANCES

Definition of knowledge acquisition: The general knowledge acquisition means the process of discovering useful and regular information from a large number of raw data (Pawlak, 2002). In open innovation environment, knowledge acquisition is external knowledge exploration from external sources (Zhou, 2003). Knowledge acquisition in this study refers to extracting knowledge related innovation from external knowledge sources by members of an OIA and storing in database in some knowledge expression.

Definition of research object: Innovative knowledge sources include both internal and external sources (Leung *et al.*, 2006). Under the context of OIAs, in this study acquisition of knowledge was divided into two types according to different innovative knowledge sources: longitudinal knowledge and horizontal knowledge (Fig. 1). The longitudinal knowledge is stored in database of enterprises information systems (e.g., ERP, OA, CRM, SCM, etc.). The enterprises databases have accumulated massive innovative knowledge which is related with production, marketing, suppliers and

Table 1: Differences between traditional technological alliances and open innovation alliances

	Types	Paradigm	Partner	Value chain activities
Traditional technological alliances	Equity and non-equity alliances	Closed innovation	Non-rivals (firms, government, research institute, etc.)	Aiming at innovation, R and D technology by members
Open Innovation alliances	Non-equity alliances	Open innovation	Rivals and non-rivals (firms, rivals, suppliers, users, government, university, public research institute, etc.)	Improving innovation of alliance by means of external and internal knowledge, commercialize in any manners outside of alliance

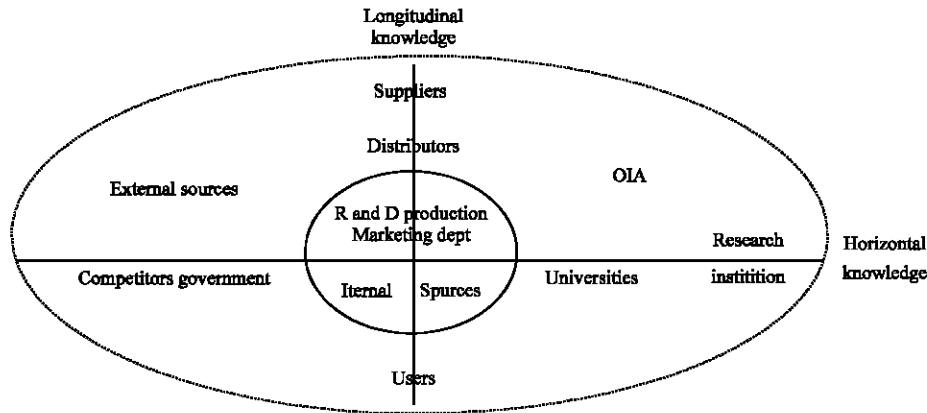


Fig. 1: Two types of knowledge acquisition in an open innovation alliance

distributors. Although, stored in databases in some structure, the data has some problem of redundancy, inconsistency and weak relationship. Rough set theory provides a method of how to obtain valuable innovative knowledge from the data. This study focuses on obtaining the longitudinal knowledge. The horizontal knowledge obtains innovative knowledge by internet (e.g., homepage of university or government, Derwent Innovation Index, WiseSearch), which will not be discussed in this study.

MODELING KNOWLEDGE ACQUISITION

Open innovation alliances knowledge acquisition model:
The information system of rough set theory is expressed by:

$$S = (U, A, V, f)$$

and:

$$A = C \cup D$$

$U = \{x_1, x_2, \dots, x_n\}$ is a finite non-empty object set, which is called a universe; A is a non-empty property set; $C = \{c_1, c_2, \dots, c_m\}$ is a conditional property set; $D = \{d_1, d_2, \dots, d_k\}$ is a decisional property set; V is value of property; f is relation set of U and A . S is an abstract description of relation data table. If there are $x \in U, c \in C$ and $f(x, c)$ is unknown (*express null value), the information system is called Incomplete Information System (IIS) Leung *et al.* (2006). If $\forall d \in D, f_d: U \rightarrow [0,1]$, the information system is called Vague Information System (VIS) (Zhou, 2010). The general formal definition of VIS is $s = (U, C, V, f; D, W, G)$. $G = (g_1, g_2, \dots, g_k)$ vague decisional map set and $W = \bigcup_{1 \leq i \leq k} W_i$:

$$g_i: U \rightarrow W_i, W_i(x_i) \in [0, 1], i \leq n \text{ and } 1 \leq k$$

If $k = 1$ and making $D = \{d\}, G = \{g\}, S = (U, C, V, f; \{d\}, W, \{g\})$ is single objective decisional information system. If $k > 1$, S is a multi objective decisional information system.

