skillMap: dynamic visualization of shared organizational context

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Abstract: Shared context facilitates knowledge communication between individuals in organizations. By visualizing organizational context in terms of social and semantic networks, graph-based systems support knowledge transparency and communication in organizations. We introduce the skillMap system that dynamically visualizes relations between individuals and their fields of expertise. By including both as nodes in the visualization, skillMap is able to visualize shared organizational context, undesired parallel developments and communities of practices.

1 Introduction

Developments towards a knowledge society [St94] and the aim of the European Union to become the world's leading knowledge–based economy [Eu00] underline the key role of knowledge as "the one sure source of lasting competitive advantage" [TN04a, p29]. Knowledge management (KM) "is defined as the process of continuously creating new knowledge, disseminating it widely through the organization, and embodying it quickly in new products/services, technologies and systems." [TN04b, pIX] It is supported by a heterogeneous group of IT-based knowledge management systems [GK02]. In this paper, we focus on KM systems that help to identify shared organizational context through visualizing relations between knowledge entities. We will first give a brief account on the importance of shared context for knowledge creation, introduce the concept of graph-based systems, present two concrete systems, KnowWho and Commetrix, and discuss their limitations. After that, we introduce our skillMap system; describe its capabilities and how it overcomes the limitations of the other two systems. The paper ends with example visualizations from the skillMap prototype.

1.1 The role of shared context in knowledge creation

One central concept in KM is the concept of ba [NK98]. Simply speaking, it states that the exchange of both tacit (difficult to articulate, e.g. know-how) and explicit (easy to formalize) knowledge between individuals is optimal in a shared physical context. Ba is „… a context which harbors meaning…, a shared space that serves as a foundation for knowledge creation." [NK98, p40] Nonaka and Konno define four different bas for different stages of knowledge creation that correspond to the four cycles of knowledge creation of the SECI-Model [NT95]: Originating ba for face-to-face interaction during socialization, interacting ba for peer-to-peer interaction during externalization, cyber ba in group-to-group interaction during combination, and exercising ba for on-the-site interaction during internalization. Despite the fact that a physically shared space for interaction is optimal, individuals cannot always get together in order to exchange knowledge in virtual or complex organizations. In this case, the shared context between individuals is reduced to shared "interpretative frameworks" [Po58, p74] that originate in shared knowledge. This shared context can be described as shared activities, social relations among organizational members, fields of work and expertise ("topics") and related documents. [Tr03, Tr05]. The visualization of such relationships poses an operationalization of cyber ba and interacting ba and identifying a shared ba between individuals increases the quality of knowledge exchange between them. In this way, the visualization of relations between organizational knowledge entities can support organizational knowledge communication and creation. The social relationships are a specifically important aspect of modelling context, because social networks describe how actual collaboration within organizations takes place [CP04].
In the following section, we will describe how graph-based systems that visualize such connections seek to support knowledge exchange in organizations. We will then introduce two examples of such network-visualization software, outline their shortcomings and, based on that, introduce our visualization approach.

1.2 Graph-based systems in Knowledge Management

According to Trier's knowledge management entity model [Tr05, p964], KM systems can include up to four different types of knowledge entities: processes / activities, documents, individuals (employees), and topics. Different systems and strategies differ in their focus on these entities. Among the different types of KM systems, graph-based systems model the interrelations between these entities and draw references from them. Graph-based systems that focus on individuals and their connections are also referred to as social software [DV05]. Graph-based systems contain vertices (or nodes) and edges (or arcs) between them. By visualizing semantic relations between entities, graph-based knowledge representations allow capturing complex knowledge domains. Examples include creativity support sys-

tems like D-ABDUCTOR [SM96], knowledge networks that help to structure data according to semantic relationships such as theBrain® or social software such as Orkut®, LinkedIn® or OpenBC®.
Social networks contained in these systems are created by the means of social network analysis (SNA). This can either be done by manually specifying relations to others or by data-mining techniques on logged point-to-point communication data, such as e-mail traffic, web-based schedules and IM-protocols.
In a company context, social networks are considered as an adequate representation of knowledge creation [Ja04], because they reveal how “work really gets done in organizations” [CP04] and how information search and retrieval is carried out throughout firms [Ha99]. Thus, knowledge bearers and knowledge dissemination in firms can be identified on the basis of social networks, increasing knowledge transparency and facilitating knowledge exchange [CP04].

