Agent support for monitoring collaborative design knowledge

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Abstract. Design teams are typically distributed across many locations and communicate with multiple media. Computer tools have been developed to support and improve such communication. Agent support of design has been discussed in terms of the support of graphical and object based systems. Another aspect of design that is often discounted is the textual dimension. Discussions of media in architectural design typically revolve around graphical forms, be they digital or analogue. This emphasis on graphics overshadows the role of text in design; the interactions of designers requires broader support. In this paper, we consider role of text-agents in support of collaborative architectural design. Text is a common medium to record information in computer technology and has a role to play in an architectural design process. In collaborative environment, a shared understanding and preserved history are important for communication. Design knowledge is accumulated through textual databases, be they email or longer documents. In this way, just as graphics can be seen as a design aid, so too can text. This proof of concept implementation of an agent system demonstrates how collaborative design can benefit from agent support.

Keywords. Collaboration, software agents, communication, text

Introduction

Successful collaboration is recognized as a major facet of design projects. A significant component of successful collaboration is effective communication in its many forms (Busby 2001; Chiu 2002) and that computer systems can be used effectively (Kiesler and Sproull 1992; Fruchter 1996), especially in geographically dispersed team settings. Much collaboration is asynchronous (Kvan 2000a). Asynchronous collaboration raises particular problems of communication, making it more difficult for all team members to remaining aware of what others in the project are thinking or doing (Muller 1997). In a geographically dispersed project team, the problems are even more difficult. Communication in design is in the form of both graphics and text. While graphical documentation is the more obvious, text-based communications have been shown to be not only essential but also beneficial to design activities (Wong and Kvan 1999).

Bulletin boards or newsgroups have a role to play in design learning (Kvan 2000b) and are increasingly used to support asynchronous and non co-located teams in professional practice. The benefits of these systems are both in facilitating communication by placing information on demand but also to act as repositories of discussions such that teams can recall past discussions. However, these online asynchronous communication tools do not solve a significant problem, namely managing the enormous volume of data that a team generates, leading to information and communication overload of team members.

Software agents have been implemented to assist users in monitoring information in computer networks (Simon, et al. 2002) and as design assistants in collaboration (Anumba, et al. 2002). With the context of communication overload in online discussions of design issues, we see that another tool is required, one that will monitor the discussions on behalf of a team member, supporting the team member's participation in team interactions. It is postulated that design teams can be well supported by text agents that monitor such online communication. To address the problem of information overload, an overview summarizing most relevant information can shorten the time to process the enormous amount of unstructured data. A proof of concept implementation, known as the Design Issues Tracking System (DITS), is discussed here.

Words and intents

Natural language is replete with ambiguity, there is no one-to-one correspondence between words and meanings (Rose & Belew 1991), a situation further confused when people use different terms to refer to the same subject (Furnas, et al. 1987). Thus, no single thesaurus can be applicable in every knowledge domain. This is a substantial problem in interdisciplinary collaborative work. While a limited domain such design and construction may be expected to have a higher congruence of meaning, experience suggest otherwise. Key concepts may employ the same words in different fields, but the meaning is possibly different. For example, a car to a traffic engineer is not the same object as a car to an elevator engineer. Conventional full text searching cannot effectively cover the needs of information retrieval (IR) in multiple domains environment, nor can a simple thesaurus. An alternative approach is required.

Chen & Lynch (1992) have pointed out that the lack of linkages between relevant information and the limits of conventional keyword-driven search technique cause difficulties in information retrieval. One successful method for information classification and query expansion is term association (Ruge 1999). A spreading activation network can find alternative terms to extend term associations. The network built from term associations creates a mind map of knowledge be created for a specific design project.

We have created a system, DITS, as an information retrieval (IR) application for extracting and monitoring design issues in extensive text discussions. Unlike approaches relying primarily on predefined relational database system (Lenat and Guha 1990; Katz 1990; Jeng and Eastman 1998), DITS applies an automatic text-mining algorithm to build up non-prescriptive knowledge base. By using a concept space, a network of keywords and their weighted associations (Chen & Lynch, 1992), an associative thesaurus can be created to provide extended information about the keywords that is subsequently useful for information searching and query expansion (Chen, et al. 1997; Ding, et al. 2001). We will not attempt here to review the many mapping efforts that utilize linguistic data, but illustrate a feasibility of applying the associative thesaurus in collaborative design.

System Overview

Construction projects bring together an unpredictable diverse collection of participants. DITS is developed to support collaborative design involving a variety of knowledge disciplines, without being prejudiced to any particular discipline. For a design product or project, each designer can use DITS to share and retrieve design concepts or issues. When a design project is initialised, a specific discussion forum is created for discussion purposes to support group discussions and brainstorming sessions. Users define the terms of interest. DITS monitors messages posted in the newsgroup, mining terms and reporting relevant information to the users. From each of these messages, DITS extracts keywords from the message body to produce a summary called a Design Tree in which term associations are shown. A conceptual representation is in Figure 1. This implementation of DITS reflects

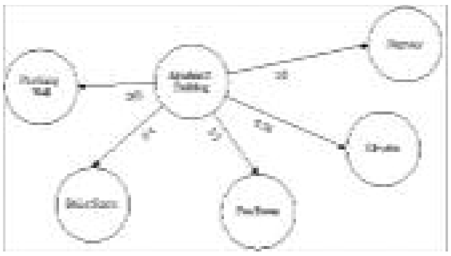

Figure 1. The concept of Design Tree

constraints of underlying technologies but is presented as a proof of concept rather than a robust optimised project tool at this time.