The subjects of longitudinal knowledge include staff, lead users, suppliers, peer firms and distributors (Lichtenthaler, 2011). That is, there are several define in this study:

- **Define 1:** U includes employees, users, suppliers and distributors of an OIA
- **Define 2:** C is set of attributes of product and technology

According to open innovation paradigm, some research program which is not fit of current business might present huge value in the future. D indicates that knowledge sources have an effect on innovation performance in this study. Therefore, the object of this study is a single aim decisional information system.

Define 3: D is a decisional set. The value of “greatly improved” is 1; the value of “no improved” is 0; the value other status is between 0 and 1.

Obviously, the data often default or loss actually and the decisional objective is vague. So, the object of this study is VIS. In the premise of keep classification ability unchanged, one knowledge reduction gets a knowledge base and multi knowledge reduction gets multi-knowledge base. Therefore, multi-knowledge base has the same formalization with attributes reduction of rough set theory, which would give prerequisite for KMS of OIAs. The algorithm is as follow (Fig. 2).

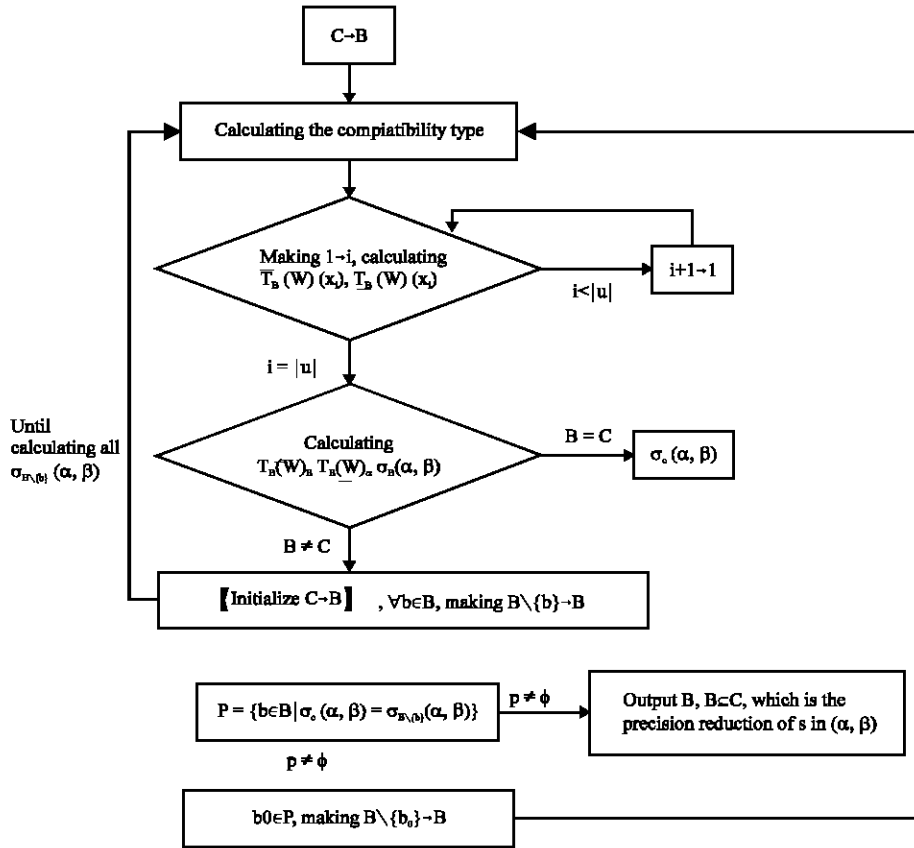


Fig. 2: Knowledge acquisition algorithm in open innovation alliances

Input: An incomplete and vague decision information system $S = (U, C, V, f, D, W, G)$ and $U = (x_1, x_2, \dots, x_n)$, $C = (c_1, c_2, \dots, c_m)$, the valid threshold $\alpha, \beta: 0 \leq \beta \leq \alpha \leq 1$.

