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Self-Modelling Knowledge Networks

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INTRODUCTION

The necessity for managing knowledge is stressed by wide array of recent publications ranging from information science to strategic management substantiating their proposition with the tremendous changes in the context organisations that are operating today. Although knowledge management (KM) literature and research projects are increasingly extending their attention from intra-organisational to inter-organisational aspects (e.g., Seufert, Back, & van Krogh, 2000; Alpar & Kalmring, 2001; Schmaltz & Hagenhof, 2003), the question of how inter-organisational knowledge management can be realised is up to now not sufficiently answered (Carlsson, 2003). That is even more true for virtual enterprises, as the following specific characteristics need to be considered: short-term focus; focus on information and communication technology; decentralised information systems; and distributed ownership. As a solution approach catering for the issues mentioned above, a prototype of a system called “selfmodelling knowledge networks” is introduced. Self-modelling knowledge networks could provide a mechanism that facilitates flexible knowledge retrieval across several nodes in networked and virtual enterprises. Thus, this approach is ideally suited for situations where knowledge resources need to be combined in a flexible way and several levels of the network are comprised.

BACKGROUND

Apparently, technological innovations such as global, Web-based infrastructures, standards, and distributed systems can lead to a substantial reduction in transaction cost. By doing so, this leverages the value creation in the network context. The focus of IT-enabled integration, however, is on the integration of data and information (e.g., price inquiries, delivery time, etc.), whereas the knowledge aspects that are inherent to

value creation processes in networked organisations are mostly neglected. A critical point is the fact that in the network context, there is no common knowledge management infrastructure that can be used by all networks participants.

In this area of research, it crucial to answer the following question: How do you to support the identification of scattered knowledge assets, the visualisation and modelling of the network structure in the context of networked organizations? Insights gained from the area of peer-to-peer computing (P2P) can contribute valuable input in this respect. The potential of P2P for knowledge management is emphasised for example by Chillingworth (2002). A P2P-based infrastructure could therefore solve some of the integration problems and thus enable the support of KM in a network context. As a contribution to the area of inter-organisational knowledge management research, the concept of self-modelling knowledge networks is introduced in the following section.

SELF MODELLING KNOWLEDGE NETWORKS

Basis for the concept of self modelling knowledge networks is a value creation process in the context of networked or virtual enterprises. It is assumed that value creation takes place through the combination of internal and external knowledge assets and that not all knowledge required is available within one enterprise. Thus, a network of enterprises or organisational units has to be established, from which or about which knowledge has to be acquired.

Starting point is a request for knowledge—knowledge artefacts or competences—regarding a specific knowledge demand and specified by a knowledge seeking enterprise. The demands can either be fulfilled by the own company or it needs to be sent to existing or potential knowledge suppliers. Doing so, information

about the availability and quality of the knowledge required will be received. Since not only information about the supplier in tier-1 is required by the requesting enterprise in order to strategically develop the knowledge network, the demands are split on each node in sub-demands, which are then forwarded to the next suppliers in the value network. Every node in tier- x receives demands from clients in tier- $(x-1)$ and communicates sub-demands, depending on the demand received, to relevant suppliers in tier- $(x+1)$. Since every node repeats the same procedure, a requestor receives back aggregated information from the whole, dynamically built network based on a specific demand sent at a specific time.

At the core of the concept of self-modelling knowledge networks is the idea that the network nodes can be identified by applying the pull principle. With the pull principle, a network node at the beginning of a (sub-) network can identify potential nodes, that is, knowledge suppliers, in a subsequent tier by performing a knowledge demand specification using standardised ontologies and taxonomies. The mapping of the different ontologies can be achieved employing ontology mapping methods (Canadas et al., 2004; Kalfoglou & Schorlemmer, 2005).

