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Knowledge Network and Knowledge Management

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ABSTRACT: The core competency of an enterprise is often found in its capability of product and service innovation, which are created in the process of knowledge flow. Knowledge flow plays the key role in supporting the knowledge sharing, acquiring, exchanging, and new knowledge generating. To facilitate the flow of knowledge and to discover the hidden dynamics that support learning and adaptation in the modern organization, the concept of knowledge network is given in this paper. Also, the knowledge dependency model based on the knowledge network and its evolving mechanism is discussed in details. In the end, a framework of knowledge management implementation is proposed.

Key Words: knowledge network, evolution, knowledge management

1 INTRODUCTION

Knowledge has become the key economic resource and perhaps the dominant source of comparative advantage [1,2]. Managing properly the valuable resource at the enterprise level through a practice known as knowledge management has been a hot topic.

Although better management of knowledge within the firm will lead to improved innovation and competitive advantage has been widely accepted, but the knowledge has been proved difficult to be managed.

Different approaches to effective utilization of knowledge at the enterprise level have been proposed, such as creating a learning culture, developing Organizational Memory Information System (OMIS), and so on. Although their bases, i.e., the knowledge management life-cycle model, are different, they all share considerable similarities. Four basic knowledge processes are summarized as in Figure 1. In addition to this life-cycle dimension, there is another knowledge management level dimension drawing from literatures [1], which includes individual, group, and organization entities. This dimension pertains to the scale of knowledge management and extends from a single person, through work groups, to an enterprise as a whole. According to these two dimensions, different knowledge management strategies and extant knowledge management applications can be classified [3].

We know the knowledge management is strongly rooted in the discipline of knowledge engineering, which has been investigated in the broad field of Artificial Intelligent (AI) for over a decade, such as decision support systems (DSS) and expert systems (ES). The research of knowledge engineering focused on the single problem-solving in narrow domain (only a few factors or rules are considered). However, solutions of the enterprise level problems with multi- objectives and under multi-constraints need a broad field of domain knowledge and cooperation between different domain experts. Reach this kind of problem- solving directly, i.e, converting the enterprise as a goal-driven complex adaptive system (intelligent enterprise), is too difficult.

Then the idea of transferring knowledge from domain experts into computers to develop knowledge-based systems (knowledge engineering) was replaced by the notion of modeling the behavior of the domain expert (knowledge management). Therefore, enterprise level knowledge management pays more attention on how to organize the heterogeneous knowledge (in part informal structures describing this knowledge), and offer an integrated view and flexible retrieval facilities. For example, one goal of knowledge management is to have the "right knowledge" available to the "right person" at the "right time" and "right place". On the other hand, the granularities of knowledge object in these two fields are different. For example, knowledge objects in OMIS are knowledge items [1] that are related different roles and tasks (activity) in an organization. While the knowledge objects in expert system are inference rules or concept lattices, which is smaller than the granularity of knowledge object in OMIS.

To better organize enterprise knowledge and to facilitate its application, a large number of knowledge

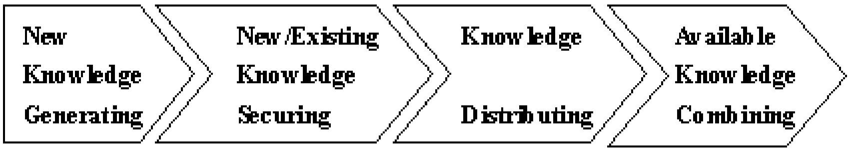

Figure 1. Four basic knowledge processes of knowledge management life-cycle

modeling methodologies and languages (ranging from "specification" to "programming" languages), have been developed [4, 6]. For example, Knowledge Analysis and Design Support (KADS) [2], which is widely used in EU, includes three levels of knowledge modeling process, i.e., process level, system level, and expertise level. Each level comprises different knowledge models that emphasize certain aspects of the system to be built. Models of expertise distinguish between four different knowledge categories (Figure 2): Strategic Knowledge, Task Knowledge, Inference Knowledge, and Domain knowledge. By the use of multiple level knowledge models, the enterprise knowledge is organized and managed. KADS views a knowledge based system not as a container filled with knowledge extracted from an expert, but an operational model that exhibits some desired behavior observed in terms of real-world phenomena. However, the tacit knowledge and the community of practice or interest are not considered in these model-based methods of knowledge organization.

