Towards Information Visualization in Cooperative, Evolutionary Knowledge Spaces

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Abstract: Contemporary knowledge management activities in an enterprise suffer from the discrepancy between the global benefit for the organization and the personal benefit for the individual knowledge worker. To ameliorate this divergence we investigate an evolutionary approach which automatically integrates the structures of individual knowledge workspaces into comprehensive organizational knowledge structures. To enable the individual user to keep an overview over both the personal information space and the various views and structures in the organization, we present a concept for dynamically-configured visualization of multi-layered concept spaces and information structures. This approach will be realized in the newly-started research project EPOS.

Key Words: Knowledge Spaces, Information Visualization, Organizational Knowledge
Category: H.5, I.2.1

1 Introduction: Evolving Personal to Organizational Knowledge Spaces

Contemporary knowledge management activities in an enterprise suffer from the discrepancy between the global benefit for the organization and the personal benefit for the individual knowledge worker. While the organization asks for universally applicable and standardized persistent structures, processes, and work organizations to achieve and maintain universally accessible information archives, the individual knowledge worker requests individualized structures and flexibility in processes and work organization in order to reach optimal support for the actual and individual activities. The resulting methodological problems which hinder the introduction of knowledge management solutions and the realization of valuable organizational memories are well known.

To ameliorate this discrepancy, the research project EPOS aims at the realization of a cooperative, evolutionary knowledge space which amalgamates individual aspects into global benefits. The individual *knowledge workspace*, realized as a set of agents in the knowledge workers' personal computer, will provide adequate and task-specific supporting information to the human. In parallel, the system will observe the work and the users' ways of information access/handling and automatically learn about in-

tentions, structures, ontologies, and work processes. Towards the user, the knowledge workspace thus acts as an adaptive information assistant.

The individual face of the *knowledge workspace* is complemented by globally oriented sharing and exchange facilities. Interacting agents from different workspaces synchronize information needs, balance structures, ontologies, and process models, and exchange context-specific relevant information. A society of agents, represented by the collection of individual knowledge workspaces, will thus reach a common and shared understanding of the structured information and knowledge used in their realm. Ultimately, the inter-agent negotiations will result in an emerging organizational knowledge corpus without the pitfalls of contemporary approaches.

In summary, EPOS will develop the technological basis for sustainable knowledge development by interacting agents which perform an integration of individual workspaces into an OM-building society.

The intended integration of local and global support and exchange, however, has important consequences for the interaction with the user: On the individual workspace, the user is confronted with continuously evolving representations of personal structures and information sources as well as with information and structures entering from the outside, that is, shared models from other knowledge workspaces. This continuous automatic information exchange between individual workspaces by agents acting in the background bears the danger that the user's orientation is lost. To cope with this problem, we focus on intelligent visualization methods that put the user's particular knowledge items into their appropriate context and thus allow the user to get a quick and comprehensive overview of all knowledge items provided by the personal knowledge workspace's agent.

This paper focusses on the requirements foreseen and the approaches used to realize comprehensive information visualization methods.

2 Motivation: Requirements for Visualization of Dynamic Knowledge Structures

EPOS will support a project-oriented work structure comprising high information loads with the need of individual interpretation, complex information structuring with competing individual and global viewpoints, and the continuous exchange and learning in flexible and sometimes ad-hoc group collaboration. For a typical EPOS application this means: Every protagonist handles information on the personal knowledge workspace (that is: the individual's PC, the laptop, the PDA etc.) and in doing so leaves traces (file system structures, folder names, file designators etc.) in the workspace. Leveraging these native structures into explicit personal information models will improve transparency for the individual worker or expert and will form the basis for improved communication.

When relevant expertise is asked for, the automatic inter-workplace communication in EPOS will help to find documents and people that satisfy this demand. To this end,

the explicit personal information models are helpful if the various individual structures can successfully be compared and mapped. Global structures arising from the ongoing exchange will help to organize and structure central repositories (whose maintenance is currently a major problem). The EPOS visualization tools will help the individual person to keep track of different relevant views, positions, and interrelations and to distinguish between own, confirmed models and external ones with possibly different degrees of confidence.

Based on the application scenario described above, we identify the following requirements:

- *Supporting search processes.* This means to arrange and present query results in relation to the workflow the user is currently involved in.
- *Techniques for visually mapping different users' information models.* The connections between the information items and their contexts have to be put into relation to each other.
- *Generalizing visualization techniques.* This enables us on one hand to handle problem-classes instead of single problems and on the other to get a systematic visualization of complex information items with respect to different users.

3 Related Work

In the EPOS system we will incorporate visualization techniques to support the user's information demand described above. In the following we will give a short overview of relevant work in this area.

Techniques for presenting large graphs are necessary for visualizing large interconnected document spaces. They range from different two-dimensional tree layout algorithms up to three-dimensional structures. [Herman *et al.*, 2000] give a good overview of these techniques. Another approach for presenting the relations between different objects is given in [Ware *et al.*, 1999]. They suggest using animation techniques for producing the perceptual impression of a causal relationship between entities.

An interesting idea for presenting the differences and similarities in a series of documents is developed in [Ribler and Abrams, 2000], where they describe a method for simultaneous comparison of series of documents combined with visualizing the detected similarities in a pattern diagram. A further interesting approach is the visualization of thematic changes within a set of documents over time [Havre *et al.*, 2002].

