AC 2009-1125: DESIGNWEBS: TOWARD THE CREATION OF AN INTERACTIVE NAVIGATIONAL TOOL TO ASSIST AND SUPPORT ENGINEERING DESIGN LEARNING

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Abstract

For both student and professional design teams, knowledge generated during the design process frequently goes uncaptured, and when it is captured, it is usually poorly organized and buried in obscure documents. The design and development process requires that collaborators build and retain knowledge through discussions, creating documents and sharing artifacts. Effective capture of both semantic knowledge and episodic knowledge can have many benefits for both student and professional design teams. The key to supporting these knowledge building problems is to develop an infrastructure that supports effective knowledge management. In this paper, we describe a framework for DesignWebs, which are dynamic, navigable networks of the documents and conversations created during the design process. A DesignWeb would enable users to see evolving connections between concepts by using a navigable web-based interface that synthesizes the design knowledge from multiple sources of information.

Introduction

Students working on engineering design projects bring together knowledge from different sources. They collaborate among themselves, share design knowledge, and negotiate with each other, faculty members and the client, in order to create engineering artifacts. This process often involves reuse of previous knowledge and the creation of new knowledge within the context of the problem. Such knowledge building is a key process skill that engineers need to acquire during their education.

Ideally in team projects, students co-construct the knowledge necessary to realize their designs through the process of proposing, counter-proposing, questioning, arguing, agreeing, and dissenting. A major problem student teams face is learning how to organize and share ideas. This frequently results in "requirements deviations" where the interpretation of interactions by two or more team members may not only be different, but conflicting[1]. Detecting such problems as they occur has advantages for the team and implications on the project's success. Actively engaging in navigating, searching and structuring knowledge as it is generated can improve the quality of knowledge sharing within groups, and possibly reduce the occurrence of requirements deviations.

Students often find it difficult to locate the right piece of information from the e-mails, reference literature, discussion transcripts, status updates, time-sheets and final reports pertaining to a design project. The situation is complicated by the evolving nature of the decisions, leading to multiple versions of documents with contradictory information. Lack of support infrastructure to help locate the information embedded in documents related to an engineering artifact in real-time is a commonly experienced problem. Being novices in design, students also lack the perspective to structure and manage documents that they generate and use. Hence even the opportunity for them to recognize, formulate and solve problems cannot meet all the desired objectives and students often find it difficult to keep track of the design evolution.

In this paper, we present a framework for an infrastructure that supports effective knowledge management for engineering design projects. The knowledge that students use in their design process comes from a variety of sources, including prior published work, past student projects, their team-mates, and the intermediate products they have produced along the way. We propose to construct the product structures underlying an engineering artifact from these relevant documents created or referenced during the course of a design project using machine learning approaches and language technologies. We present a qualitative analysis of data collected in a capstone engineering design course and the preliminary design of information management technology that we refer to as *DesignWebs*.

DesignWebs build upon the concept of co-word analysis that maps the strength of association between keywords in textual data[2]. However, they provide added functionality of providing the user with a way to navigate to the source document fragment and a synopsis of the target content. The *DesignWebs* are expected to enable instructors and students to retrieve and synthesize information from multiple sources in a student engineering design project, from queries generated explicitly by them or implicitly during browsing.

Need for DesignWebs

The Problem

Team-based project courses offer students the opportunity to recognize, formulate and solve problems. Such an approach is considered useful by instructors since it exposes the students to conflicting goals with multiple perspectives and approaches that must be resolved in the design process. In order to achieve effectiveness in these courses, an important aspect for students is learning to structure the process. Problems with information management in student teams occur on multiple levels including within project group knowledge sharing, across project group knowledge sharing, and global information access and integration[3]. DesignWebs address these problems simultaneously.

<u>Within team knowledge sharing</u>: One problem that we propose to address is that students working on team-based project courses often find it difficult to keep track of the design evolution. As documents are generated by different team members or sub-team modules at different times during a project, not everyone is aware of what is in all the documents. This leaves scope for difficulties in locating the right information among evolving documents (e.g. different versions of the final report), or static documents that are referred to frequently (e.g. a key reference or manual) and can lead to wasted efforts. Even for teams with well-structured document management systems, finding the correct paragraph or document fragment for a given topic can be difficult.

<u>Across team knowledge sharing</u>: One naïve conception of project work that students may have is that design is a one-time local event. With their limited experience and perspective, they may miss important connections between their sub-team and the larger team that they are part of. Design work is always part of a larger on-going, community-wide conversation. Thus, we must

facilitate knowledge sharing not only within teams, but also across teams as well as with past and future teams.