Although DITS supports text medium and process design information, the concept is valid for other media. Here, we have employed text as the primitive element in our collaborative environment not only because of the ease of processing text but also because of the importance but often unsupported role of text in design activities, as noted above, but note that graphical primitives could be handled in a similar manner. In general, DITS is designed for the following purposes:

a) Capturing knowledge from various resources (e.g. newsgroups);

b) Representing knowledge in computer readable and retrievable format;

c) Sharing knowledge among collaborative team members;

d) Learning knowledge from past design experience; and

e) Reusing knowledge in concept generation.

Experimental Evaluation

We conducted a series of experiments to evaluate the proposed system and approach. The design of the experiment is based on the theme-based evaluation framework previously developed in the evaluation of various information retrieval systems (Chau, et al. 2002; Chen, et al. 2001). Within this framework, several experimental tasks are designed to conduct evaluation of the extent and use of proposed text-mining tools facilitating users' identification and elaboration of major themes related to certain topics.

The input reference data came from studio discussion (reported in Kvan 2000b). In the whole design studio, there were total 512 messages posted. Based on this design information, we prepared a series of requests for subjects to retrieve appropriate information on specific design issues known to be covered in the database. Subjects were asked to summarize the findings from the database using one of three methods: message reader, DITS and Design Tree. By analysing the results retrieved, we can compare the effectiveness of the systems employed to help students locate relevant messages from the bulletin board and gain a general understanding of the target topics.

Twenty-seven undergraduate students from the Department of Architecture at the University of Hong Kong were recruited to participate in the experiments. Twenty of them were from Year 1 class, while seven were from Year 4 class. All of the students performed theme identification and elaboration tasks from each topic. For each task performed by the subjects, the design issues and time spent in the experiments were recorded for further analysis.

Group A is six of Year 1 students who were asked to work individually to summarize themes from the findings of original WebBoard system. Group B is another eight of Year 1 students who were required to perform the same topics by using DITS. Group C is the remaining students conducted the similar experiment by only using the associative keywords mappings, Design Tree, generated in DITS. There was an assumption that Year 4 students are better able to articulate design issues during the conceptual design stage. To evaluate this hypothesis, those Year 4 students were assigned to make use of the Design Tree only. Table 1 shows various groups of students perform the above tasks accordingly. The data analysis was further conducted by following the comparison as the arrow sign shown.

	Group B	Group A [illegible]	Group C
Year 3	[illegible]	[illegible]	[illegible]
Year 4	[illegible]	[illegible]	[illegible]
[illegible]			

Table 1. Experimental arrangement

Each group of subjects was unaware of experimental details other than their own. The order of the two query tasks was inverted for half the experiments to remove the effects of learning system operations.

Performance measures

Two experienced designers were recruited as expert judges. Based on their experience, they summarized two lists of design issues for those two designated subjects into themes individually. Then a full list of the student finding themes was consolidated and sorted in alphabetic order, which allowed the experts individually to judge the relevance of each theme, thus producing a validated ranking.

Several quantitative rates are used to measure the performance of each subject. Precision and recall measures are well-accepted approach to evaluate the search results (Chau, et al. 2002; Chen, et al. 2001; Shakshuki, et al. 2003; Volk, et al. 2002). The F-measure is the harmonic mean that combines precision and recall into single measure (Van Rijsbergen 1979). To evaluate the efficiency of individual systems, the time each student spent on each topic is recorded for further analysis. Furthermore, the theme length is also calculated to examine the quality of subject findings. These primary measures of effectiveness and efficiency are shown as follows:

Precision	=	Number of correct themes identified by the student / Total number of themes identified by the student
Recall	=	Number of correct themes identified by the student / Total number of themes identified by expert judges
F-measure	=	2 * Recall * Precision / (Recall + Precision)
Time	=	Total time spent for each query
Theme length	=	Number of words found in each theme phrase

Results

Using the measures above, results were computed for effectiveness, efficiency and word length of reported theme.

Effectiveness

Precision, recall, and F-measure rates were compared pair-wise between the groups. No evidence was found that DITS or the Design Tree improved on the effectiveness of searching for any users.

