Textual support of collaborative design

Wilson Wong and **Thomas Kvan**
The University of Hong Kong, China

Discussions of media in architectural design typically revolve around graphical forms, be they digital or analog. For example, much current research addresses the relationship between design sketching and cognitive process affecting the products of individual designers. This emphasis on graphics overshadows the role of text in design. While most CAD tools pursue increasingly realistic computer graphics, the interactions of designing require broader support.

In this paper, we consider the importance of text in 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 the collaborative environment, a shared understanding and preserved history are important for communication. In this way, just as graphics can be seen as a cognitive aid, so too can text. Any singular design medium is insufficient to present the design idea thoroughly. Several design media should coexist.

This paper outlines the cognitive background graphics in design, then reviews the role of text in design collaboration, drawing upon experimental results from cognitive science and architectural settings. As a conclusion, the paper sets out a direction for future research and development of tools to support collaborative design communication.

Other than graphics

It is self-evident that drawing generally plays a significant role in architectural design (Goldschmidt, 1994; Robbins, 1994; Lawson, 1994) and in engineering (Ferguson, 1992). They find that drawings are indeed able to assist the cognitive process during the process of design.

It has been noted too that drawing can be seen as a conversational process itself (Schön & Wiggins, 1992) and that the act of drawing externalizes thoughts that may otherwise be unrecognized (Goldschmidt, 1991; Goel, 1995; Soufi & Edmonds, 1996; Purcell & Gero, 1998). This extends the arguments in cognitive science that diagrams perform the role of supporting cognitive processes by extending cognition beyond the internal cognitive processes of the designer (Larkin & Simon, 1987; Scaife & Rogers, 1996). Indeed, it has been observed that active engagement in drawing which leads to highly dense sketches correlates with demonstrated ability in design, suggesting that the act of sketching is supporting a deeper level of design thinking (McGown, Green & Rodgers, 1998). Similar findings have been observed in reviews of practice. For example, Lawson (1994) found that architects do not just treat drawings as the representation and documentation of design, but also as the process of discovery and thinking of design. From these investigations, conclusions have been drawn about computer-based sketching systems and their functions in supporting design (Verstijnen, Hennessey, Leeuwen, Hamel & Goldschmidt, 1998).

Since the first introduction of Sutherland's SKETCHPAD system in 1963, system developers have focussed on tools to support computer graphics in design. Faster and less expensive processors are coming to product better quality of graphical images. Real-time generated three-dimensional modeling is possible with modest computing tools. It is common to find that computer-aided design systems are understood only as graphical systems. It has been noted that current graphical design media are inadequate in and of itself to support architectural design (Lawson & Loke, 1997). Limitations to current graphical systems have been explored, for example, most three-dimensional CAD programs do not easily support early conceptual phases of design (Verstijnen, et al., 1998). Porter & Goodman (1988) assert that drawing by hand remains undisturbed as the central activity in the design process. Verstijnen, et al. (1998) draw a similar conclusion that electronic sketching device, like paper and pencil, support unspecified input appear to be more suitable electronic idea generation tools. However, the existing computational technique is weak at preserving a unique data structure for restructuring the design from such free-handed drawing. While existing popular CAD tools help in the documentation and presentation of design ideas, significant portions of the design process are not addressed by these tools.

Various types of design representations can assist the designers to explore and understand the design. There is no evidence to prove that any singular design medium can fulfill the participants' expectation. For example, drawings need to be supplemented by other semantic operators, such as gestures (Tang, 1991). A building's form, function, structure, materials, and details all relate to, and impact, one another (Groh, 1997). All these information can be divided into two groups: form and concept. In many cases, the form and structure of the design can be described by the underlying concept. The close-coupled relationship can be found in the text and other design media. In addition to graphical representations such as two-dimensional drawings, three-dimensional models, animations, the creation of architectural designs is supported by words, spoken and written (or typed).