Global information access and integration: Another naïve conception of project work observed among students is the tendency to neglect existing authoritative sources of knowledge in favor of creating knowledge from first principles. Effectively identifying and using authoritative knowledge sources is a skill students need to learn. A related problem is that as project work progresses, the concept each team member has of what the goal is and what is relevant changes. Because of this, the set of external resources regarded as valuable may evolve and change; in addition, the notion of which resources are valuable is in both a shared community-wide model and an individual model. As students collaboratively create documents that record the team knowledge building process, they need to be made aware of sources of knowledge beyond the borders of their team knowledge. To be useful to the students, these sources must clearly relate to specific issues they have in their design work. As participants in the process, instructors can raise student awareness of existing, relevant knowledge and support the integration of that knowledge within their own knowledge building process.

The Solution: DesignWebs

Using recent advances made in machine learning and language technologies, this paper proposes an information management technology that we refer to as DesignWebs. DesignWebs make use of many existing information management technologies, including document indexing, ranking, and retrieval, text classification, text segmentation, clustering, summarization and visualization. Constructed from the discussions, references, and evolving design documents during the design process, DesignWebs enable the user to see the connections between the concepts used in an artifact at different levels. A DesignWeb can reveal current state of the project and the underlying structure of the design. In addition, it allows for different views such as by time, by authors, by topic, etc. The DesignWeb has a navigable web-based interface for synthesizing the design knowledge from multiple sources of information used by students during a design project, including e-mails, discussion forums, status reports, different versions of reports, reference materials, and documents from prior completed student projects.

Visionary Scenario

Every semester our university offers a project-based, multi-disciplinary undergraduate design course which teaches students the design of real-world software-intensive systems for industry sponsors. The course draws students from Computer Science, Electrical and Computer Engineering, Industrial Design, Human-Computer Interaction and Mechanical Engineering. The teams in this class design solutions to problems - sometimes the solution results in a report and sometimes in both a report and an engineering artifact; in either case, the students are actively engaged in designing both the solution and the report that presents the solution.

One year, a student in this class is working is developing a module for a mobile device that involves a text to speech application. The instructor tells her that two years ago the class in this course developed an OCR module for a cell-phone as part of the Trinetra project to assist visually impaired individuals in their daily activities, namely shopping and public transportation (*across team knowledge sharing*). Even though she is able to access the information from the previous year, she makes little use of it because she finds it easier to reconstruct the information than to search for it within the old reports and presentations.

Suppose instead she had a DesignWeb from two years before. Through her class Kiva, she would access the Trinetra DesignWeb, which contains the documents, discussions, links and references from the design project that occurred two years ago. All these information sources would have been automatically segmented, clustered, and linked, using the methods described in the following sections. Most of the DesignWeb would have been about the Trinetra structure; however, she could have quickly searched in the Trinetra DesignWeb to find the subweb for the OCR module. She would have navigated within the OCR module and explored various aspects of the OCR design by the previous team.

She would read the segment of the final report on the OCR mobile module as well as some of the Kiva conversations and supporting documents that led to the final decisions in the OCR design. She would import the OCR node (with its associated document fragments, discussions and web links) from the previous year's DesignWeb and link the node to her team's current DesignWeb. She would make a post on the Kiva discussing what she found in the documents and propose some new directions that build on the prior work (*within team knowledge sharing*). Shortly thereafter, the instructor would return from a conference with a draft of a paper by a colleague on image processing using cell phone cameras. He would add the paper to the DesignWeb and give the team the contact information for his colleague's graduate student (*global information access and integration*).

Significant Impacts for Design Learning

An important distinction in our work is the difference between problem-based learning (PBL) and design project learning. PBL is "an instructional method in which students learn through facilitated problem solving"[4]. While the two have much in common (student-centered, open-ended, team-based), PBL takes place in a classroom with a teacher/facilitator always present, making the role of the instructor significant for its analysis.

To study learning in a typical engineering design class, it is essential to study the process as it occurs naturally within the design teams. However, in most project-based courses, instructors have difficulty monitoring what students are learning and whether students are spending time in a way that maximizes their learning. In contrast to the typical Problem-Based Learning scenario, much of the group work takes place outside of the classroom and outside of the instructor's view. The most commonly cited benefit of project-based learning is that it provides the opportunity for students to develop higher-order reasoning skills [5,6]. However, without the opportunity to be present for much of the group work, instructors are at a loss to assess whether this valuable group knowledge building is occurring or to offer support when needed.

Most engineering project courses are taught by faculty who are experts in the topic area, but few of whom have expertise in group learning and facilitation. Although the instructors' guidance can help students in overcoming some of the troubles that occur during group work [4,7,8], instructors often have difficulty discerning when support is needed because much of the work is done when instructors are not present. On the other hand, student teams have difficulty in information management and require support infrastructure to effectively share productive information and enhance group knowledge building. DesignWebs can present the web of knowledge created as student teams use them and act as a tangible representation of knowledge building process to assist in design reflection. These can also serve as an assessment instrument by the instructors to track the group processes unobtrusively and automatically.

