Dynamic Models of Knowledge in Virtual Organizations

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Abstract. The dynamics of knowledge is important for virtual organizations (VOs) knowledge management (KM) to improve the fast response capabilities and flexible problem solving capabilities of VOs in complex environments. This paper proposes a method of modeling knowledge dynamics in VOs, which is composed of three models: knowledge flow model, knowledge conversion model and knowledge sharing space model. The models depict the dynamics of knowledge and design the operation mechanisms of knowledge in VOs from the perspectives of flow attributes, evolution and innovation features, and sharing and cooperation of knowledge.

1 Introduction

The real and specific problem that underlies the Grid concept is coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations[1]. Virtual Organizations(VOs) are dynamic collections of a number of semi-independent autonomous entities each of which has a range of problem solving capabilities and resources[1][2]. These entities coexist and share resources in VOs in a controlled fashion, so that they may collaborate to achieve a common goal.

Over the past few years, research efforts within the Grid community have produced a lot of protocols, services and tools that address the challenges in seeking to build scalable VOs. Nevertheless, careful study of underlying requirements leads us to identify a broad set of common concerns and requirements[1]. For example, the need for highly flexible sharing relationships and collaborative processes is fundamental to many diverse disciplines and activities. Knowledge Management(KM) plays an important role in promoting the efficient sharing and collaboration, and innovation and productivity in a cooperative team such as VO[3]. By knowledge sharing and reuse, the entities in VOs may enlarge their knowledge storage, so that they can make rapid and accurate estimation about their surroundings and problems, which produces better decisions. Furthermore, highly cooperative problem solving capabilities can be acquired by efficient knowledge sharing and collaboration throughout the whole VO, so that the efficiency and scientificalness of organization decisions can be improved.

Traditionally, it is necessary for KM to be able to capture and represent their knowledge assets, to share and reuse their knowledge for different applications and different users, and to create a culture that encourages knowledge sharing and reuse[4]. Therefore, former KM research is mainly focused on knowledge representation and dissemination, and the knowledge modeling is mainly static based on ontology[5]. But the characteristics of VOs demand more capabilities of KM such as more flexible and

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controllable knowledge sharing capabilities, and collaboration capabilities of the entities in VOs. Thus, KM in VOs needs also dynamic models of the flow attributes, evolution, sharing and collaboration relationships of knowledge in VOs, so that the operation mechanisms of knowledge in VOs can be comprehended, represented and designed more explicitly and adequately, which will improve the problem solving capabilities of VOs. Therefore, we propose three models which are suitable for depicting knowledge dynamics in VOs: knowledge flow model, knowledge conversion model and knowledge sharing space model.

2 Related Work

CommonKADS methodology has become the de facto standard for knowledge modeling which proposes six models from the perspectives of organization, task, agent, communication, knowledge and design[5]. The knowledge model is divided into models of domain concepts and relationships, a model of the required inferences, and a model of the control required on the inferences[4]. Multi-perspective modeling[4] enables a number of techniques to be used together, each technique being the most appropriate for modeling that particular aspect of knowledge. Multi-perspective modeling is important because organizational knowledge is very complex and heterogeneous, and there is no single method that can model all these accurately and appropriately[5]. This method uses a collection of knowledge models to describe knowledge in organizations from six perspectives of what, how, when, who, where and why.

Another research effort of dynamic knowledge modeling in large scale knowledge sharing and collaboration in VOs is the research work of China Knowledge Grid Research Group[6]. They proposed a multidimensional knowledge space model, a knowledge operation language, and a knowledge flow model for realizing effective knowledge sharing in VOs. And they are making progress on knowledge grid applications in cooperative research and education.

3 Knowledge Flow Model

One of the most important distinctions between knowledge flows and data flows or information flows is that there are multi-dimensional flow attributes in knowledge flows. For example, in time dimension, knowledge is successively discovered, mastered, evolved and updated; in form dimension, knowledge changes from hiding in people's heads to being able to be expressed in words, finally to being accumulated as people's experience and intuition.

