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Toward Synergistic Approaches to Knowledge and Information Visualization

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Abstract: Two fields of research are heavily interested in developing visualizations for helping users coping with complex tasks and ill-structured subject matter resources: knowledge visualization and information visualization. The goal of knowledge visualization is to assist students in learning and problem solving by providing tools for fostering externalized cognition. The goal of information visualization is to provide knowledge-based access to information resources and help users in making sense of the resources they are looking for in information retrieval. The contribution draws attention to digital concept maps as cognitive tools which may provide a basis for the development of synergistic approaches that may help visualizing, accessing, and managing both knowledge and information and foster resource-based learning.

Keywords: Knowledge Visualization, Information Visualization, external Representation, external cognition, Concept Map, Synergy
Categories: I.3.6, E.1

1 Introduction

Students studying self-regulated are often overwhelmed by complex and ill-structured subject matters. This is particularly true in resource-based e-learning scenarios [Rakes 1996] using the Internet as a global learning resource. Information literacy is needed to make effective use of resources. Visualizations are suggested to help learners coping with subject-matter complexity and ill-structuredness [Holley and Dansereau 1984], [Jonassen et al. 1997]. Graphical external representations foster externalized cognition [Scaife and Rogers 1996].

Two fields of research are heavily interested in developing visualizations for helping users coping with complex tasks and ill-structured subject matter resources: knowledge visualization and information visualization. The goal of knowledge visualization is to assist students in learning and problem solving by providing tools for fostering externalized cognition. The goal in information visualization is to provide knowledge-based access to information resources and help users in making sense of the resources they are looking for in information retrieval. The idea behind all visualization methods is that orientation, visual search, and cognitive processing of complex subject matter may be enhanced if structures behind ideas, knowledge, and information, as well as their relevance for coping with a particular task are made

explicit. Researchers in the fields of information visualization and knowledge visualization are trying to develop and use tools for fostering access to information and knowledge resources. Although there is a common interest in facilitating content accessibility and making sense of represented knowledge and information elements by developing visual artefacts, there are hardly any attempts to search for synergies for enhancing learning. The goal of the paper is to draw attention to digital maps, particularly concept maps, as cognitive tools which may provide a basis for the development of synergistic approaches that may help visualizing, accessing, and managing both knowledge and information and foster resource-based learning.

1.1 Trends in Information Visualization

In the research field of information visualization one central approach is to develop models and electronic devices for structuring large and complex information sets of abstract data, e.g. data files of digital libraries. To accomplish this, there is a current development to employ information visualizations using three spatial dimensions for data representation. Information visualizations are "computer-supported, interactive, visual representations of abstract non-physically based data to amplify cognition" [Card et al. 1999, p. 6]. The Navigational View Builder is an example for information visualization. It is a tool for allowing the designer of hypermedia systems to interactively develop efficient views of the underlying information space. This tool has been used to visualize a section of the World Wide Web dealing with research activities at the Graphics, Visualization, and Usability Center at Georgia Tech (http://www.cc.gatech.edu/gvu/people/alumni/sougata/Nvb.html). The tool allows the user to use various strategies in order to form effective views.

Until recently, research and development of information visualization tools is driven by technical questions. The focus is on enhancing accessibility of information in large information bases and the usability of the visual interface. However, it is now recognized that information visualization and information access may be improved by taking into account aspects of knowledge visualization and knowledge management. "Instead of serving as information providers, digital libraries could become knowledge repositories by effectively categorizing, analysing, and organizing their contents" [Shen et al. 2003, p. 1]. In order to improve the intelligibility of interfaces for visual search concept maps may be used as tools for facilitating navigation and access to information resources [e.g. Shen, et al. 2003], [Sebrechts 2005], [Carnot et al. 2001]. Until now, there is a lack of empirical evidence on how to cope with the problem of intelligibility of visualizations and what means to be used to supplement visual semantics and fostering sense making. Some evidence on how the accessibility, localization, and processes of sense-making of information based on visualizations may be enhanced may result from research and development in the field of knowledge visualization.

1.2 Trends in Knowledge Visualization

The goals of knowledge visualizations in the context of teaching and learning are to help students to support memory functions and to elicit, (co-)construct, structure and restructure, elaborate, evaluate, locate and access, communicate, and use ideas,

thoughts as well as knowledge about relevant contents and resources based on an external representation of their knowledge [Jonassen et al. 1993].