The meaning of CAD can be interpreted as computer-aided drawing, drafting or design. As we have noted, design can be manifested in numerous ways. However, application developers seem to overlook non-graphical media. Drawing encompasses any program that allows users to leave traces and marks on the screen, such a paint program. Drafting implies a more structured construction of the drawing and therefore requires a larger set of more complex tools to create the drawing. Design implies support in decision making, something that com-

mercially available systems today do not offer. Most existing CAD tools address themselves to the efficient methods on design documentation and presentation, but such tools seems to neglect the multifaceted processes of design. Some drafting systems have extensions to them which make drafting more efficient but do not cross the line into design because the systems cannot handle constraints, monitor work and give feedback, etc. A more completed CAD tools should allow the design participants to deal with text, graphical and numerical data in the process of design, management and communication. This paper explores for one part of this large picture, that of design.

The role of text in the design phase

Even where drawings are used, the importance of words has been noted, for example by Schön:

"But as Quist says these things, he also draws... His words do not describe what is already there on the paper but parallel the process by which he makes what is there. Drawing and talking are parallel ways of designing, and together make up what I will call the language of designing." (Schön, 1983, p. 80)

The importance of verbal and textual communication in design learning has also been highlighted by Sonnenwald. In a design teaching exercise in which design proceeds without the benefit of spoken or written communication, the author notes:

"Depriving students of verbal and written communication is a powerful way to introduce them to the importance of communication in design" (Sonnenwald, 1996, p. 298)

In fact, text and form may serve different purposes in design. Ulusoy (1999) studies on the graphical presentation and verbal expression related with the students' ability in design. The preliminary result reveals that designing is related mostly with visual thinking as the action of decision making and synthesis, while understanding design is related with linguistic faculties. The interaction between verbal and visual conceptualization is indeed complex, and both expressions are generally agreed to be close related. This idea can imply the textual information can assist the analysis for understanding the design rationale. The shared understanding of various issues is one of the main purposes on the computer-supported collaboration.

Some researchers have begun to explore the role of the different information captured by computer-mediated applications in the various design phases. Lawson & Loke (1997), for example, emphasize that word plays an important role especially in the early design phase. It is difficult to preserve design concepts in preliminary drawings, contributing to misunderstandings between participants of the design process. They find that word rather than picture is able to support a range of interpretations in expressing early design ideas.

Apart from assisting the creation phase of design process, text can also be used in various phases. Architectural design is bounded in practice by building regulations, client constraints, and the architect's design intent. Much of this conceptual information can be presented and recorded in textual format. It is noted that text also plays an important role in practice. External information is presented in the form of codes of practice, design guides or product specification (Macleod, McGregor & Hutton, 1994). This kind of text information provides a standard and general agreement, which can avoid the argument of the final design product from different participants in design process.

Based on such an architectural project can last for a prolonged period, the implications for bookkeeping design and pointing toward descriptions that the designer may find usefully embedded in computer-based aids (Porter, 1988). He observes that by putting all design idea together into a sort of chain of reasoning or argument, they replicate the design. This is easier done in text although drawings have a role. A preserved history of design concepts can be recorded in such bookkeeping. In order to organize the historical information, text is a common medium to provide informative and descriptive along with drawings.

The role of text in collaborative design

Schön takes the act of drawing one step further. He refers to the architect having conversations with the drawings (Schön, 1983; Schön & Wiggins, 1992). From the assumptions about the importance of drawing, many collaborative design tools have focussed on graphical processes of communication to the exclusion of textual (e.g. Tang & Minneman, 1990). For example, the application developers have mainly focused on the concurrent and version controls of drawings in the early research for groupware (Katz, 1990).

However, we note that research (e.g. Schön, 1983; Verstijnen, et al., 1998) has typically addressed interactions between the designers and their own drawing. Although the architects can self-communicate with their drawings, it is not the case in collaborative environment. Their 'dialogues' in the drawings may not be realized by other participants. From this point of view, textual description of their design drawings should be used to preserve their design concepts. In the collaborative design, such sharing and exploration of ideas would frequently occur along the whole design process.