A related issue is that beyond the final products produced by teams each year, the knowledge products from this discovery process are a resource that can be valuable to students working on projects in subsequent semesters. However, the knowledge generated by students in project courses is not typically accessible to students in subsequent semesters. Because of this, time is lost when students rediscover what they could glean from the legacy of their forerunners' knowledge construction efforts. Perhaps even more serious is that students lose the opportunity to gain valuable skills in reuse and repurposing ideas, insights, and innovations from prior work. These skills would not only make them more effective engineers, but would also enhance their ability to be lifelong learners.

Background

Computer supported collaborative learning (CSCL) approaches

Engaging in reflective activities in interaction, such as explaining, justifying and evaluating problem solutions and documenting collaborative knowledge construction, have been shown to be potentially productive for learning[9]. Researchers working on CSCL approaches have addressed the multi-faceted issues of collaborative learning in team-based project courses by using mixed methods[10]. Previous approaches have also employed human-computer interaction (HCI) methodologies to iterate on design in the context of use and discussed their implications on student and professional design teams. Other design process studies have used computational linguistics to analyze time variant patterns of "story telling" in multidisciplinary student design teams through oral and written histories left by the designers through their documentation, presentation material, and e-mail communication[11]. In order to explain the interactions between cognitive activities of design, research models have been developed that employ epistemic, teleological and temporal links to explain the interactions between cognitive activities of design and learning[12].

Problem Based Learning

Problem-based approaches to learning have advocated the importance of experience in solving problems to enhance both content and thinking strategies among students[13,14]. They emphasize that in PBL, students do self-directed learning that makes them reflect critically about what is being learned[15]. To aid in this, researchers use a technique called the "reflective toss". In the reflective toss, the teacher makes the student elaborate on his statement with an intent to help him clarify meaning and better understand her own thinking[16]. One of the major assumptions in these PBL approaches is that students work in collaborative groups with "a continued attempt to construct and maintain a shared conception of a problem."[17] As mentioned earlier, the very existence of the problem of "requirements deviation" suggests that this is not always the case.

Team process has also been studied as an outcome of the team member inputs and team performance, by using team communications as a process variable to represent team behavior and team information processing. While these research approaches viewed team communications from the team cognition perspective, they did not consider the value embedded in such team communications for helping an outsider (new team member or faculty member) to understand the team's functioning.

Machine Learning and Language Technologies

Advances have been made in machine learning and the language technologies that provide new opportunities for assimilating and presenting the information contained in documents through an interactive and intuitive interface.

Topic Segmentation

The previous work on automatic topic segmentation can be broadly classified into two types: (1) lexical cohesion models, and (2) content-oriented models. In lexical cohesion models the text segmentation is guided primarily by distribution of terms used in it. So the lexical co-occurrence of thematically-related or synonymous terms indicates continuity in topic and the introduction of new vocabulary refers to a new topic, implying a boundary between the two. In content-oriented models, the re-occurrence of topic patterns over multiple thematically similar discourses are evaluated. We plan to use lexical-cohesion based approach known as TextTiling owing to its encouraging initial results.

Summarization

Recent work on text summarization of scholarly articles includes using lexical cues to analyze the functional structure of technical papers[18], multi-paper summarization using reference information[19] and Cross-document Structure Theory (CST) for multi-document summarization[20]. CST takes into account the rhetorical structure of clusters of related textual documents and creates taxonomy of cross-document relationships. Owing to its multiple advantages we plan to use the CST approach for our research.

Cluster Analysis

Cluster analysis is used to maximize intra-cluster similarity and minimize inter-cluster similarity[21]. Researchers in language technologies have developed tools to assist non-experts of machine learning to cluster text fragments into a set of non-overlapping clusters[22]. However, most of these tools perform flat clustering of documents into disjoint sets and connections of equal strength. These are not good enough for our purpose and so we plan to perform hierarchical clustering to address these issues.

Co-word Analysis

Co-word analysis is "a content analysis technique that is effective in mapping the strength of association between keywords in textual data.[2]" The basic principle of co-word analysis is that it reduces a "space of descriptors (or keywords) to a set of network graphs". These graphs do not display data like other statistical graphs, but construct multiple networks that highlight associations between keywords, and where associations between networks are possible[23]. Krsul[2] gives an excellent description of the algorithms used for constructing the networks that highlight the strongest associations between keywords.

Information Visualization

TouchGraph is an open source Java environment for the creation and navigation of interactive network graphs[24,25]. TouchGraph offers several desirable features for visualizing networks, such as high level of interactivity, fast rendering, pan and zoom capability, locality control, etc.[26,27] Due to these advantages with Touchgraph, we plan to it for creating the DesignWeb interactive network graphs.