Output: The precision reduction of S is $B \subset C$ in (α, β) :

Step 1: Making $C \rightarrow B$

Step 2: Calculating the compatibility type $T_B(x_1), T_B(x_2), \dots, T_B(x_{|U|})$

Step 3: Making $1 \rightarrow i$, calculating upper approximation and lower approximation of x :

$$\overline{T}_B(W)(x_i) = \max \{W(y) | y \in T_B(x_i)\} \quad (1)$$

$$\underline{T}_B(W)(x_i) = \min \{W(y) | y \in T_B(x_i)\} \quad (2)$$

$$\overline{T}_B(W) = \sum_{i=1}^i \overline{T}_B(W)(x_i) / x_i \quad (3)$$

$$\underline{T}_B(W) = \sum_{i=1}^i \underline{T}_B(W)(x_i) / x_i \quad (4)$$

If $i < |U|$, then turning Step 4; If $i = |U|$, then turning Step 5:

Step 4: Making $i+1 \rightarrow i$, turn to Step 3

Step 5: Calculating $\overline{T}_B(W)_\beta = \{x | \overline{T}_B(W)(x) \geq \beta\}$, $\underline{T}_B(W)_\alpha = \{x | \underline{T}_B(W)(x) \geq \alpha\}$:

$$\sigma_B(\alpha, \beta) = \frac{|\overline{T}_B(W)_\alpha|}{|\underline{T}_B(W)_\beta|} \quad (5)$$

If $B = C$, getting $\sigma_c(\alpha, \beta)$; otherwise, Step 6:

Step 6: (initialize: $= C \rightarrow B$) $\forall b \in B$, making $B \setminus \{b\} \rightarrow B$, turn to Step 2. Then, running the program to Step 5 until calculating all $\sigma_{B \setminus \{b\}}(\alpha, \beta)$, making $P = \{b \in B | \sigma_c(\alpha, \beta) = \sigma_{B \setminus \{b\}}(\alpha, \beta)\}$. If $p = \phi$, turn to Step 7; Otherwise, $b_0 \in P$, making $B \setminus \{b_0\} \rightarrow B$, turn to Step 2

Step 7: Output $B, B \subset C$, which is the precision reduction of S in (α, β)

Example: To analyzing simply, this study simplified the data of database. Hypothesis the object set is $U = (x_1, x_2, \dots, x_9)$, x_i represents staff, lead users, suppliers, peer firms, etc. Hypothesis the conditional property set is $C = (c_1, c_2, c_3)$, c_i represents attributes of product and technology. The value of attributes substitute by 1, 2, 3

Table 2: Information system of the example

A/U	x ₁	x ₂	x ₃	x ₄	x ₅	x ₆	x ₇	x ₈	x ₉
c ₁	1	1	3	1	*	3	3	3	2
c ₂	2	*	2	2	2	1	2	1	3
c ₃	1	3	3	*	1	*	*	2	*
D	0.8	0.6	0.9	0.7	0.8	0.5	0.7	0.6	0.5

U is a finite non-empty object set, including x_i; x_i represents 4 staffs, 3 lead users, 1 supplier, 1 peer firms, A is a non-empty property set, including c_i, c_i represents attributes of product and technology, The value of attributes substitute by 1, 2, 3 and default value is expressed by *, D is a decisional property set, the value of which between 0 to 1, $W = 0.8/x_1 + 0.6/x_2 + 0.9/x_3 + 0.7/x_4 + 0.8/x_5 + 0.5/x_6 + 0.7/x_7 + 0.6/x_8 + 0.5/x_9$

and default value is expressed by *. Hypothesis decisional property set is $D = \{d\}$. The bigger d suggests greater improvement. The S sees in Table 2. After calculating, when the threshold is (0.6, 0.6), the precision reduction of S is $B = (c_1, c_2)$.

CONCLUSION

Knowledge acquisition is a complex systematic engineering involving the area of mathematics, information science, artificial intelligence, etc. This study researched open innovation alliances knowledge acquisition model based on rough set theory. It researched knowledge reduction taking advantage of the incomplete and vague decisional information system knowledge reduction model based on compatibility relation.

In conclusion, this study proposed a model of open innovation alliances knowledge acquisition based on rough set theory. The following work will design and realize prototype system. And, empirical study will be conducted in OIAs. The validity of the model will be tested and the model would be improved. Moreover, this study discussed knowledge acquisition model of longitudinal knowledge. The knowledge acquisition model of horizontal knowledge is also a future research direction.

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