A fuzzy trust evaluation method for knowledge sharing in virtual enterprises

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ABSTRACT

The success of virtual enterprises (VEs) depends on the effective sharing of related resources between various enterprises or workers who perform related activities. Specifically, VE success hinges on the integration and sharing of information and knowledge. Trust is an important facilitator of knowledge sharing. However, the trustworthiness of a peer is a vague concept that is dynamic and that often shifts over time or with environmental changes. This study designs a trust-based knowledge-sharing model based on characteristics of VEs and the knowledge structure model to express knowledge associated with VE activities. Subsequently, the factors that affect the trust evaluation are identified based on the characteristics of trust and VEs. Finally, this study develops a knowledge sharing, decision-making framework in which a fuzzy trust evaluation method for sharing knowledge is proposed based on VE activities and the interactions among workers in allied enterprises. The method consists of three sub-methods, including an activity correlation evaluation method, a current trust evaluation method, and an integral trust evaluation method. Under the premises of secure VE knowledge and reasonable access authorization, the proposed knowledge-sharing method provides the trust level between a knowledge-requesting enterprise and a knowledge-supplying enterprise to improve the willingness of the latter to share more valuable knowledge, ultimately increasing the efficiency and competitiveness of VEs.

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1. Introduction

Virtual enterprises (VEs) represent a dynamic networking alliance that can react sensitively to changing market opportunities and gather knowledge resources from a wide range of enterprises using Internet technology to develop, design, manufacture, and market goods and services (Yang & Lin, 2008). The success of a VE depends on the effective sharing of related resources between activities performed by various enterprises and, in particular, on the integration and sharing of information and knowledge among alliance enterprises.

Knowledge sharing refers to the exchange and discussion of knowledge among members of an organization, between internal and external teams, or between organizations for the purpose of improving organizational competeness by the effective exchange, integration, and synergy of knowledge (Chen, 2008; Lawson, Petersen, Cousins, & Handfield, 2009). Knowledge sharing is difficult to implement. Previous investigations of enterprise knowledge sharing have tended to focus on the deployment of

information technological infrastructure, such as document management systems, information search technologies, and forums, to improve the environment for knowledge management (Fla'via Maria, Marcos, Borges, & Erick, 2006; Gollmann, 1999; Lin, Wang, & Tserng, 2006). Strader, Lin and Shaw (1998) and Chen (2008) adopted an access control perspective to investigate knowledge access authorization of users to assist enterprises in knowledge sharing.

Knowledge sharing within VEs is determined by key factors such as the VE process and trust among the enterprises. Trust has been defined as a psychological state that comprises the intention to accept vulnerability based on positive expectations regarding the intentions or behavior of others without the ability to monitor or control that other party (Zolin, Hinds, Fruchter, & Levitt, 2004). Knowledge sharing in distributed environments requires more a priori trust than face-to-face communication (Riegelsberger, Sasse, & McCarthy, 2003). Investigations have found that a higher level of trust corresponds to greater willingness to share knowledge (Cheng, Hailin, & Hongming, 2008; Quigley, Tesluk, Locke, & Bartol, 2007; Willem & Buelens, 2007). However, trust depends on an implicit set of beliefs, which are vague. Trust is a multi-dimensional construct (Mayer, Davis, & Schoorman, 1995; Kanawattanachai & Yoo, 2002) and has various definitions that are appropriate to different application domains (Ford, 2003). Trust varies with time, the environment, and other factors. Therefore,

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objectively evaluating trust has become an important issue in the field of knowledge sharing.

To integrate knowledge that is distributed across allied enterprises while providing the VE members with authorized access to knowledge that is related to or required for tasks of interest, this study proposes a knowledge-sharing method for VEs that is based on the process of VEs and considers trust among allied enterprises. To develop the methodology, a knowledge-sharing model is designed based on the characteristics of a VE, and then a structure of activity-related knowledge is designed to express the knowledge of VE activities. Subsequently, the factors that affect the trust evaluation are identified, derived from the characteristics of trust and VEs. Because trust always involves ambiguity and subjectivity and is difficult to estimate experimentally by modeling some graded phenomenon, trust degree cannot be specifically measured using crisp values. Therefore, a fuzzy-based trust evaluation method is developed; it includes a method for evaluating the correlation among activities, the current trust evaluation method, and the integral trust evaluation method. Assuming secure VE knowledge and reasonable access authorization, the proposed knowledge-sharing approach provides a decision-making support framework centered on trust evaluation between a knowledge requester and a knowledge supplier that will improve the willingness of the latter to sharing valuable knowledge and consequently will increase the efficiency and competitiveness of VEs.

2. Related literature

This section surveys a number of related studies of VE activity and knowledge, trust, knowledge sharing, and fuzzy theory.