In related research, knowledge domain visualization maps have been used to represent the structure and evolution of scientific fields using journals, research articles, authors, and descriptive terms[21]. Domain visualization has been a widely researched area in bibliometrics, scientometrics (quantitative study of scientific communications, which applies bibliometrics to scientific literature) and language technologies.

Approach

Data Source

To illustrate the effectiveness of DesignWebs, we analyze the student interactions in a project-based, multi-disciplinary design course. For asynchronous meeting capture between students in this course, a web-based, asynchronous collaboration tool known as the Kiva (http:/thekiva.org) has been used[28]. The core interaction of the Kiva combines aspects of both email and bulletin boards to keep threaded discussions intact. Students can post documents, diagrams, conversations, meeting notes, notes to self, task assignments, and so on. The discussion pages are designed to feel like a chat session in which students respond easily to one another.

Typical Kivas have many thousands of posts organized into hundreds of threads. For example, the class that we analyze had 41 students who created hundreds of topic threads, each with an average of about 10 posts per topic with more than 1000 files posted by the students. Evidently, the enormity of topic threads on such web-based communication tools and the unfamiliarity of the later teams with the context of discussions within previous teams make it difficult for students to learn from the knowledge gained by their peers.

DesignWeb Creation

Topic Segmentation

Most documents in the data collected during student project courses are progress reports that cover many aspects of the project; however, we need to segment the documents so that each segment is about a single topic. This is necessary for understanding the structure of the design artifact and for targeted information retrieval. We divide the documents into segments, each of which deals with a separate topic. We used the TextTiling approach[29] so that retrieval can occur at the level of document passages rather than whole documents.

Text Summarization

The user should get a short preview of the document fragments that every node in the DesignWeb points to. Extraction-based document summarization techniques do this by using significant sentences from the text based on position, content and length information and then combining them, while Maximum Marginal Relevancy achieve this by reducing redundancy. Our initial experience with extraction-based approaches suggests that they do not work well for document fragments that are short (2-3 sentences). We are currently working to improve the summarization algorithms. A relevant information technology that we plan to repurpose and reuse is the Summarization Integrated Development Environment (SIDE)[30]. SIDE uses text segmentation and classification technology to find structure in text that can then be used to locate important passages of different types. Using this structure, it is then able to generate extractive summaries at various levels of granularity[31,32].

Clustering

We use a combination of top-down clustering (Bisecting K-Means) and bottom-up clustering (Agglomerative Clustering) to cluster the collection of text fragments resulting from the summarization step. We are working on performing hierarchical clustering, allowing connections at multiple levels, and possibly even with a variety of different connection strengths as can be obtained through statistical clustering techniques.

Information Visualization

Internally, DesignWebs will maintain an explicit representation of the web-like structure of specific design web representations as they evolve for each project where the DesignWebs application is used. Since we are using the open source TouchGraph[24] framework to support zoom-in and zoom-out navigation through the design web representation at the interface level, we will use the same XML data structure representation supported in its open source implementation.

While the TouchGraph representation provides an intuitive metaphor for navigating through an existing multi-level, web-like representation, more functionality is required for supporting the process of elaborating that representation with new nodes and links, which is an important part of the interaction students and teachers will have with the DesignWebs. Currently, our system can only use only the text associated with images. Mining visual information provided by image features is beyond the scope of this research.

Example DesignWeb

In the following sequence of figures, the interface is a mockup, but the underlying data is derived using the techniques described above using the data from the class. Figure 1 shows the major clusters of topics when the DesignWeb is opened. The left pane contains a summary of the highest level node and the bottom pane displays a scrollable panel of the document segments that have been used to create the DesignWeb.

The user can rearrange the spatial display of the nodes in the DesignWeb, can click on a node to see its summary, can explore a node to find the document segments it represents and what other topics it contains, can see how topics are connected to other topics, can redisplay the web by author or time, and can search the DesignWeb for words or phrases.