In the context of teaching and learning as well as in empirical research, existing tools, particularly concept mapping tools, have been mainly studied and employed to teach conceptual knowledge, to support knowledge acquisition, and to assess structural knowledge [Jonassen et al. 1993]. A concept map is a spatial array that represents elements of knowledge by means of nodes and links, the nodes representing ideas, concepts, and beliefs and the links relations between them [Novak and Gowin 1984]. Concept mapping is conceived to be essential for a constructivist approach to learning and problem solving. "Constructing concept maps stimulates us to externalize, articulate, and pull together information we already know about a subject and understand new information as we learn" [Kommers and Lanzing, 1997, p. 424].

Computer-based mapping tools open new possibilities to support knowledge-based work. They provide functions not only for the visual representation of thoughts and concept knowledge but also for annotations of individual knowledge elements and content knowledge. In addition, concepts and thoughts may be linked to knowledge resources and information to which they are related. [Coffey et al. 2002] suggest that "this method supports construction of an informal but semantically rich representation of expert knowledge and the simultaneous creation and identification of critical supplementary resources that materially augment the representation" [p. 7]. In addition, the authors suggest that "resource-appended concept maps make useful, highly accessible learning resources" [p. 7]. It is suggested that these tools are appropriate for helping users in self-regulated resource-based online learning as well as managing knowledge and knowledge resources [Tergan 2003].

2 Toward Synergistic Approaches

2.1 Some Basic Commonalities

A common focus of information visualization and knowledge visualization is to organize information and knowledge in a way that it may be accessed easily, comprehensively, and intelligently. Research on information and knowledge visualization has shown that visualization techniques may contribute to unburdening working memory, reducing cognitive load, and fostering effective studying and visual search for represented elements. Up to now, both research approaches investigate the question of visualization from different perspectives. However, there are some common interests, so that synergy effects can be expected. Synergistic approaches may aim at fostering user-centeredness of visualizations. For example, both research approaches are concerned with questions of visualization in the new field of dynamic-interactive visualizations. They both use comparable techniques and methods of visualization and aim to support visual searching, localization and individual utilization of represented elements with concise, psychologically reasonable and functional visualizations. Therefore, they both have to focus on how to construct visualizations for the external representation of the respective elements that relate to the users conceptions and foster knowledge-based intelligent use. Furthermore, synergy effects may be expected with respect to the kind of visualizations used. Information visualizations focus on using two or three spatial dimensions for

representing information. However, with regard to the type of data represented they mostly visualize multi-dimensional data (e.g., by means of using spatial coding and color coding). Contrarily, knowledge visualization restricts itself mainly to two-dimensional visualizations. However, for knowledge visualizations there is a current trend to integrate representations of concept knowledge, content knowledge and resource knowledge. Thus, multi-dimensional and multi-layered representations and visualizations of knowledge may be sometimes appropriate. Synergy effects may also be expected if current knowledge visualization techniques relying exclusively on the node-link method for representing structures of semantic contents [Dansereau 2005] and may take over or adapt information visualization techniques for highlighting different structures and making elements more salient to users with different interests in using a visualization.

2.2 Concept Mapping as a Bridging Technology

Advanced digital concept mapping is suggested a promising bridging technology on top of which synergistic approaches to knowledge and information visualization may be developed. In the following some examples are outlined demonstrating the bridging power of concept maps. The examples focus on approaches using computer-based mapping tools for the conceptual organization as well as access of knowledge and knowledge resources available, e.g. in individual content repositories on the PC and the World Wide Web. Two kinds of approaches may be distinguished: (1) Visualizing knowledge and information for fostering learning and instruction, (2) knowledge-oriented organization of information for fostering information use.

In approaches aiming at visualizing knowledge and information for fostering learning and instruction focus on knowledge visualization information as text, audio, or video documents are conceived as knowledge resources that are associated with the conceptual knowledge represented in the map. In general the resources have been pre-selected from a broad range of information resources, e.g., located in the Web, on the PC, or in a digital library, and have been evaluated as relevant for backing, verifying, elaborating, and extending the meaning of a particular concept [Rakes 1996]. They may, however, also be stored on any server in the World Wide Web and searched for and located by the users themselves. Digital concept maps used in such a learning and working scenario have two main functions: They may function as a representation device of the knowledge that is relevant for making sense of the structure of elements in a task-relevant segment of a subject-matter domain. They may also be used as a personal repository for fostering resource-based learning and working.

Typical examples of approaches aiming at fostering learning and instruction are presented by [Alpert and Gruenenberg 2000], [Alpert 2005] and [Cañas et al. 2004], [Cañas et al. 2005]. [Alpert and Gruenenberg 2000] criticize that traditional concept maps tend to represent the conceptual macrostructure of a domain only, leaving the knowledge about contents and resources to which the conceptual knowledge structure refers unrepresented. In their approach “Webster” the authors describe a Web-based concept mapping tool aimed at maximizing the representational capabilities of concept maps and satisfying psychological and pedagogical requirements for a more comprehensive representation of both knowledge and information associated to it. It permits both a broad flexibility in terms of the kinds of knowledge and information that may be represented as well as a structuring of that knowledge and information.