2.1. Activity and knowledge in VEs

Activity theory is a set of basic principles for constituting a general conceptual system (Kaptelinin & Nardi, 1997, 2006; Holland & Reeves, 1994). Beckett (2004) used the theory as a framework for discussion of the organizational attributes associated with VE operation. The unit of analysis in activity theory is an activity directed at an object which motivates activity. An activity contains various artifacts, for example instruments, signs, procedures, machines, methods, laws, forms of work organization (Nardi, 1996). Activities are composed of goal-directed actions. Different actions may be performed by different VE workers to meet the same goal. In activity theory, the constituents of activity are not fixed, but can dynamically changes with conditions (Kaptelinin & Nardi, 1997). In this study, activity theory is helpful to understand and analyze different kinds of VE activities.

Activities of VEs must be analyzed to provide an understanding of the knowledge that is required for particular activities. Knowledge can be structured experiences, values, text-based information, or unique expert insights. It resides in not only documents that are stored in a knowledge management system but also in daily routine tasks, processes, executions, and norms (Davenport & Prusak, 1998; Lee, 2001). Since categories of knowledge vary with perspective, this study considers three dimensions in categorizing knowledge in a VE.

(1) Abstractness. This dimension can be divided into (a) *formal knowledge*: conceptual knowledge that is derived by the generalization, analysis, and validation of data collected by scientifically objective means and (b) *practical knowledge*: specific job skills, experience-based rules, causal relationships, or input/output of enterprise activities derived from practices and generally preserved in knowledge cases and personal experiential knowledge databases (Beckman, 1997).

(2) Phenomenon comprehension and application purpose, which is divided into (a) *declarative knowledge* (*Know-what*): concepts, composition, and structure of an event; (b) *causal knowledge* (*Know-why*): knowledge of causes and consequences of an event; (c) *procedural knowledge* (*Know-how*): knowledge of processes, steps, and methods associated with the execution of an event; and (d) *relational knowledge* (*Know-with*): knowledge of relationships between an event and other important factors (Quinn, Anderson, & Finkelstein, 1996).

(3) Openness: Given the need for some knowledge to be securely protected, knowledge can be divided into (a) *public knowledge*: defined as knowledge related to the VE project that all member enterprises must provide and share and (b) *private knowledge*: techniques or knowledge related to the VE project that are owned but not directly shared by enterprises, which can thus decide whether or not to share such knowledge based on an evaluation of trust with another party.

2.2. Trust

Trust has been defined in various ways for various situations and specific contexts. Trust is a multi-dimensional and multi-level dynamic concept (Lewicki & Bunker, 1996; Butler, 1991). Mayer et al. (1995) claimed that trust comprises ability, benevolence, and integrity. Mishra (1996) extended this concept by defining four dimensions of trust—concern, reliability, competence, and openness. Meyerson, Weick, and Kramer (1996) proposed the concept of swift trust, which applied to members of temporary teams, who tend to relate to each other according to roles rather than as individuals. Accordingly, a specific definition of trust pertaining to employees in an organization involves positive expectations, such as integrity, capability, truthfulness, goodwill, and ability, which relate to the competence and reliability of fellow employees within the organization (Ellonen, Blomqvist, & Puumalainen, 2008). Chowdhury (2005) identified two main forms of trust: (1) cognitive trust, based on cognitive reasoning regarding reliability of performance and competence and (2) affective trust, based on emotional ties with someone. Koehn (2003) investigated four forms of trust: (1) goal-based trust, which appears between two people who think they share a common objective; (2) calculative trust, which attempts to predict what the trusted party will do by seeking evidence of the other's trustworthiness; (3) knowledge-based trust, which arises when people are familiar with each other and/or interact frequently; and (4) respect-based trust, which is reinforced when the two parties in a relationship have a similar love of virtue, excellence, and wisdom and are willing to engage in dialogue and ongoing conversation with a view to understanding each other better.

2.3. Trust associated with knowledge sharing

Trust evaluation is a valuable means of promoting knowledge sharing (Gruber, 2000; Ling, San, & Hock, 2009; McEvily, Perrone, & Zaheer, 2003). Renzl (2008) provided empirical evidence that trust in management facilitates knowledge sharing by reducing fear of loss of one's unique value. Restated, a trusting person is more willing to provide useful knowledge to others. Newell, David, and Chand (2007) and Lin (2008) investigated issues related to trust and the sharing of knowledge in globally distributed IT work teams and developed a threefold typology of trust that included commitment, companion, and competence trust. Commitment trust is based on contractual agreements between members who expect to derive mutual benefits from their cooperative relationship. Commitment trust can reduce team risk and uncertainty