2 Concrete Systems

In this section, two concrete graph-based systems that visualize organizational knowledge flows are presented. After discussing each system individually, we propose our own system and outline its advantage compared to the first two systems.

2.1 KnowWho

Fujitsu’s KnowWho-System [Ig03, Ts03] visualizes the semantic structure of products and innovations at Fujitsu as a graph. Selecting a product switches to a social network view with the expert on the selected product as the central node (compare fig. 1). With reference to Trier’s knowledge entities (see above), KnowWho visualizes the connections between employees, between employees and topics (products in this case) and documents (associated with products). The system’s visualization engine is based on the static visualization engine from the D-ABDUCTOR system [SM96]. The data for KnowWho’s social network is automatically retrieved from Fujitsu’s repositories. Meeting schedules and joined publications of technical documents provide the basis for network construction. The semantic network of product-interrelations is built via data-mining on technical documents. Yet, however advanced the data-mining behind KnowWho, its visualization has certain limitations. Generally, graph based systems face the specific challenge to integrate a highly comprehensive visualization. Sugiyama [Su02, p11] gives a detailed overview of graph drawing rules and frameworks. Graphs typically have to obey a set of 20 static structural rules (e.g. placement of high degree vertices in the center and identical drawing of isomorphic sub graphs) and have to be editable and changeable dynamically in such a way that "the human mental map of a graph" [Su02, p11] and the continuity of cognition is preserved. The issue with Fujitsu's System is that it does not preserve the continuity of cognition because clicking a node in either network switches to a static new layout of the graph, and the transition between the two states of the network are not presented in a continuous way.

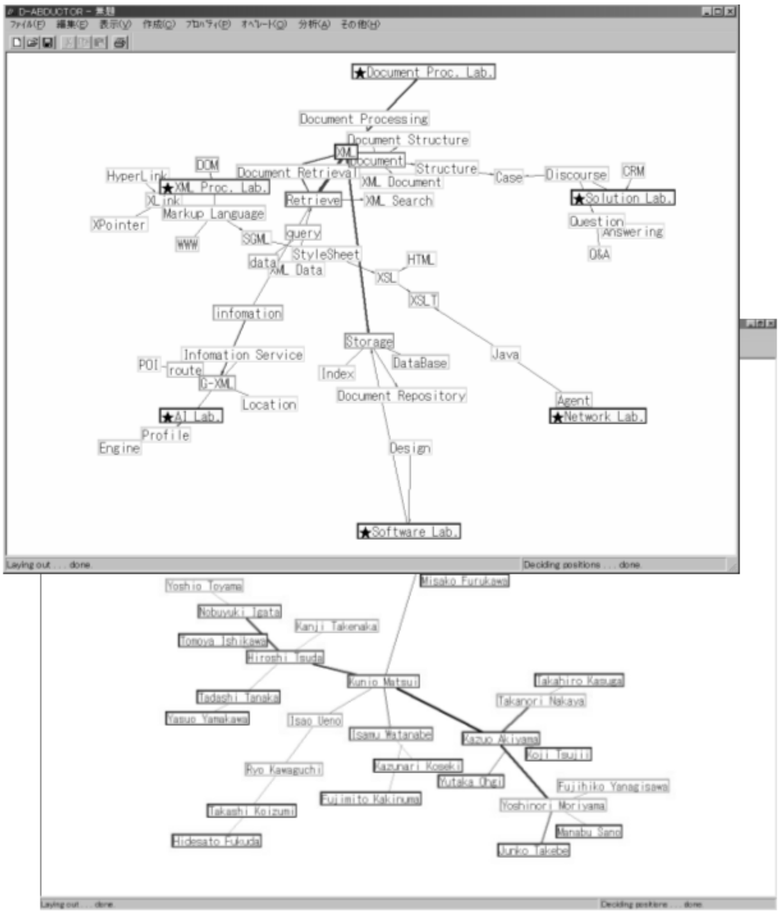

Figure 1. Fujitsu's KnowWho Human Knowledge Navigator [Ig03, p2]. The top window displays the semantic structure of related products, services and technologies. Clicking a node brings up a second window (below) that displays a social network with the expert on the selected technology in the center.

Moreover, the graph is created automatically and without displaying its logic to the users. Even though this automation saves maintenance costs, it is also a problem, because users have no control over the system and thus may not feel involved whereas user participation is an important acceptance factor for KM systems [MS05].