One of present examples for textual support in collaborative design can be found in argumentative approach to design. McCall & Johnson (1997) create a hypertext system to improve design by encouraging argumentative. It seems successful in capturing the rationale that designers actually use during an argumentative discussion between participants.

It is also observed that geometrical representation of design cannot individually exist in collaborative design. The nature of collaborative design can be presented as

'Design activities can be viewed as the process of developing a design system and identifying relationships between entities within the system. The collaborative activity then has access to not only the resulting geometry of the individual design activity, but to the semantics of the design." (Saad & Maher, 1996, p. 191)

As such, various design media coexisting along the whole design process are required in order to represent different categories of design information in collaborative environment. Saad & Maher (1996) point out that several design media should coexist in collaborative design that allow designers use drawings, verbal and text-based specifications, 3D models, photographs and video to document and communicate their ideas. Based on the similar concepts, Fruchter (1996) proposes an interdisciplinary communication mediated computer environment for exploring alternatives and capturing design intent. From her analysis, both shared semantic and multiple graphic representation are essential in a collaborative design environment. These are two examples in which can see the relationship among text and other design media.

A statement which illustrates a common approach to the development of tools for computer supported collaborative design can be found in Tang:

"*Collaborative drawing tools should not be based only on what features computer technology offers... the design of collaborative technology needs to be guided by an understanding of how collaborative work is accomplished.*" (Tang, 1991)

In order to understand the nature of collaborative work, some researchers have begun to study the role of various media and methods impacted on collaborative design. It has been observed that design collaborators communicating using textual chat lines produced better results than those communicating using audio links did (Vera, Kvan, West & Lai, 1998). While this result is inconclusive, its implications are tantalizing and a reminder that tools to support collaborative design should include textual communication.

Vera, et al. (1998) also find that communication modes can be varied without affecting the final result of design. As the bandwidth of communication reduced, subjects shifted the content of their exchanges from discussing low-level issues

to engaging in much more high-level discussion. A key issue in implementing collaborative systems in practice will not be the technology but the nature of the collaboration (Kvan, 1999). Communication is central to collaboration. In order for it to be effective there must be a mode of communication. Kvan (1997) concludes that design collaboration is loosely coupled. From this point of view, coordination among the project participants is relatively more important to improve the process of communication. For this reason, the graphical design representation insufficient for design communication.

A lesson from information highway

The rapid development of computer networking and related digital technologies now reduces the boundary on both the time and space. One of the breakthroughs here is the popular use of Internet. We are not going to analyze the success of Internet, but pointing out the role of text. It is observed that hypertext information is the main content inside World Wide Web. Although the hyperlink access can be found in other media, such as images and 3D models, the users may still find difficulty to be aware of the contents in next level of hyperlinks without any text description. It shows the importance of the coexistence of other media and text.

Text can be employed in a number of ways in computer-mediated collaborative work. Electronic mail is a simple method of sending a text message from one person on a network to another. Other types of information can also be sent by email as the form of attachment, but text is still one of the main media for communication. Similar to the same concept, various text domain applications can be found useful on the distribution and exploration of information, such as newsgroups, gopher and electronic bulletin boards.

In fact, textual information is the most desirable for taking the balance between machine-readable and human-understandable implementation. Extensible Markup Language (XML) is one of the latest examples to use textual semantics to extend the interpretation ability on documents for automating the validation process (Khare & Rifkin, 1997). Similar example can also be found in the early development of Metadata, which is commonly used as data description about documents in Hypertext Markup Language (HTML) for maintaining human-readable document (Lassila, 1998).

More and more people have begun to find much benefit from using electronic media over computer networks instead of more traditional recording media. The situation similarly occurs in the field of architecture. The virtual design studio establishes a new paradigm for the computer-aided design. Many studies focus on developing the guidelines for framing and conducting effective and successful virtual design. However, it is generally agreed that communication and coordination of shared resources can control the success of the virtual design studio. Wojtowicz (1995) has organized the process and feedback in one of the pilot studies on the virtual design studio. From these findings, it has been observed that the digital dialogues (e.g. email and chat) can preserve the design intent, concept and other social activities.