Clearly, an enterprise's real edge in the marketplace is often found in complex, context-sensitive knowledge which is difficult, if not often impossible, to codify and store in ones and zeroes. This core knowledge is found in individuals, communities of interest and their connections. Another method of knowledge organization is represented in this paper. The formal definition knowledge network is given, based on which the environment that makes knowledge flow between those different knowledge resources can be managed.

2 KNOWLEDGE NETWORK AND ITS EVOLUTION

We know the ultimate goal of knowledge management is to make the enterprise to be a goal-driven complex adaptive system (CAS). It can automatically and quickly provide feedback and decision-making according to the changes of external market environment.

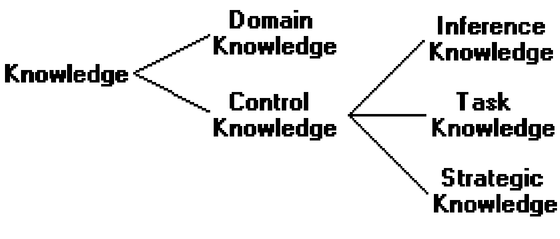

Figure 2. Knowledge Categorization

However, a problem-solving process needs the induction and inferences based on some necessary material, in which the conjunction between different memory objects (including concepts, experience etc) play an important role. If the different knowledge sources, such as active transaction databases, experts (person or intelligent software), and so on, are looked as the basic material or stack of thinking. Using the brain as a metaphor, what we should do next is to employ one kind of network with flexible and adaptive structures to connect different isolated knowledge objects together. We call this network as knowledge network that can self-organize internally in response to changes externally. It directs the flow of knowledge in or across the enterprises. Also, it is the foundation of automatic inference and decision-making.

2.1 *Knowledge network*

The knowledge network is defined as a 3-tuple, KN=(V, F, W), in which V={n1, n2, ¼, nm} is a finite set of nodes, FÍ V´ V is a finite set of directed arcs that connect different nodes, and W: F®D is a weight function. D is a set of fuzzy numbers, which will be discussed in detail.

Each node ni of KN represents a knowledge resource which maybe a knowledge worker or an expert system. Because each node of KN is not only the consumer but also the provider of the enterprise knowledge, there may be two contrary directed arcs connecting two nodes. Then our knowledge network is a general directed graph [6], i.e., allow multi-connections between any two nodes in direct graph.

To make the knowledge network applicable, each node is encapsulated as an agent. The weight of the arc ni®nj denotes the degree of dependency of agent ni to agent nj. In addition, each agent (node) of the knowledge network has multi-dimensions structuring scheme for its knowledge assets, from core competencies to individual expertise, by which the knowledge of organization are mapped and categorized.

2.2 *Knowledge dependency model*

Each agent completes its task through the interac tions with other agents. In the history of his interaction with other agent, he has estimation about expertise of other agents as well as their interest. And then, when he receives a new task, he knows from which agent and the possibility of the useful knowledge can be obtained. To describe agent ni's dependency to other agent, his dependency model DM(ni) is defined as DM(ni)t ::= (dni(n1)t, dni(n2)t, ¼ dni(nm)t), in which dni(nk)t is dependency degree of ni to nk at time t. To quantify the objective dependency degree assignment, the fuzzy expression is used here. Each dni(nk)t is a fuzzy number, for simplicity, a triangular possibility distribution function is used to represent it. For example v(x)=(a, b, c) in which 0£a<b<c£1.

However, to facilitate its usefulness in practice, an agent only give the number of b, and the number a and c can be generated automatically. Let x=min(1-b, b), then a=b-x and c=b+x. For example, the (0,0.5,1) and (0.6,0.8,1) in figure 3, its reasonability is clearly, the evaluation 0.5 is more fuzzy than 0.8. On the other word, one is more sure his evaluation 0.8 than 0.5. D denotes the set of the fuzzy numbers v(x)=(a, b, c) that satisfy x=min(1-b, b), then a=b-x and c=b+x.

After the dependency model of individual agent has been given, the dependency model of the knowledge network can be obtained as DM ::={DM(n1), DM(n2), ··· DM(nm)}.

Based on the dependency relation between different nodes of the knowledge network, it is easy for individual agent to submit or access the knowledge (coworker or related expert system) in the organization memory, then facilitate individual learning and creative work by combination.