By defining a knowledge demand, primary requirements and dependent requirements can be identified and the respective information can be communicated—

sending a *demand*— to the respective network nodes, that is, potential suppliers for dependent requirements, in the subsequent tier, as these suppliers are generally known by the initiating lot. This procedure is repeated by the nodes in the respective tiers until the final tier is reached. Then, the information from the nodes further upstream is aggregated and split-lot transferred to the initiating node. Every node in tier- x receives demands from clients in tier- $(x-1)$ and communicates sub-demands, depending on the demand received, to relevant knowledge suppliers in tier- $(x+1)$. Since every node repeats the same procedure, a knowledge seeker receives back aggregated information from the whole, dynamically built network based on a specific demand sent at a specific time. Having the fact that the seeker-supplier relationship may change over time, new dynamically modelled networks—which may differ from the actual ones—are built whenever sending out new demands to the suppliers in the subsequent tiers. The following example demonstrates the idea.

The concept is illustrated in the following as shown in Figure 1. The figure on the left shows a complete demand driven knowledge network constituted of existing (highlighted nodes) and alternative sub-networks. Existing sub-networks are those the knowledge seeker already uses. Alternative sub-networks are networks, which are built by sending a demand for a specific knowledge artefact to new chosen knowledge suppliers,

Figure 1. Different knowledge networks

with yet no direct relation to the knowledge seeker. The whole network is demand-driven, since the knowledge seeker communicates a specific knowledge demand to existing and selected alternative nodes in tier-1. Subsequently, the nodes in tier-1 report themselves the corresponding sub-demands to their respective suppliers. For example, for node 1-2, these are the nodes 2-3, 2-4 and 2-5 in tier-2. In the following, these nodes report the newly defined sub-demands to their related nodes in tier-3, which split-lot transfer the requested information including, for example, a specification of the requested knowledge.

The seekers aggregate the information received from all nodes contacted for a specific request with the own information and send it back to the supplier 1-2 in tier-1. Having aggregated the information of all nodes, the node 1-2 adds its own information before split-lot transferring it to the knowledge seeker. Figure 1 on the right highlights an alternative knowledge sub-network fulfilling the requirements regarding a specific demand sent. Through sending out knowledge demand, transparency about the network is created. The network participants, their interrelationships as well their knowledge and competences can be visualised. In the following section, an exemplary knowledge demand will be described, thus showing a use case of the system.

Exemplary Knowledge Demand

A large manufacturer of Diesel Engines for power plants plans to adapt the marketing and sales strategy for a particular engine type to focus on a specific industry (e.g. mining industry). For that purpose, it is required

to obtain detailed knowledge on *operating experiences* concerning the employment of engines in this industry. The possible conceptual structure of that knowledge can also be visualised by modelling it according to Allweyer (1998). This notation is an extension of Architecture of Integrated Information Systems (Scheer 1998), which is a widely used modelling language in information systems design in Europe. Knowledge as a concept comprises several different sub-concepts consisting of implicit (depicted as a round shape) and explicit knowledge (depicted as a rectangular shape). The advantage of this approach is that the knowledge type of the particular knowledge concept is directly visible. That includes customer knowledge (general marketing related information, e.g. contact details of mining companies etc.), industry knowledge (specific knowledge about that industry) and the actual operating knowledge comprising explicit knowledge manifested in service reports, warranty claims, performance data sheets etc. and implicit knowledge of service engineers, technicians, warranty managers.

The knowledge *operating experiences* is widely scattered across several participants in a network-like structure: the manufacturer, autonomous sales offices, foreign representative offices, engineering companies, consultants, authorised repair shops, independent repair shops and finally the end user, that is, the mining company. As each of those participants was or is at some stage involved in, for example, the sales, service, after-sales, warranty claims or operating activities, they all can be considered as potential sources for some parts of the knowledge required. Lacking a central IT-infrastructure that comprises all the participants, the process of retrieving the knowledge cannot be conducted without

Figure 2. Exemplary data model of knowledge demand

Figure 3. Excerpt of developed domain ontology

considerable manual and time-consuming effort. Based on that understanding of the required knowledge, the actual knowledge demand can be modelled as a UML diagram as shown in Figure 2. The knowledge demand *operating experiences* is modelled as the specification of an abstract concept having the characteristic dimensions context, content and meta information according to Abecker et al. (1998). As the knowledge desired is—in this case—created in or by a particular organisational function conducting particular processes or activities, this context is specified with *has been created at* and *has been created by* using enterprise ontologies.