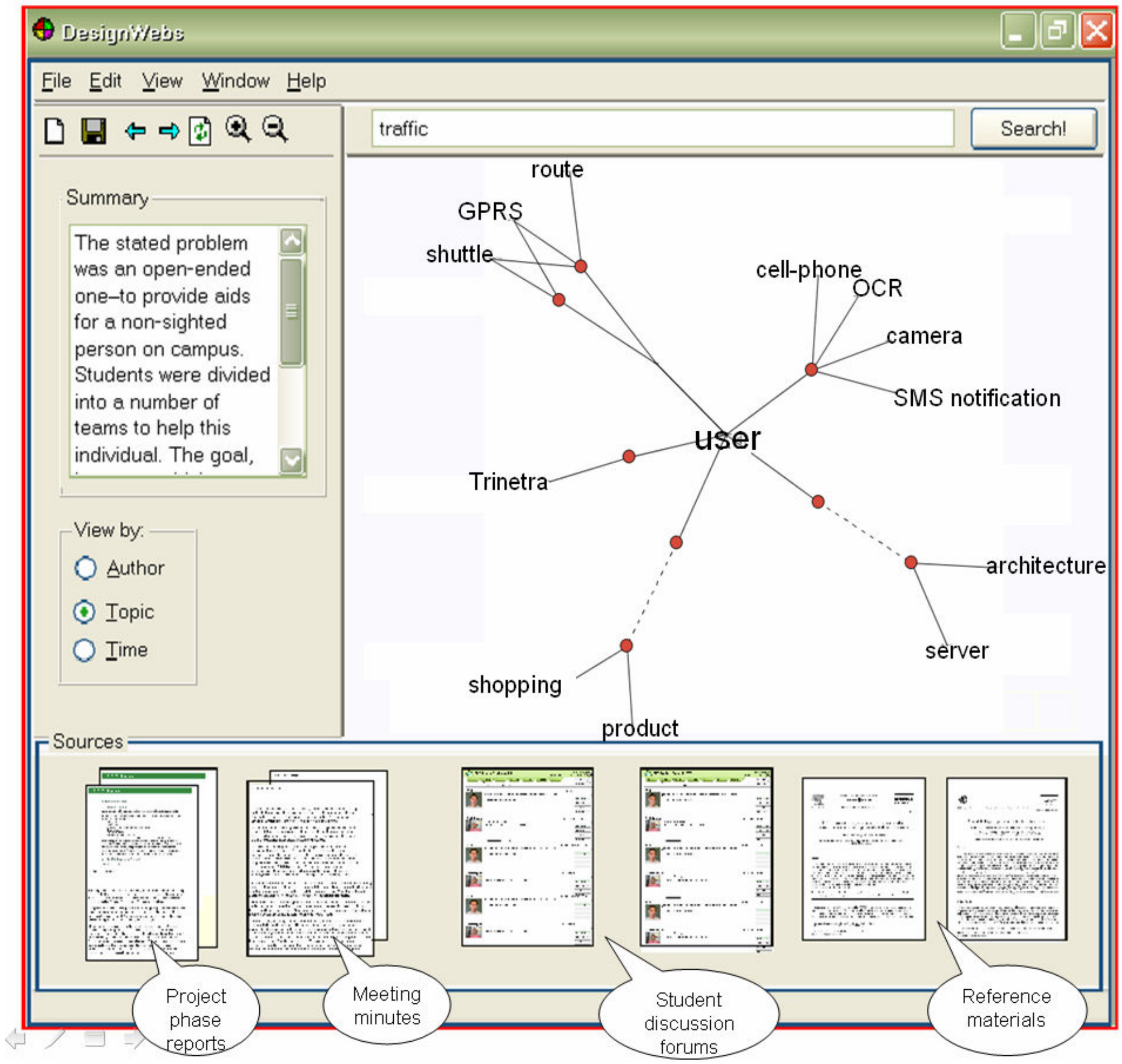

Figure 1. Opening screen of the DesignWeb

In Figure 2, the student has clicked on the OCR node, which is in the top right in Figure 1. This action opens the node and shows the topics within it. Figure 2 shows the DesignWeb after the OCR node is opened. The student scrolls through the documents at the bottom of the screen and selects the cluster of document segments that were used to create the summary for this node. This cluster contains date-stamped versions of the documents, but since the student is only interested in the conclusions, she looks just at the final version as shown in Figure 3.