2.3 *The evolution of knowledge network*

The dynamic of the knowledge network is caused by two kinds of forces. One is improvement of the single knowledge resource's capability, which causes evolution of the dependency model. The other is the change of community of practice or of interest, which caused the evolution of the structure of the knowledge network.

Inspired by the Hebbian principle of learning [7,8]: the link between nodes of the network that have been activated within the same interval of time is reinforced, three kinds of information are used to describe the evolve process, which will be discussed below. However, due to the fact that there

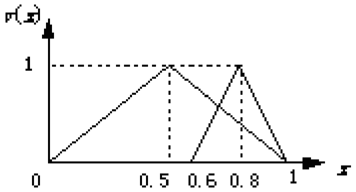

Figure 3. Triangular possibility distribution

are two directed connections between two nodes of knowledge network, the difference to Hebbian principle is that the interaction only reinforces one direction.

In the evolving process of the knowledge network, three kinds of information are considered. One is historical information of the interaction between two any agents of the knowledge network. The second one is the evolving trend information, i.e., information about the recent interactions between any tw agents of the knowledge network. These two kinds of information are about the gradual evolution. Integrating them together, an experimental formula is given: dni(nk)t+1=(1-a)dni(nk)t +av+b(v-ev), in which v is the evaluation of the new interaction, ev is the evaluation of the preceding interaction, a and b are the corresponding coefficient.

The third kind of information is generated from recommendation or transitivity that introduces variation to the knowledge network's structure. For example, agents ni and nk are not connected directly, but they all connected to nj, but nj introduce nk to ni in an interaction, then an initial connection is set up. We use rule dni(nk)t+1=d dni(nj)t+1 to set the initial weight, in which dni(nj)t+1 is the degree of dependency of ni to nk, and the d is a coefficient.

Each agent in the knowledge network only concerns the nodes in which it can obtain useful knowledge. This mechanism is entirely associative in nature and claims to achieve global optimization of network structure through the adjustment of local connections and is as such in accord with the associative nature of the community of practice or interest and the absence of centralized control.

3 KNOWLEDGE MANAGEMENT FRAMEWORK

Nonaka and Takeuchi [9] represent the life cycle of organizational knowledge as four phases of knowledge conversion between tacit and explicit knowledge, i.e., socialization, externalization, internalization, and combination. Based on this work, Borghoff and Pareschi [1] explain knowledge management as the management of the environment that makes knowledge flow through all the different phases of its life cycle. To support the environment management that facilitates knowledge flow in an enterprise, a framework of knowledge management is proposed as Figure 4, in which knowledge flow play a central role. Three other components, i.e., the knowledge modeling methodology, enterprise ontology, and knowledge network, constitute the environment of knowledge flow. An OMIS, which is used for the capture and management of the skill, expertise and competencies available to an enterprise, must support these three components.

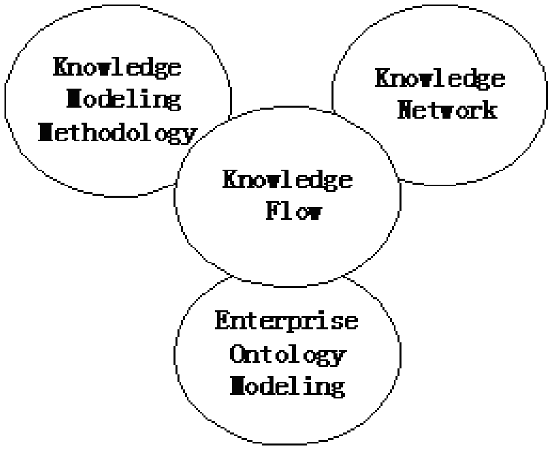

Figure 4. Framework of knowledge management

3.1 *Enterprise ontology modeling*

The major role of the Enterprise Ontology is to act as a communication medium, in particular, between different people (including users and developers across different enterprises) and different implemented computational systems (including modules of the enterprise tool set, DBMS, spreadsheet etc.). In a pragmatic way, enterprise ontology can be seen as a semantic network. The nodes are concepts or entities and the arcs represent relationships or associations among the concepts. This ontological network is augmented by logic axioms, which represent a set of attributes, functions, relations, constraints and rules that specify the structure (state) of the concepts and govern their behaviors. In this ontological network, the concepts are categorized and classified in taxonomies to which inheritance mechanisms can be applied.