For presenting relevant information within large sets of raw data there exist data aggregation approaches like [Tang and Shneiderman, 2001]. They describe a dynamic data aggregation method combined with dynamic queries to large raw data sets that support the user in discovering patterns or clusters in this raw data. For providing search results in a more convenient manner [Leuski and Allan, 2000] describe a system that

combines known visualization techniques like ranked lists or clustering mechanisms to an on-line user-interface for an information retrieval system.

In some cases users need combined multiple views onto their set of data. This task is addressed by configurable visualization systems for complex data sets like in [North and Shneiderman, 2000]. They describe a system that permits the users to define views on their data themselves by combining a given set of visualizations according to the relations among their data.

4 Approach

The information available within one user's personal knowledge space consists of highly complex structures. These may be personal information models underlying the user's work processes or simply large amounts of pieces of information as a result of previously expressed information needs. This complexity even increases when we consider all the users' personal knowledge spaces that together form the organizational memory.

When we have a closer look at these knowledge spaces, we identify four domains: the document spaces, the personal and organizational information models, the processes and the users. Each domain is usually populated by a set of entities that are implicitly or explicitly linked to other entities within the same or within other domains: Each user within the organization has got one or more document spaces to store his information items. For structuring his knowledge he relies on his personal information model. Additionally, on the level of the organizational memory, there is one global model, the organization's ontology. Besides that many process models describe different tasks of the user's work.

In this domain model we find three dimensions to consider for visualization: each single entity in a domain (which can be a multivariate space itself), a set of entities in one domain (e.g., all processes a user is involved in) and finally the inter-domain views including views on knowledge shared across the users' organization (e.g., the connection of process steps with knowledge from the organizational memory).

While there exist many research results that address problems from the first and second dimension, there is still a demand for research in dimension three. Especially, here we get domain-spanning information of different kinds: This may on one hand be arbitrary structural information linking objects from two or more domains or on the other be a large set of query results from one domain.

Inspired by the previous research work of [North and Shneiderman, 2000] and [Kreuseler *et al.*, 2000] we address the visualization requirements expressed above by developing a so-called 'domain browser'. This will allow us to integrate visualization techniques appropriate to the users' problems in one framework. Techniques like Focus and Context and Multiscale Visualization or Multiscale Pan and Zoom systems as described in [Stolte *et al.*, 2002] enable the user to interact with such complex information structures. For the purpose of presenting the structures and models to the user that represent his knowledge patterns the EPOS system allows the definition of different views.

By looking at some of these views simultaneously a deeper understanding of ongoing processes can be achieved. If, e.g., a user wants to get an overview of the documents and the underlying concepts that are related to the task he is currently performing, a view might be very helpful to him that in one pane presents his current process model, in the next one the actual task within this model and in two other panes the related documents and the underlying concepts.

Beyond the view of the single user's knowledge workspace the domain browser will also be applied to the broader scope of visualizing the knowledge provided by other users as well as the organizational memory. This allows the user to put his knowledge into context with knowledge available across his organization.

In the same way we will provide views on search results that can be assigned to the structures in the knowledge space of the user. This information extends the view he has got from his knowledge space before entering the query. In this way new domain-spanning information is integrated seamlessly into the user's workspace.

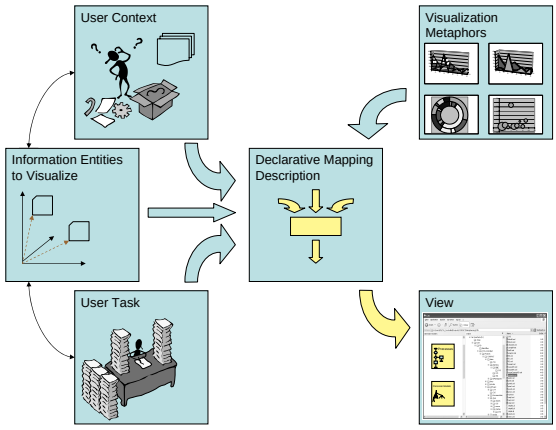

Figure 1: Mapping of information entities, user context and user tasks to visualization metaphors

For realising the goals described above we are developing a declarative description language that performs a mapping between the set of information entities to be visualized and user context and tasks on one hand and a set of given visualization metaphors on the other. As a prerequisite we will categorize these information objects at first and build up an ontology of them. The mapping itself will be performed within the domain browser where the mapping rules are applied to the given information entities and the current user context and thus the appropriate visualization is automatically generated and parametrized from the available visualization metaphors (see figure 1). The basic

operation for performing that task is finding mappings between several structural views (or ontologies) of the information corpus. Here, we hark back on the ontology negotiation approach sketched in [van Elst and Abecker, 2002], integrating structural as well as document classification based evidence for mappings.

5 Summary

The presented approach addresses the application problem of visualizing complex relations within an organizational memory. We will tackle this problem by evaluating existing solutions for the dimensions one and two in our domain model. By combining and extending them in the domain browser we will create a means that gives the user new insights not only into the structure of his own knowledge space but also into that of the whole organization. With this novel combination of visualization techniques in conjunction with the EPOS approach to advanced knowledge management we provide a new solution to the described application problem.

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