2.2 Commetrix

Commetrix [Tr05] is another example of a graph-based system that seeks to support knowledge processes through graph visualization. It is primarily focussed on identifying and supporting intra-organizational expert groups (communities of practice). "It aims at eliciting the structure of the expert group by analyzing the communication networks stored in data archives. … This set of data can be visualized as an actual network of experts." [Tr05, p979]. The system displays individuals (employees) as nodes and communication between individuals as edges between nodes. These edges are labelled with the most frequent topics of communication between two nodes which are obtained through data-mining techniques.

In Commetrix, the continuity of cognition is preserved through smooth animations when changing the displayed network. For example, Commetrix offers a timeline-function that displays an animation of how the network configuration changed over time.

Strictly speaking, Commetrix includes only employees as graph nodes. Edges between employees are labelled with topics, but contrary to KnowWho, these topics are not semantically related themselves as nodes of a graph. The advantage of organizing topics semantically lies in the ability to discover related topics and in making statements on the degree of their relatedness, which can be modelled through path distance. In Commetrix's visualization, it is not possible to visualize topics that are semantically closely related to the topic of a knowledge exchange between two individuals. However, these closely related topics may be the subject of frequent communication of other employees that are linked to the individuals in the visualization. Thus, the actual size of the community of practice may be underestimated.

Another advantage of visualizing topics as semantically connected nodes instead of labels of communication edges lies in the possibility of discovering undesired parallel developments, i.e. two people working on the same topic without being aware of each other (that is, without having an edge between them that symbolizes communication). Such a constellation can be visualized as a topic node with edges to two individuals that don't have a communication edge between them.

Commetrix may be very useful for identifying communities of practices on a strict topic within organizations, but it may not be as suitable for discovering such parallel developments In contrast to KnowWho, Commetrix is able to preserve the continuity of cognition when visualizing the graph structure.

3 skillMap

In this section, we introduce the skillMap-System [MSH05], show that it preserves the continuity of cognition through dynamic visualization and that it includes a variety of knowledge entities that lead to a wide scope of functionalities such as visualization of possible parallel developments.

3.1 System design

The system consists of two interlinked components: A social network of individuals and a graph (semi-lattice) of the individual fields of expertise or knowledge. Figure 2 outlines this structure.

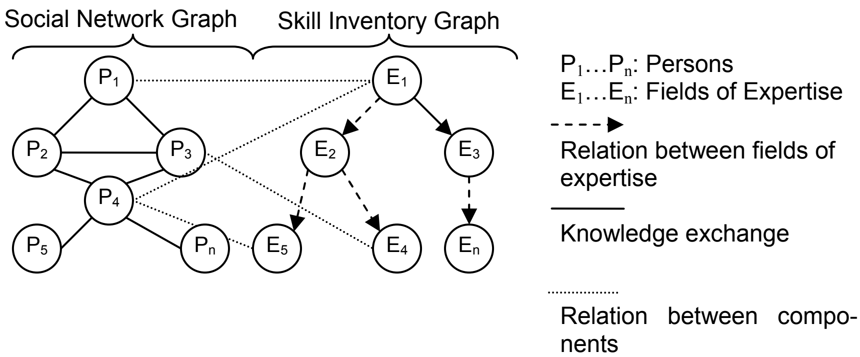

Figure 2**:** Schematic representation of skillMap system components.

With reference to Trier's Knowledge Management entity model (see above), the skillMap includes employees and topics as nodes and is thus able to visualize the semantic relation between both. At the current stage of development, the social network graph and the skill inventory graph and their respective connections are implemented in a prototype that is undergoing beta-testing within Berlin's research center on Internet Economics (InterVal). In this prototype, the social network graph and the skill inventory graph were elicited manually. The social network was obtained through a web-based social network survey and the skill inventory graph was obtained through workshops and group discussions with project members. Similar to Wiki-Webs, the skill inventory graph can be edited by all users of the system. As users edit and amend the graph freely for their individual fields of expertise, the skill inventory graph converges towards a stable status of structure consent. The result is a mirror of the entire organizational expertise.