The content is modelled using domain ontologies. In this case, the knowledge artefact should include technical details (e.g., *performance data*, *idle time*), the specific engine type (*Engine 32/40*) and the relevant application area *mining*. The meta information which uses information ontologies is made up of the specification of the knowledge type, as the knowledge artefact desired could be either *implicit* or *explicit*. For the research project presented here, a domain ontology has been developed with the basic concepts as shown in Figure 3. The whole ontology consists of 45 concepts, which are all specified. Further, attributes have been added to classes and instances. In order to develop the system, functional tasks had to be identified. These are presented in the next section.

Functional Tasks

The functional tasks are derived from the main processes of the KM model described by Riempp (2003). In this context, we will only consider the tasks that can be automated by a business application. For that reason, the process of knowledge *application* is not

considered. As the concept of self-modelling knowledge networks is primarily aimed at supporting the retrieval and exchange of knowledge in networks, we will focus on the KM processes of *locating*, *exchanging*, and *developing* knowledge, which are expected to undergo the most evident changes due to their cross-company focus. The functional tasks have been illustrated in a function decomposition diagram as shown in Figure 4 (elementary functions have not been depicted due to space restrictions). Processes and tasks that will be automated have been shaded. Following, only selected tasks will be described, focusing on changes to current tasks of the KM process.

- Identify knowledge network:** This task comprises the process of locating knowledge according to Riempp (2003) and undergoes the most evident changes in the shift to a network perspective. In the conventional process, transparency about available knowledge is created by an internal and external screening process of knowledge sources, that is, knowledge embedded in human actors or in knowledge artefacts. Based on a network perspective, knowledge identification requires more information about knowledge than merely data on existing and potential nodes in tier-1. Instead, the knowledge networks connected with those suppliers have to be identified and evaluated, for example, by comparing alternative knowledge networks. Therefore, the task supplier selection is part of the process that leads to the modelling of knowledge networks. The perception of the network as dynamic network constitutes the basis for the identification of knowledge networks.

- **Acquire knowledge from network:** This task comprises the process of exchanging and distributing knowledge. Again, the focus shifts from exchanging and distributing knowledge in the organisation—in case the knowledge is already available there—or from the a single external source—in case the knowledge is bought externally—to the network perspective.
Knowledge or knowledge artefacts are distributed across several nodes, with each node adding its partial contribution to the fulfilment of the knowledge demand. First, the relevant knowledge artefacts need to be identified. After that, a process called knowledge acquisition describes the integration of the external knowledge. In this context, the form of knowledge—implicit or explicit—is distinguished. The integration of implicit knowledge—embedded in a human actor—cannot be automated and thus the capacity of the business application ends here. In this case, the business application serves as an initiation tool. The integration of explicit knowledge—stored in databases or embedded in artificial intelligence applications—however, can be automated. For that purpose, the access protocol has to be negotiated to allow the knowledge seeker's information systems to access the supplier's data. After that, the knowledge demand is communicated, that is, an inquiry is conducted. The relevant knowledge artefacts are then split-lot transferred to the knowledge seeker.
- **Qualify knowledge network:** This task represents parts of the KM controlling process which in the network context encompasses several nodes in the evaluation of their contribution towards the knowledge goals of the knowledge seeking organisation. In addition to the selection of suitable knowledge networks, the performance improvement of strategically important networks is one of the major goals. Main prerequisite is the constant evaluation of the actual performance of selected knowledge networks by defined benchmarks. The application should support respective evaluation methods enabling the user to identify imminent problems in the network and to initiate appropriate measures for qualification of network partners.

Having identified and characterised the tasks for the domain of self-modelling knowledge networks, on the

basis of the semantic data model and the information objects, the BCI method (Albani, Keiblinger, Turowski, & Winnewisser, 2003), which has been developed for the design of domain specific business component applications, has been employed to develop a component model. The underlying idea of business components combines components from different vendors to an application, which is individual to each customer. The principle of modular black-box design has been chosen allowing different configurations of the final system by combining different components regarding the need of the specific node, ranging from a very simple configuration of the system to a very complex and integrated solution of the system. The system, therefore, will not only provide basic functionality needed on each network node, but it will also provide the possibility of adding new functionality while composing additional components to the system, for example, adding a component for the evaluation of networks. As the detailed description of the BCI method would go beyond the focus of this article, only its result, the component model, is described in the following:

The component model is shown in Figure 5 in accordance with the notation of the Unified Modelling Language (OMG, 2003). Additionally, the component model provides two system components, persistence manager and collaboration manager, responsible for the technical administration of the data and for the collaboration between network nodes. The information managed by the single business components is made persistent through the persistence manager. The main reason for introducing the persistence manager is based on the idea of having business components concentrating on the business logic while having system components taking care of implementation-specific details. This has an impact on the distribution of the system on network nodes, having the fact that different companies use different physical database systems as data storage.

The component model handles that situation in having the persistent manager taking care of implementation-specific details without affecting the business logic of the system. The system provides two semantic storages for data.

The supply network database stores all supply networks containing the aggregated information of knowledge suppliers contributing to a specific demand. For each demand, a new network is generated by split-lot transferring data from all suppliers and aggregating

Figure 5. Component model for the domain of self-modelling knowledge network

the information in the supply network development component. Such a network is then stored in the supply network database through the services provided by the persistent manager and called by the knowledge supply network development component. The information can, for example, be retrieved in order to visualise and develop the networks. The performance database provides storage for the companies' performance information.

Example clients requesting collaboration services from the system can either be graphical user interfaces (GUI), asking for data, for example, to visualise networks, or other network nodes sending demands to suppliers. The collaboration in the system is executed by the *collaboration component*. Regarding the complexity of collaboration in inter-enterprise systems we refer to Albani et al. (2004) and Bazijanec et al. (2004) for further information.

FUTURE TRENDS

As mentioned above, it is essential for the area of knowledge management to address inter-organisational

aspects in order to enable KM across the borders of single enterprises. A critical point is the absence of a common IT infrastructure in the network context that can be used by all networks participants. The area of decentralised, P2P-based knowledge management seems to be very promising in solving that challenge. However, this area of research is still comparatively incomplete (c.f. Tsui, 2002, 2004). Further work needs to be done in order to test existing prototypes in different settings and to refine their performance in real-world contexts. For the work presented in this article, in the next step, existing research in the ontology area (e.g., Apostolou et al., 2002) will be incorporated.

CONCLUSION

This article presented research in the field of knowledge management for networked and virtual enterprises substantiating the necessity of extending the knowledge management perspective towards a network approach. The domain of self-modelling knowledge network was introduced, describing the relevant tasks in a functional-decomposition diagram and presenting

a component model. The major advantage of the self-modelling approach for KM is the fact that, similar to P2P, if necessary, for every individual knowledge demand a knowledge network can be established that requires neither a centralised infrastructure nor the integration of different and separate knowledge management systems.

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KEY TERMS

Inter-Organisational Knowledge Management:

Inter-organisational Knowledge Management refers to a specific occurrence of knowledge management comprising basic knowledge management processes between two or more independent organisations.

Knowledge: Knowledge is defined, according to Steinmüller (1993), as the combination or connection of information.

Knowledge Management: Knowledge Management (KM) “(...) refers to the critical issues of organizational adaptation, survival and competence against discontinuous environmental change. Essentially it embodies organizational processes that seek synergistic combination of data and information processing capacity of information technologies, and the creative and innovative capacity of human beings.” (Malhotra, 2005)

Knowledge Management System (KMS): KMS describes information systems that are designed to support certain KM processes like the dissemination or application of knowledge.

Knowledge Worker/Work: Knowledge work refers to work conducted by knowledge workers. That is work that comprises to a large extent the tasks of retrieving, evaluating, integrating and creating knowledge.

Ontology: Ontology is defined as “(...) an explicit specification of a conceptualization” according to (Gruber, 1993) and describes basic terms and concepts within a certain domain as well as the relationship between those concepts.

Peer-to-Peer: Peer-to-Peer (P2P) in this context refers to a network architecture consisting of nodes mutually sharing information and function

Self-modelling Knowledge Networks: Self-modelling Knowledge Networks describe a decentralised system without central servers comprising nodes with the capability to save data, receive and send demands in order to support inter-organisational KM.