Through the provision of consistent core of basic concepts and language constructs, and then the syntactic and semantic standardization of knowledge representation, it is intended to assist acquisition, representation, and manipulation of enterprise knowledge. Also, it can assist structuring and organizing libraries of knowledge and explanation of the rationale, inputs and outputs of the enterprise tool set modules.

3.2 *Knowledge modeling methodology*

What the knowledge modeling methodology concerns is to reduce the complexity of the knowledge-modeling activity and then the process. It focuses on the enterprise knowledge's organization and modeling.

The knowledge modeling methodology includes two aspects. One is the formal representation of structure and unstructured enterprise knowledge, i.e., the knowledge representation in the discipline of knowledge engineering. And the other is to design the architecture for all the enterprise knowledge, i.e., the knowledge modeling of knowledge management.

Through abstracting from a problem (or task in the enterprise) sufficiently to recognize the generic nature of that problem and then associating different kind of knowledge to different kind of problem, the specific piece of knowledge that is most relevant to the current problem can be easily found in the enterprise knowledge repository, and then executed to solve the corresponding problem.

To facilitate the organization of the enterprise knowledge, different kinds or levels of model, for example, task or process-oriented model, can be used according to the different levels or aspects of the enterprise knowledge. Also, various diagrammatic representations can be used for different kinds of models to facilitate knowledge modeling activity.

3.3 *Knowledge network*

We know that an organization's data is found in its computer systems, but a company's intelligence is found in its biological and social systems. To reveal the behavior inside and between organizations, knowledge network, on the one hand, directs the knowledge flow through the whole enterprise, on the other hand, it uncovers interactions within and across the boundaries of the different organization in an enterprise and reflects the organization behavior.

Also, the life cycle for the usefulness of knowledge is continuously becoming shorter. The business environment does not allow only static structures and does not reward those that follow prescribed configurations in the face of rapid change. The fast economy requires flexible, adaptive structures that self-organize internally in response to changes externally. However, an enterprise's core knowledge is found in individuals, communities of interest and their connections, then the evolving of the knowledge network is an important part of knowledge management. It exhibits both how knowledge is shared in emergent communities of practice, and how it is utilized in key business processes. In short, it uncovers the hidden dynamics that support learning and adaptation in the modern organization.

4 CONCLUSIONS

The community of practices, which is importance for successful knowledge management in an (virtual) organization, is a network of social relationships that cannot be reduced to any functional model. The knowledge network is defined in this paper for identifying maps of relationships in organizations of knowledge objects as they evolve, respectively, through time and through space. Then the "brain" metaphor is employed to describe its evolution. The basic idea is that links between different objects are similar to associations in the brain, as supported by synapses connecting neurons. The strength of the links, like the connection strength of synapses, can change depending on the frequency of use of the link. This allows the network to "learn" automatically from the way it is used. Also, the work described in this paper gives a framework of implementing knowledge management in an enterprise. We hope that it would take a step toward integrated analysis and design of knowledge management system.

REFERENCES

[1] Borghoff, U.M. and Pareschi, R., (Eds.), Information Technology for Knowledge Management. Springer-Verlag, 1998.

[2] G. Schreiber, H. Akkermans, etc. Knowledge Engineering and Management - The CommonKADS Methodology. MIT Press. Second printing 2001.

[3] Bringing Knowledge to Business Process: Papers from the 2000 AAAI Symposium March 20-22 Standford Technical Report.

[4] Steels, L. Components of Expertise. AI Magazine, (1990) 11(2).

[5] Karbach, W., and Vob, A. (1993). MODEL-K for Prototyping and Strategic Reasoning at the Knowledge level, in Second Generation Expert Systems, Springer Verlag, Berlin, Germany.

[6] Brualdi, R. A. 1992 Introductory Combinatorics. Elsevier Science Publishing Co., Inc., New York, Second Edition.

[7] Hull, C. L. The acquisition of receptor - Effector Connection. Primary reinforcement in Robert C. & Richard Teevan (ed.), 1961, "Reinforcement", part 1 pp9 - 15, D. Van Nostrand Company, Inc.

[8] Thorndike, E. L.: The law of Effect, excerpt from Dalbir B. & Stewart, J., "Motivation", Nature of Reinforcers pp 184 - 187, Penguin Books, 1966.

[9] Nonaka, and Takeuchi, H. The knowledge Creating Company: How Japanese Companies Creat the Dynamics of Innovation. New York: Oxford University Press 1995.