The inclusion of knowledge entities as different node types makes the system capable of dynamically visualizing shared context (see figure 4).
As mentioned above, shared context is an important precondition for successful exchange of both tacit and explicit knowledge. In absence of physical ba, the organizational context is operationalized as the social- and knowledge-environment of individuals. This context is what I know, the documents I work on, the people I work with, the knowledge of the people I work with (transactive knowledge, compare [Br03]) and the documents they work on.
The skillMap visualizes this context with the help of its two-component design as follows: Person-nodes from the social network graph are connected to the expertise nodes in the skill inventory graph according to individual expertise with undirected edges. Each person is also related to the documents he or she produced. These connections are specified manually by the users themselves. In this way, a person vertex from the social network graph is linked to all the fields of expertise that he or she has in the skill inventory and to all documents that he or she authored. The newly combined graph is referred to as *skillMap*. Placing an employee node in the center of the visualization (compare figure 4) thus visualizes his or her organizational context.
Assigning people to competencies is not a new concept and is already in practice with yellow pages systems. However, yellow pages systems only store a link between two objects (person and skill(s)) without further connecting the objects at the ends of the connecting line. By merging the social graph and the skill inventory graph into one *skillMap*, several uses of the system become evident:

1. The system can visualize who-knows-who, who-authored-what, and can report a line of connections from any given person inside the organization to another.
2. The system can visualize who-knows-what by displaying the fields of work and expertise for any member of the organization.
3. By visualizing persons that are connected to the same expertise node but have no social edge between them, the user can identify members of the organization that work on the *same* field without *knowing* each other (e.g. P_1 and P_4 in figure 2).

Especially the last characteristic is a benefit new to KM systems because it can reduce undesired parallel developments.

3.2 Visualization and technical background

The skillMap is implemented in Java as a distributed client-server web based application and relies on JavaWebStart for launch. Continuity of cognition in the skillMap is achieved by smoothly animating all changes of graph layout. Therefore, preFuse [He04], a toolkit for interactive information visualization, was chosen. Its capability of dealing with a vast number of nodes as well as its impressive graphic processing performance were crucial for the decision for preFuse, which is used for creating skillMap's graph structure and for its visualization and navigation. PreFuse has been designed in order to "augment human cognition by leveraging human visual capabilities to make sense of abstract information, providing means by which humans with constant perceptual abilities can grapple with increasing hordes of data" [HCL05, p1] and we are thus positive that the continuity of cognition will be achieved. For the skillMap and social network views, the user can choose between a static Fruchterman and Rheingold layout and a dynamic fore-directed layout (compare [Su02] fur a description of both), both supplied by preFuse. Especially the constantly hovering spring embedded algorithm has received positive feedback from beta testers because of its playful appearance.

A platform independent standard for describing the structure of the graph was chosen in order to allow simple data exchange with other applications. XGMML [PK01], a XML-derivate used in many graph-based applications, was chosen as standardized data exchange format.

The underlying graph structure is stored in a SQL-database from which the XGMML representation of the graph is generated by the server and transmitted to the client. The system architecture is summarized in figure 3.

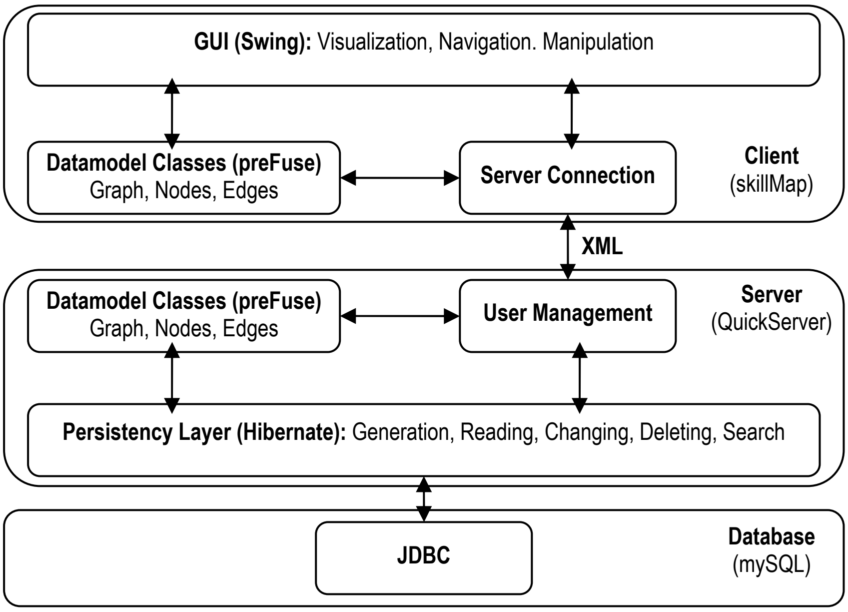

Figure 3: skillMap system architecture

3.3 Examples

skillMap is currently under evaluation at the research centre InterVal where it will be used under realistic circumstances from mid-June 2005. Figures 4 – 7 give examples of different visualizations from the prototype.