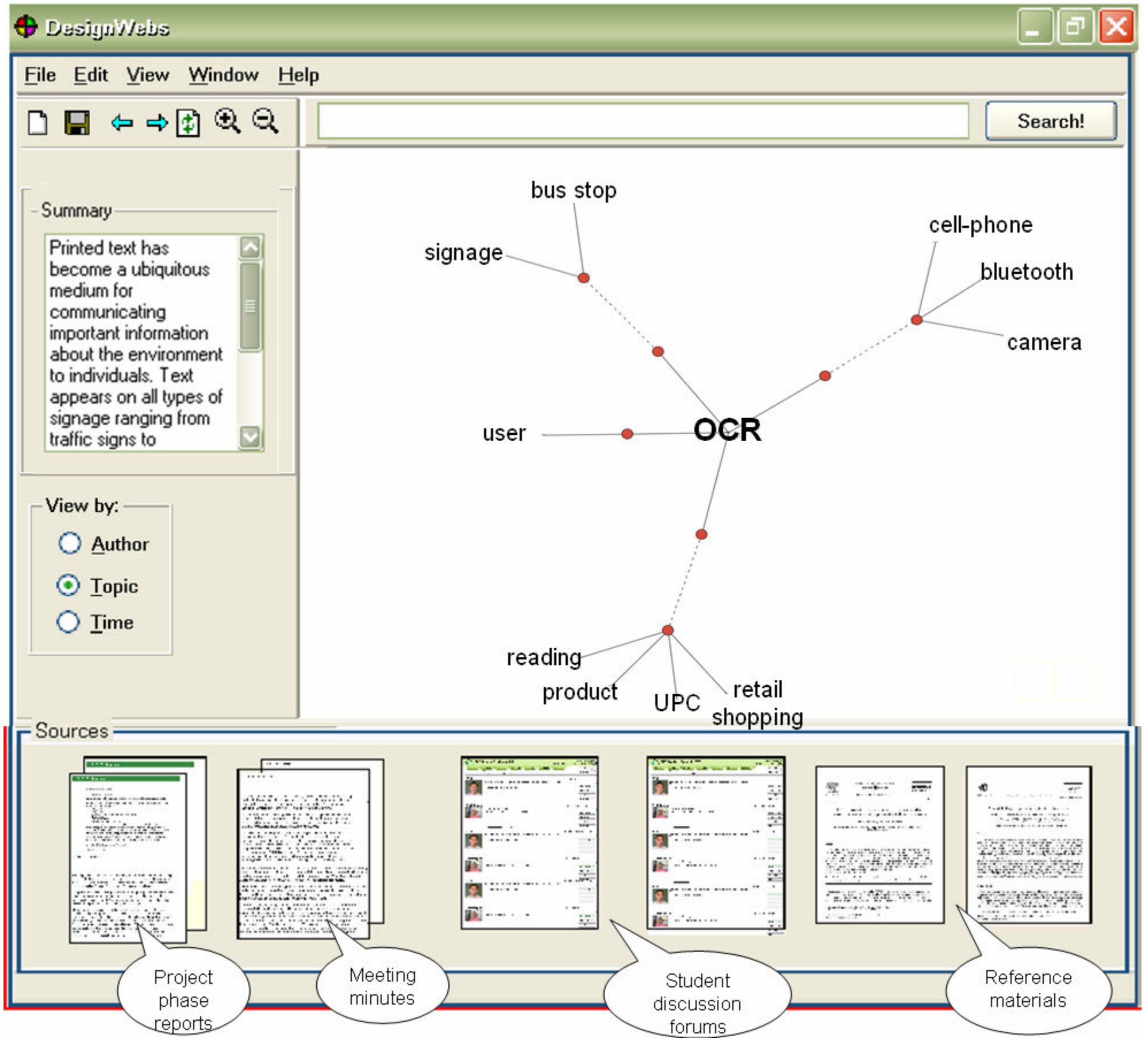

Figure 2. Optical Character Recognition (OCR) DesignWeb

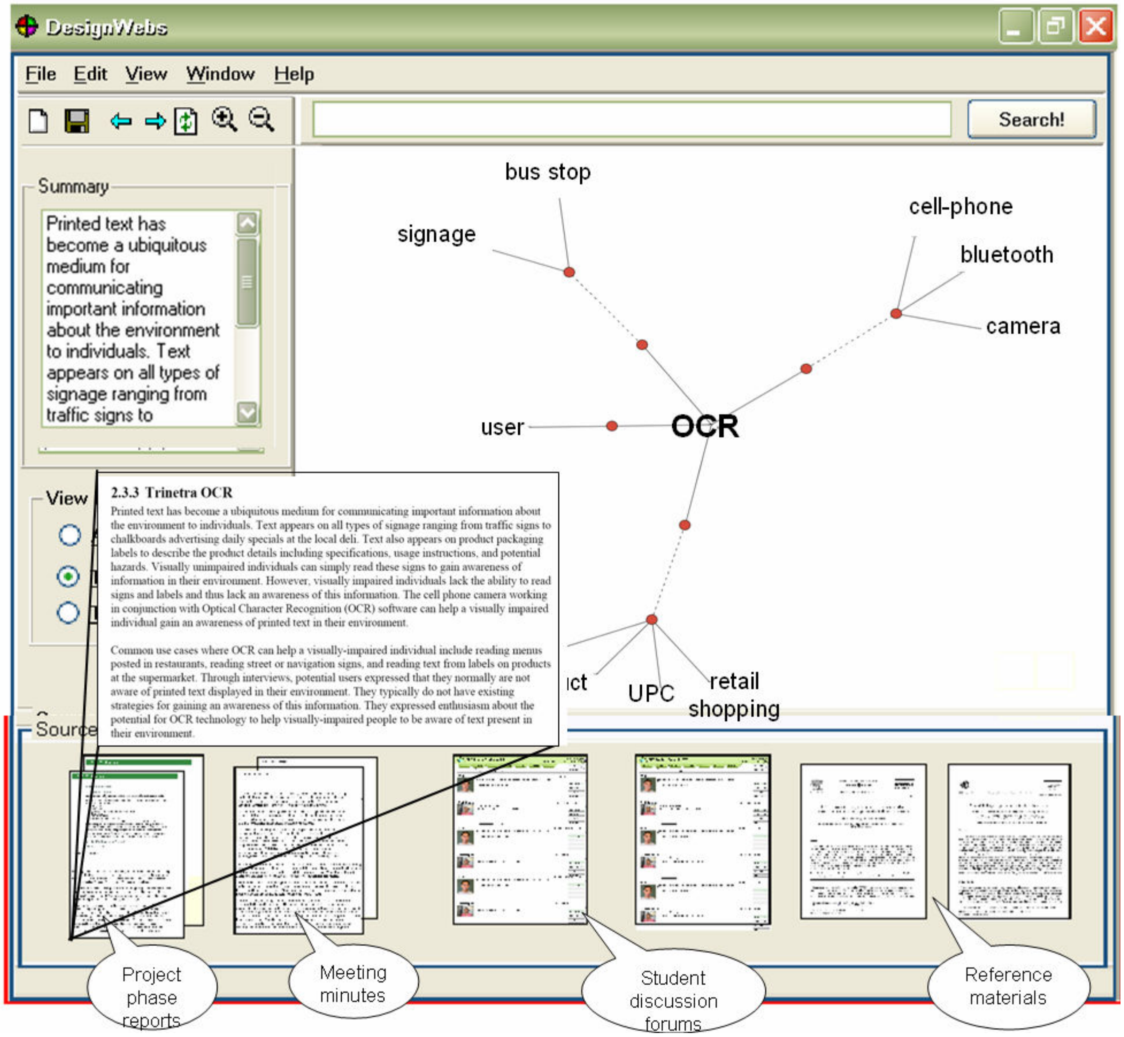

Figure 3. Viewing a document fragment in a DesignWeb

Scope

Student Design Documents

Our emphasis in this research is on using the discussion forums on the Kiva and discussion transcripts, status updates, time-sheets and final reports pertaining to a design project. Future research will incorporate the audio transcripts of student discussions during team meetings since our observation shows that interesting discussions often happen there. In addition, we are currently focusing only on student design projects. However, this research is significant for professional designers working on industrial projects as well.

User Interface

The primary expected research contribution of this work is the creation of algorithms to preprocess and analyze student design documents. We plan to present the structure of an engineered artifact in an easy-to-navigate user-interface.

Conclusions & Future Work

DesignWebs will provide a robust, dynamic, and automatic method for students to organize, navigate and synthesize the documents and conversations that occur while designing an engineering artifact in project-based courses. These are expected to support student learning by acting as aids to assist them in reflecting on design and providing a bird's eye-view that is otherwise not possible due to information scattered in design discussions and documents. Design reuse between student teams and capturing design process-in-context are research areas that require more substantiated research. We are currently creating a prototype for the DesignWebs using data collected through the Kiva, as described earlier. We believe that with the proposed DesignWebs, we can evaluate not just the effectiveness of previous interesting and successful approaches on a bigger corpus, but also extend their hypotheses to see how connections between different ideas in an engineering project evolve with time.