Efficiency

Time was recorded as the total duration of the search task including the response time of the system, the browsing time of the topic, and the writing time of the answer. Figure 2 shows the average time spent to finish a search task among various groups. Each student was required to complete two search tasks. To reduce the impact of the learning curve of unfamiliar systems, only the second search tasks were taken into account, i.e. adjusted average time spent. Figure 2 shows the effect of the learning curve of unfamiliar systems. In Group A, the time difference was negligible; this was expected as the subjects had learned to use the newsgroup in another course. The time differences among the other three experimental groups revealed that users of DITS and the Design Tree were able to finish a search task more quickly than with the newsgroup interface reviewing raw data. To verify the significant level of the differences, a t-test was conducted to compare the efficiency of three systems as to the same type of samples, i.e. Year 1 students. The test showed that the improvements of Group B and C are significantly better than that of Group A for Year 1 students.

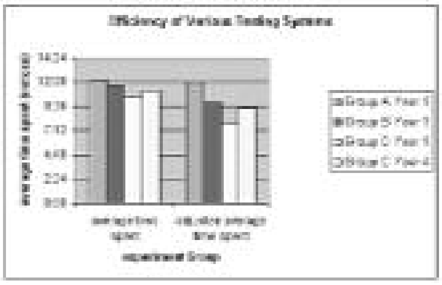

Figure 2. Average time spent for search vs. experiment group

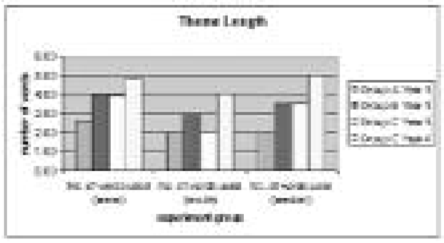

Figure 3. Number of words used vs. experiment group

We thus conclude that users were more efficient using DITS or Design Tree. DITS provided a collection of related keywords highlighted on messages during each search task. The Design Tree presented a hierarchy of associative keywords for users to review. A key contributory factor in the better efficiency achieved was that the associative keywords provided a summarized overview for the scope of search topics. As a result, a user can focus only on relevant keywords rather than spending more time to scan through all the messages.

Theme length

The number of words used in each theme reported indicates refinement of the idea identified. A longer phrase suggests a more articulated idea. The absolute length of theme did not count in the verb “to be” (e.g. is, am, and are) and the articles (e.g. a, an, and the). Figure 3 shows that Group B and Group C used more words to describe a theme on average than that of Group A. By comparing last two experiment groups, it was also noted that Year 4 students tended to use more words to mention a theme on average. T-test results indicate significant differences in the length of theme among the first three experiment groups. According to the findings from Group C, the difference of the theme length between Year 4 and Year 1 students is also significant.

We conclude that DITS and Design Tree support a longer detailed description of a theme encouraging explanation of design ideas finely. There was another interesting finding in Group C experiment. The mode of theme length collected from Year 4 students was much larger than that of Year 1 students, i.e. 4 vs. 2 (Figure 3). It revealed that Year 4 students examined more carefully keyword cues from the Design Tree, while Year 1 students had less background knowledge to elaborate design ideas. It was additionally supported by evidence that the mean, mode and median length of theme were almost the same for Year 4 students (Figure 3).

Discussion

The development of computer systems to support design has focused on two particular sets of activities in construction. We have ample supply of graphical tools for drawing and systems of management tools to support process control. Communication between team members remains a problem. Textual support of design is not readily available. Thus, a system that supports textual communication can be of value.

Construction projects are typically complex organizational entities involving disparate parties, each focused on it own issues yet tightly interlinked with issues of concern to other parties. Each party accumulates information and makes decisions based on this information. Poor communication has been shown to be the root of many construction problems. A tool that monitors communications with the intent of alerting a participant to the occurrence of a communication on an issue of related interest is obviously of value to supporting project communication. The proof-of-concept system provides such support.

The concept of agents monitoring conversations does not need to be limited to text communication, although this is easier to implement as of now. Design communication ("conversations") exists in the context of graphical images as well (Do, et al. 2000).

The results from the experimental evaluation are encouraging. Although there is no proof showing either DITS or Design Tree is better than the original WebBoard in terms of effectiveness, students are able to achieve the same degree of satisfactory results during design idea exploitation. In terms of efficiency, DITS and Design Tree indeed provide better support in organizing information. Relevant keywords are highlighted in DITS, while the associative keywords are organized into a hierarchy tree structure by using the Design Tree. The user can spend much less time to explore the information from the data archive, especially by means of the Design Tree. In terms of the word length of theme, the keyword-based summary encourages users to describe their findings more finely, while they are reluctant to read though all the messages and re-phrase their findings in plain-text environment, i.e. WebBoard. This suggests that a participant in a collaborative design project could monitor a large number of communications more effectively using a agent-based system that summarises communication content.

The vocabulary of construction is complex, not only for its breadth, but for its ambiguity. Terms are not strictly defined. Professional use has not constrained interpretations of words. Being a creative activity, the ambiguity is important. Furthermore, construction brings together a very wide range of players, each with their own worlds of meaning. Thus the problem in construction is particularly difficult. The DITS system does not, as yet, handle ontological aspects of communication. An ability to handle these will of course improve the benefits of use as well as increase the power of such monitoring. Here we demonstrate a feasible approach to support machine-learning algorithm to solve the problem of information and communication overload.

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