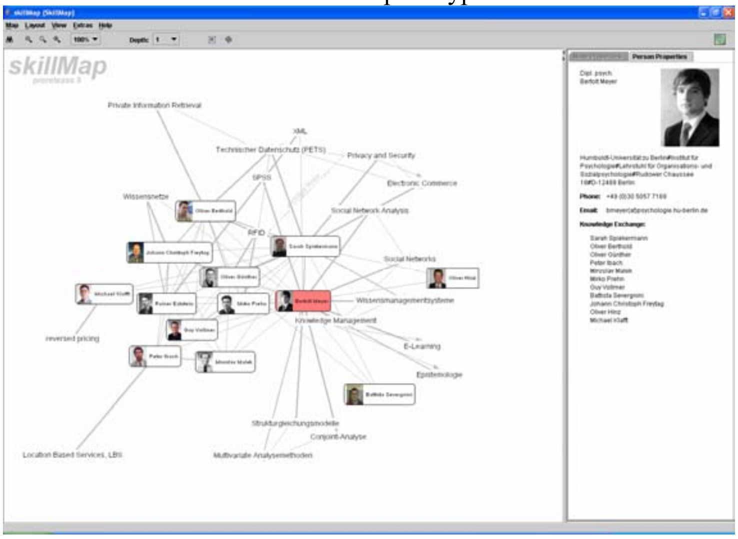

Figure 4**:** System interface after log-in. The first-degree social network of the user, his fields of work and expertise and the fields of work and expertise of his colleagues are visible. This gives the user an impression of the organizational context he or she is imbedded into.

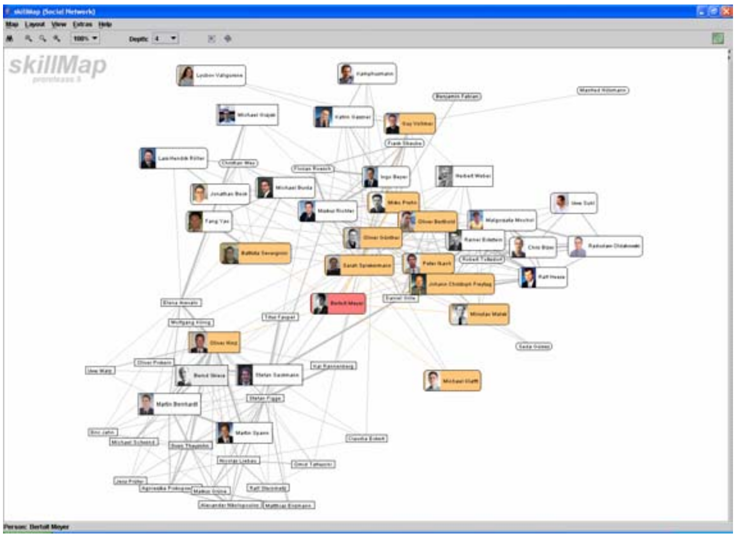

Figure 5: View of the entire social network graph of the organization. The own node is displayed in red, all other directly connected individuals are yellow.

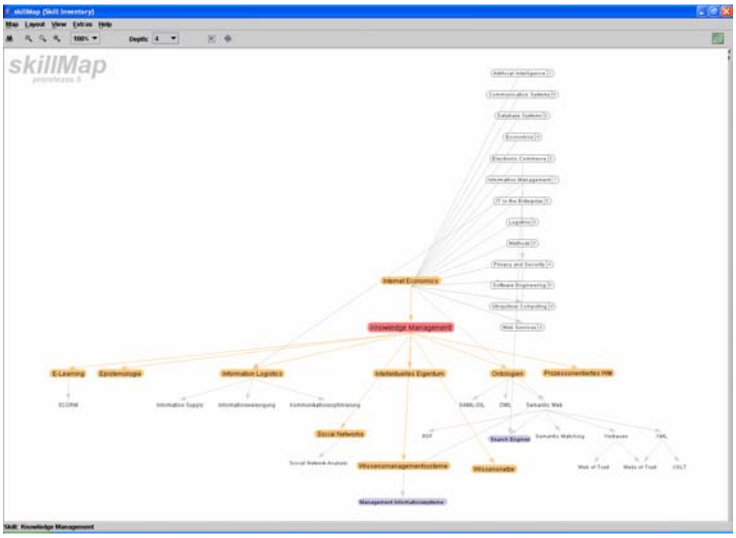

Figure 6: Skill Inventory Graph with the ‘knowledge management’ node in the centre.