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Bibliography

1. Mabogunje, A., Carrizosa, K., Sheppard, S., and Leifer, L., Towards a science of engineering design teams, *International Conference on Engineering Design ICED'01*, Glasgow, August 21-23, 2001.
2. Krsul, I. V., *Software Vulnerability Analysis*, Ph.D. Thesis, Purdue University, 1998.
3. Dym, C. L., Representing designed artifacts: The languages of engineering design, *Archives of Computational Methods in Engineering*, **1**(1), pp. 75-108, 1994.
4. Hmelo-Silver, C. E., Problem-Based Learning: What and how do students learn? *Educational Psychology Review*, **16**(3), pp. 235-266, 2004.
5. Evensen, D. H., observing self-directed learners in a problem-based learning context: Two case studies, in Evensen, D. H., Hmelo, C. E. (Eds.):*Problem-based learning: A research perspective on learning interactions*, Mahwah, NJ, Lawrence Erlbaum, Associates, pp. 263-297, 2000.
6. Blumberg, P., Evaluating the evidence that problem-based learners are self-directed learners: a review of the literature, in Evensen, D. H., Hmelo, C. E. (Eds.):*Problem-based learning: A research perspective on learning interactions*, Mahwah, NJ, Lawrence Erlbaum, Associates, pp. 263-297, 2000.
7. Meloth, M. S., and Deering, P. D., The role of the teacher in promoting cognitive processing during collaborative learning, in O'Donnell and King (Eds.): *Cognitive Perspectives on Peer Learning*, Lawrence Erlbaum associates, NJ, 1999.
8. McGrath, J. E., *Groups: Interaction and Performance*, Prentice-Hall, Eaglewood Cliffs, NJ, 1984.
9. Baker, M. and Lund, K., Promoting reflective interactions in a CSCL environment, *Journal of Computer Assisted Learning*, **1**, pp. 175-193, 1997.
10. Hmelo-Silver, C. E., Analyzing collaborative knowledge construction: multiple methods for integrated understanding, *Computers and Education*, **41**, pp. 397-420, 2003.