With respect to representation, Webster offers expressive power for the representation of core knowledge of a domain as well as external knowledge and information resources. The essential mechanism supporting representational breadth is the notion of permitting digital media in the form of static graphics, animations, audio, or video to be incorporated directly into concept maps. Thus "Webster maps can represent the core, fundamental, essential knowledge of a domain − externalized implicit knowledge and visual and auditory imagery integral to a domain − as well as external knowledge and information resources that support a deeper understanding of the domain" [Alpert 2005].

The currently most advanced Web-based approach on concept mapping is the IHMC CmapTools approach presented by Cañas and associates [Cañas et al. 2004], [Cañas et al. 2005]. As in Webster also in CmapTools conceptual knowledge represented in a Cmap may be linked with content knowledge and information resources coded as text, images, sound clips, and videos accessible in personal or public repositories. In CmapTools too the use of concept maps has been extended beyond knowledge representation, to serve as a browsing interface to a domain of knowledge and associated information. The authors outline special features of the approach for integrating, making accessible, and using knowledge and information. IHMC CmapTools has been used in a variety of contexts, e.g. as an orientation and navigation device [Carnot et al. 2001], as a means for modelling and sharing experts' knowledge [Coffey et al. 2002], and as a tool for information and knowledge visualization for students and instructors, in the context of courseware development and course delivery [Coffey 2005]. Of particular interest is the use of CmapTools as a means for autonomously searching and mining the Web for either retrieving information which is potentially relevant knowledge resource for elaborating concepts in an existing concept map or mining the Web for information that can aid users in constructing, verifying, correcting, or extending a concept map [Cañas et al. 2004] [Cañas et al. 2005]. Concept maps in this way "can be used to construct a search environment that improves on the results of commercial search engines, and to take advantage of the large amounts of information contained by these search engines to aid users during the construction of concept maps" [Cañas et al. 2005].

In several other approaches concept maps are used as a bridging technology to complement functions and potentials of information visualization technologies or are themselves influenced by principles and ideas generated in the field of information visualization [Burkhard 2005], [Novak and Wurst 2005], [Sebrechts 2005]. In these approaches on the one hand knowledge visualizations profit from techniques of information visualization and make use of complementary visualizations to represent, create, and transfer knowledge among individuals [Burkhard 2005]. On the other hand the use of concept maps in information visualization approaches provide answers to the hitherto unanswered question of whether all semantics in data structures can be captured adequately in visual form or should to be complemented with linguistic information [Sebrechts 2005].

3 Summary and Final Comments

In this paper the question of how to integrate ideas of information and knowledge visualization into synergistic approaches has been addressed. Digital concept maps

have been suggested as tools to bridge the gap between the two approaches information and knowledge visualization. Particularly, advanced Web-based concept mapping tools may be appropriate for developing synergistic approaches aiming at both knowledge and information visualization. The paper has focused on two types of Web-based concept mapping tools: Webster and IHMC CmapTools functioning as examples for other tools currently existing on the market. The tools allow for the development of approaches that may accomplish both visualizing knowledge and information for fostering learning and instruction, and knowledge-oriented organization of information for fostering information use. Recently developed approaches show how Web-based concept maps may be used for cross-community sharing of knowledge [Novak and Wurst 2005]. Cañas and associates have even extended the use of concept maps and have shown how to integrate knowledge visualization and information visualization into a coherent approach to foster effective searching for information in the Web and for constructing knowledge based on information that has been mined from the Web by means of a mapping tool. Along with [Cañas et al. 2005] it is suggested that "by taking advantage of the particular topological and semantic characteristics of concept maps, they can be used to construct a search environment that improves on the results of commercial search engines, and to take advantage of the large amounts of information contained by these search engines to aid users during the construction of concept maps". Further synergies between knowledge and visualization tools will emerge if the approaches take into consideration that on the one hand processing information visualizations in many cases cannot be successful on the basis of visual semantics only, but needs knowledge for enhancing sense making. On the other hand, knowledge visualizations cannot focus on conceptual knowledge only, but have to integrate content knowledge and information resource knowledge. There is a growing amount of approaches taking the symbiotic relation between information and knowledge into consideration [Tergan and Keller 2005]. It may be suggested that "as better tools are developed that take advantage of the characteristics of concept maps, further integration and synergies between knowledge and visualization tools will emerge" [Cañas et al. 2005].

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