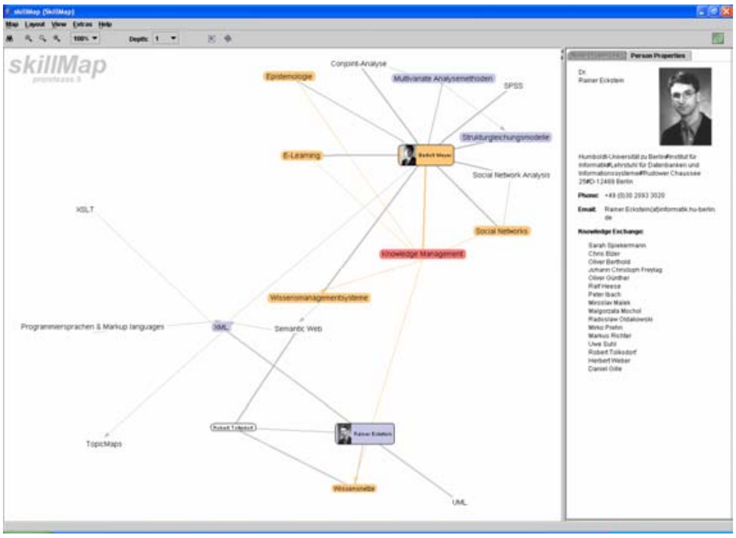

Figure 7**:** Possible unrecognized parallel development: Two individuals work with the same technology (XML) and have expertise in similar fields (Knowledge Networks & KM resp, path distance = 1) but do not know each other.

4. Conclusion and Outlook

Graph-based systems present a powerful possibility to support knowledge exchange by visualizing shared context. A discovered shared context between two individuals can lead to a fruitful exchange of knowledge between them and triggers intra-organizational communication. Furthermore, knowledge transparency inside the organization is improved. In this paper, we have presented two existing graph-based knowledge management systems, KnowWho and Commetrix. While KnowWho has certain limitations in its visualization that are not present in Commetrix, Commetrix offers a more limited functionality because it only visualizes one knowledge entity as nodes, whereas KnowWho includes employees and topics as semantically connected graphs.

By including individuals, topics and documents in individual graphs that are semantically interrelated and by implementing animated and smooth transitions, skillMap overcomes both of the above limitations. The system is currently undergoing its first beta-test within a distributed research project and first feedback from users is positive. Further work will focus on implementing the document graph, adding filters and interfaces to other applications, especially for obtaining social network and skill inventory graphs. To this point, the mayor weakness of the skillMap lies in its inability to automatically construct these graphs through data mining on unstructured data. By providing interfaces to other software packages that are capable of this, we hope to overcome this issue.

5 References

[Br03] Brauner, E.: Informationsverarbeitung in Gruppen: Transaktive Wissenssysteme. In (Thomas, A.; Stumpf, S. Eds.): Teamarbeit und Teamentwicklung. Verlag für angewandte Psychologie, Göttingen, 2003; pp 57-83.

[CP04] Cross, R.; Parker, A.: The Hidden Power of Social Networks. Harvard Business School Press, Cambridge, MA, 2004.

[DV05] Dudek, J.; Voß, J.: Kooperation als wichtigster Bestandteil des Konzepts / Weblogs, Wikis & Co.: Social Software in Bibliotheken (in German). Buch und Bibliothek, 3/2005, 221-225.

[EC00] European Council. (2000). Lisbon European Council 23 and 24 March 2000: Presidency Conclusions. Retrieved 24.09., 2003, from http://www.europarl.eu.int/summits/lis1_en.htm, 2000

[GK02] Gronau, N.; Kalisch, A.: Knowledge content management system - a framework integrating content management and knowledge management. Paper presented at the International Conference on Information and Knowledge Engineering (IKE'02), Las Vegas 2002.