11. Song, S., Dong, A. and Agogino, A., Time variation of design “story telling” in engineering design teams, *International Conference on Engineering Design ICED’03*, August 19-21, Stockholm, 2003.
12. Sim, S. K., and Duffy, A. H. B., Evolving a model of learning in design, *Research in Engineering Design*, 15, pp. 40–61, 2004.
13. Barrows, H., & Tamblyn, R., *Problem-based learning: an approach to medical education*, NY: Springer, 1980.
14. Torp, L., and Sage, S., *Problems as Possibilities: Problem-Based Learning for K–12 Education*, 2nd edn., ASCD, Alexandria, VA, 2002.
15. Bereiter, C., and Scardamalia, M., Intentional learning as a goal of instruction, in Resnick, L.B. (Eds.): *Knowing, Learning, and Instruction: Essays in Honor of Robert Glaser*, Erlbaum, Hillsdale, NJ, pp. 361–392, 1989.
16. Hmelo-Silver, C. and Barrows, H.. Goals and strategies of a problem-based learning facilitator, *The Interdisciplinary Journal of Problem-Based Learning*, **1**(1), 2006.
17. Roschelle, J., Learning by collaborating: convergent conceptual change, in T. D. Koschmann (Ed.), *CSCL: theory and practice of an emerging paradigm*, Mahwah NJ: Erlbaum, pp. 209–248, 1996.
18. Kando, N., Text-level structure of research papers: Implications for text-based information processing systems. In *Proceedings of BCS-IRSG Colloquium*, pp. 68-81, 1997.
19. Nanba, H., and Okumura, M., Towards multi-paper summarization using reference information. In *Proceedings of IJCAI-99*, pp. 926-931, 1999.
20. Radev, D. R., Hovy, E., and McKeown, K., Introduction to the special issue on summarization. *Computational Linguistics*, 28(4), pp. 399–408, 2002.
21. Börner, K., Chen, C., and Boyack, K. W., Visualizing knowledge domains, *Annu. Rev. Inform. Sci.*, **37**, pp. 179–255, 2003.
22. Arguello, J., and Rosé, C. P., Museli: a multi-source evidence integration approach to topic segmentation of spontaneous dialogue, *Proceedings of the Human Language Technology Conference of the North American Chapter of the ACL*, New York, pp. 9-12, 2006.
23. Coulter, N. Monarch, I., and Konda, S., Software engineering as seen through its research literature: a study in co-word analysis, *Journal of the American Society for Information Science*, 49(13), pp. 1206-1223, November 1998, 1998.
24. Shapiro, A., Method of animating transitions and stabilizing node motion during dynamic graph navigation, US Patent No. 20050180330, TouchGraph LLC, 21 Hearthstone Terr, Livingstone, NJ, US, <http://www.freepatentsonline.come/20050180330.html>; http://sourceforge.net/projects/touchgraph, 2005.
25. Alani, H., Tgviztab: an ontology visualisation extension for protégé, *Knowledge Capture 03—Workshop on Visualizing Information in Knowledge Engineering*, ACM, Sanibel Island, FL, pp. 2–7, 2003.
26. Herman, I. Melancon, G., and Marshall, M.S., Graph visualization and navigation in information visualization: a survey, *IEEE Transactions on Visualisation and Computer Graphics*, 6(1), pp. 24-43, 2000.
27. Wills, G.J., NicheWorks - interactive visualisation of very large graphs, *Proc. Graph Drawing '97,* Rome, Italy, Springer-Verlag, pp. 403-414, 1997.
28. Finger, S., Gelman, D., Fay, A., Szczerban, M., Smailagic, A., and Siewiorek, D.P., Supporting collaborative learning in engineering design, *International Journal of Expert Systems and Applications*, 31(4), November, pp. 734-741, 2006.
29. Hearst, M., TextTiling: segmenting text into multi-paragraph subtopic passages, *Computational Linguistics*, 23(1), pp. 33-64, 1997.
30. Kang, M., Chaudhuri, S., Kumar, R., Wang, Y., Rosé, E., Cui, Y., Rosé, C. P. (2008). Supporting the Guide on the SIDE, in *Proceedings of Intelligent Tutoring Systems (ITS ’08)*
31. Christel, M., Evaluation and user studies with respect to video summarization and browsing, multimedia content analysis, management, and retrieval, *IS&T/SPIE Symposium on Electronic Imaging*, San Jose, CA, 2006.
32. Farell, R., Fait-weather, P., and Snyder, K., Summarization of discussion groups, *Proceedings of CIKM’01*, 2001.