Here we adopt the dynamic knowledge flow model proposed by Nissen[7], which is the integration of the spiral model and the life cycle model. The spiral model[8] employs the two dimensions of epistemological and ontological to describe a knowledge flow, which is characterized by a "spiral" dynamic through four organization processes: socialization, externalization, combination and internalization. The life cycle model includes six discrete phases of knowledge as it flows through the organizations: creation, organization, formalization, dissemination, application and evolution[7]. The two models are integrated and extended to construct a four-dimensional model of knowledge flow dynamics. The four dimensions are: life cycle, time, explicitness (epistemological) and reach (ontological). To illustrate the model using three variable pictures, we fix time at some time period as a constant and then the model is shown in Fig.1. The vector sequence K-S-E-C-I-V corresponds to the processes of knowledge creation, socialization, externalization, combination, internalization and refinement. The KMLC arcs represent knowledge management life cycle, and P&P are policies and procedures.

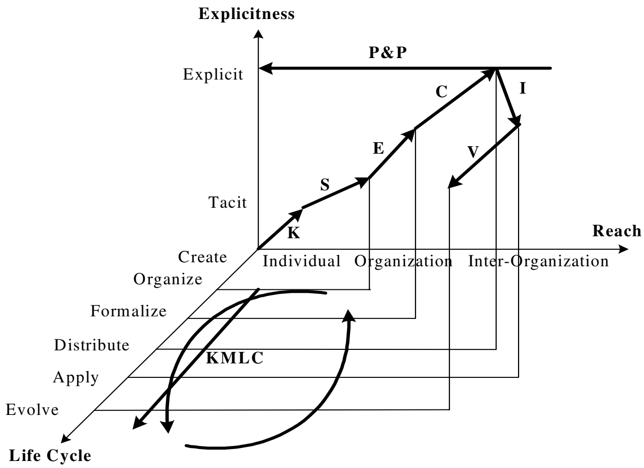

Fig. 1. Knowledge flow model (time as constant) (adapted from[7])

The model is very useful in depicting and visualizing knowledge flows. If the three-dimensional representation of knowledge flow space in which life cycle is fixed as a constant is divided into octants by making binary distinctions along each of the three axes, the three coordination approaches termed standardization, planning and mutual adjustment drawing from the organizational design and coordination theory can be mapped into several regions of the divided space. Then we can use the manifest knowledge flow pattern to determine which coordination approach is likely to be most effective in a given context[7].

4 Knowledge Conversion Model

The complexity of KM lies in the innovation feature of knowledge. Knowledge is attached to human beings so that it can be created, updated, deducted, induced and applied. We call this process Knowledge Conversion Process(KCP). If this process goes along for the problem solving goal and finally gets the useful knowledge, then the process is required. The entities in VOs share their knowledge and collaborate for a common goal so as to find satisfying knowledge conversion processes.

We classify the knowledge sources of VO entities into two classes: one is the knowledge storage of an entity (denoted as E), denoted as Ko, which on the whole behaves as the existing knowledge base distribution; the other one is the knowledge that an entity E acquires from other entities, denoted as Kg, which on the whole behaves as knowledge passing and sharing[9]. Kn represents the new knowledge that an entity E gains from the knowledge conversion process. A single process is called Knowledge Conversion Unit, denoted as CU. Along with the progress of CUs, Kn is enlarged and updated. The changes of Kg embody the interactions and collaborations between VO entities. We use a Petri-like form to illustrate the CU as Fig. 2.

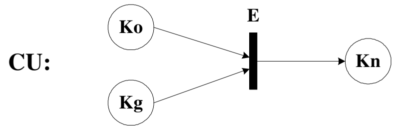

Fig. 2. Knowledge conversion unit

Apparently, not all knowledge interactions can produce KCP. According to the relationships between Kg and Ko, we may classify the interactions and the corresponding entity activities which cannot produce KCP into the following classes:

(1) If there is no relevancy between Kg and Ko, then the entities cannot make any conversion, so Ko remains;
(2) If there is relevancy between Kg and Ko, but
 - Ko is the same as or contains Kg, then Ko remains, called Containing Pattern;
 - Ko contradicts with Kg, then: if Ko is true, then Ko remains; if Ko is false, then Ko can be abandoned despite of Kg being true or false, called Contradiction Pattern;

(3) If Kg contains some rules that require the entities to decompose Ko into the knowledge with smaller granularity, then the process cannot be considered as KCP, because the process cannot produce new knowledge.