[Ha99] Hansen, M. T.: The search-transfer problem: The role of weak ties in sharing knowledge across organization subunits. Administrative Science Quarterly, 44, 82-111, 1999.

[He04] Heer, J.: Prefuse: a software framework for interactive information visualization. Retrieved from http://jheer.org/publications/2004-Heer-prefuse-Masters.pdf, 2004

[HCL05] Heer, J., Card, S. K., & Landay, J. A. (2005). Prefuse: a toolkit for interactive information vi-sualization. Retrieved 31.01., 2005, from http://jheer.org/publications/2005-prefuse-CHI.pdf

[Ig03] Igata, N.; Tsuda, H.; Katayama, Y.; Kozakura, F.: Semantic groupware and its application to KnowWho using RDF. Paper presented at the 7th IEEE International Symposium on Wearable Computers, White Plains, NY, October 21-23, 2003.

[Ja04] Jansen, D.: Networks, social capital and knowledge production (FÖV discussion papers ; 8). Speyer: Forschungsinst. für Öffentliche Verwaltung, 2004.

[MS05] Meyer, B.; Scholl, W.: Comparison of paradigmatic views in knowledge management: an empirical case study on shortcomings in KM. In (Ferstl, O. K.; Sinz, E. J.;

Eckert, S.; Isselhorst, T. Eds.): Proc. Wirtschaftsinformatik, Bamberg,. Physica, Heidelberg, 2005, pp. 1003-1022.

[MSH05] Meyer, B.; Spiekermann, S.; Hertlein, M.: skillMap: identification of unrecognized parallel developments and of Communities of Practice in distributed organizations. Paper presented at the The First World Congress of the International Federation for Systems Research (IFSR2005), Kobe, Japan, November 14th – 18th, 2005.

[NK98] Nonaka, I; Konno, N.: The concept of "ba": building a foundation for knowledge creation. California Management Review, 40(3), 40-54, 1998.

[NT95] Nonaka, I.; Takeuchi, H. (1995). The knowledge-creating company : how Japanese companies create the dynamics of innovation. Oxford Univ. Press, New York, 1995.

[Po58] Polanyi, M.: Personal Knowledge. Routledge & Kegan Paul , London, 1958.

[PK01] Punin, J.; Krishnamoorthy, M.: XGMML (eXtensible Graph Markup and Modeling Language) 1.0 Draft Specification. http://www.cs.rpi.edu/~puninj/XGMML/draft-xgmml.html, Retrieved 14.07, 2005.

[St94] Stehr, N.: Knowledge societies. Sage, London, 1994.

[Su02] Sugiyama, K.: Graph drawing and applications for software and knowledge engineers. World Scientific , Singapore, 2002.

[SM96] Sugiyama, K.; Misue, K.: A generic compound graph visualizer/manipulator: D-ABDUCTOR. In (Brandenburg, F.-J. Ed.): Proc. Graph Drawing, Symposium on Graph Drawing, GD '95, Passau, Germany. Lecture Notes in Computer Science. Springer, Heidelberg, LNCS 1027, 1996, pp. 500-503.

[TN04a] Takeuchi, H.; Nonaka, I.: Knowledge Creation and Dialectics. In (Takeuchi, H.;. Nonaka, I Eds.): Hitotsubashi on Knowledge Management. Wiley, Singapore, 2004, pp. 29-46.

[TN04a] Takeuchi, H.; Nonaka, I.: Preface. In (Takeuchi, H.;. Nonaka, I Eds.): Hitotsubashi on Knowledge Management. Wiley, Singapore, 2004, pp. IX-XIII.

[Tr03] Trier, M.: IT-gestütztes Management viruteller Communities of Practice (in German). Retrieved from http://www.integrata-stiftung.de/files/p14_trier.pdf, 21.09, 2005.

[Tr05] Trier, M.: A Tool for IT-supported Visualization and Analysis of Virtual Communication Networks in Knowledge Communities. In (Ferstl, O. K.; Sinz, E. J.; Eckert, S.; Isselhorst, T. Eds.): Proc. Wirtschaftsinformatik, Bamberg. Physica, Heidelberg, 2005, pp. 963-983.

[Ts03] Tsuda, H; Advanced "KnowWho" with Semantic Web technology: Human Knowledge Navigator. Retrieved 21.09., 2005, from http://www.labs.fujitsu.com/en/techinfo/okar/sw/knowwho_catalog200307en.pdf