KCP appears in the following cases when there is relevancy between Kg and Ko:

(1) Complementarity Pattern, i.e. Ko and Kg are complementary so that they can be combined into new knowledge through synthesis activities of entities;
(2) Induction Pattern, i.e. the contents of Ko and Kg can be induced and generalized to new knowledge such as principles and experience;
(3) Deduction Pattern, i.e. the entities can deduce new knowledge from Ko through the preconditions or rules provided by Kg;
(4) Enlightening Pattern, i.e. the contents of Kg enlighten the entities on Ko, which results in the association of ideas and the creative activities of the entities.

5 Knowledge Sharing Space

Different entities in VOs have different objects and benefits. They hold and control their own private resources, and have relatively dependent problem solving capabilities and operation mechanisms. They come together dynamically for common tasks and goals, but their own benefits are still existent. Moreover, they expect that by sharing resources and collaborations, their own benefits can be maximized while they achieve the common goal. Therefore, this sharing must be controllable and limited. We propose the conception of Knowledge Sharing Space(KSS) which includes four related but different space concepts:

(1) Common Space: In the common space, the entities can communicate with each other and share their knowledge assets without restriction. All the knowledge resources are authorized and open completely.
(2) Private Space: In the private space, the entities manage and utilize their private knowledge assets, and keep the direct protection and absolute control power on them.
(3) Organizational Shared Space: This is the interface between common space and private space. In this space, the entities can share their knowledge and keep the control of them at the same time, and they will protect the resources from illegal intrusion and malice destruction.
(4) Accessory Space: This is used to support the knowledge requirements from non-VO entities. It can be connected to the common space through an authorized interface and the entities in the accessory space can use parts of the knowledge resources in the common space.

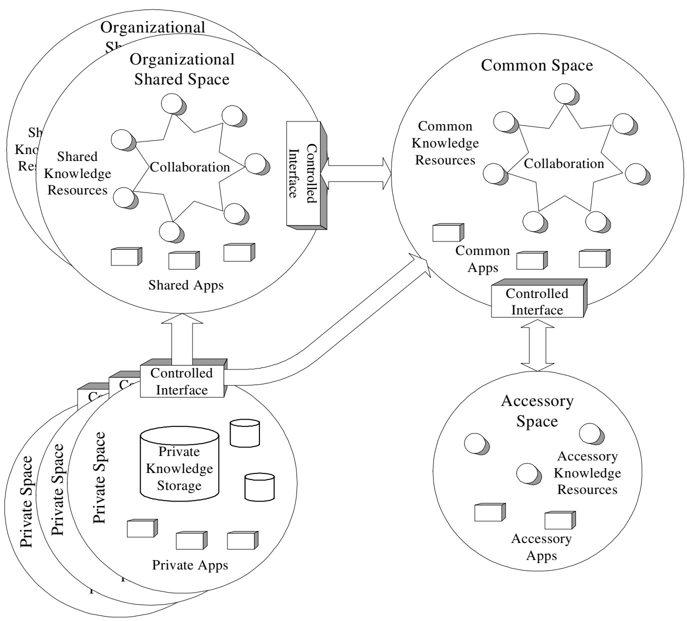

Fig. 3. Knowledge sharing space conceptual model

The KSS conceptual model is shown in Fig. 3. VOs may define their own abilities, standards and interfaces required. The entities in VOs can hold, operate and manage their private space according to their organization strategies and procedures which are consistent with the general policies. Using the KSS, the entities can share knowledge and applications and collaborate with each other while keeping security controls. According to different task requirements, the entities may adjust the usage of the shared knowledge resources and applications and integrate new knowledge resources and applications. Thus, the KSS not only ensures the flexible and controllable sharing and collaborations in VOs, but also has some extensibility, which enables VOs to meet the needs in critical moments and to adapt to rapid and continuous changes.

6 Conclusion

The paper proposes three dynamic models of knowledge in VOs from multi-perspective modeling point of view. The three models reflect the flow attributes, evolution and innovation features, sharing and collaboration relationships of knowledge in VOs. The paper only brings forward the profile of the modeling idea. The models will be refined and new models such as cooperative relationship model will be added if needed in the future.

The structures of modern large-scale VOs are becoming flat, the management and decision links are shortening, and the horizontal contacts and collaborations are being enhanced. Self-management, self-decision and active collaboration will be new patterns of organization operations. We believe KM will be more and more important as a technique of organizational coordination, control and adaptation in the future.

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