Textual support is not only useful in collaborative architectural design, but also generally important in other disciplines under collaborative environment. Nunamaker, et al. (1995) find a better support compared with the conventional face-to-face meeting when using computer tools to support negotiations and discussions in military, political and commerce, even though the communications were only involved text messages. Based on this electronic meeting system, Weatherall & Nunamaker (1996) describe more relevant concepts and working procedures, which had been used in several business organizations.

Suggested future research

"*Our customers need to capture design intent...In the past, that was done with constraints built into the geometric model, showing this line should be parallel to that line, for instance. But constraints don't say why the lines should be paralleled.*" (Potter, 1995, p. 58)

Although some current systems provide a book-

keeping database for capturing design intent and attaching annotation, such systems do not adequately convey intent. These systems restrict the users to access their familiar user-interfaces and design processes (Saad & Maher, 1996; Jeng & Eastman, 1998). The users may be reluctant to accept the changes and dominated by their own personal preferences.

In collaborative work, tracking communication and intent has been identified as important but there are few tools yet with which to do this in a loose-coupled environment. Following this argument, an agent system is proposed to help search, track and monitor design coordination over the existing email system.

The proposed agent system is integrated with the existing system in order to minimize the side effect from the users' working habits. As has been shown, the design intent can be found and preserved in the existing email. The agent system can search the email archives to develop an information flow on some specific topics from all participants. Such system can also show the application of agent technology on the field of architecture. There are four system components in the proposal: data collection, data retrieval, agent negotiation, and information delivery. These components represent the workflow from data input to information retrieval.

While not much research is completed in the technological support of collaborative design, there is even little in the area of process support. Kvan (1999) points out that appropriate processes are essential in supporting successful collaboration. Several studies have shown that adding video has no benefit over chat in the efficiency of communication process (Chapanis, Ochsman, Parrish & Weeks, 1972; Weeks & Chapanis, 1976; Kvan, Vera & West, 1997). These kinds of findings have implied that the conventional simulation of physical communication process may not be suitable to electronic media thoroughly. From this point of view, the proposed agent system can be treated as an enhanced email system for studying the efficiency of design process under low bandwidth environment within asynchronous communication.

A scenario

Design information can be logged in the existing asynchronous communication among the participants. Taking an email system as an example, the information can be shared during a sender transmitting a message to a recipient. Some of these messages are relevant to build up a knowledge archive, which is the database for the participants seeking and keep trend of the design rationale later.

During the process of information retrieval from a team member, the searching criteria are based on the setting of user's profile which is updated continuously. In the proposed agent system, each participant has an agent representative to perform the searching. Each agent representative can exchange the information with others in case the agent needs to use others' preference to enhance the quality of its performance.

After the searching result returned to the retriever, the design information is available in a hyperlink format. Therefore, the retriever can trace the historical records of the specific subjects that discussed by other team members. If the previous information is not enough, the retriever is also able to locate a relevant team member for further discussion.

Most of the process and functionality described is already implemented in various systems. However, there are many different approaches and considerations for various situations. Some of the main issues that can be addressed for the system design are listed as follows:

Data collection

• Due to the system complexity and flexibility, there are several different ways to build up the message archive. The message archive is a separate allocation from the team member's mailbox. The selection of messages which to be archived can be implicitly decided by the users or automated by system (e.g. email filter).

• An implemented system may allow the follow-

ing user actions: 1) the sender can decide to archive the message, 2) the recipient can decide to forward message to archive, 3) a special email system is tailor-made for design team, 4) a bulletin board discussion is used for design project, or 5) all messages can be archived without consideration of the related topics.

• The archived messages may need to be preprocessed by using inverted index methods. It depends on the speed of information retrieval and the size of database.

Data retrieval

• As Furnas, et al. (1987) have shown, people use a variety of terms to refer to the same subject. From this, we note that alternative access words are needed for users to get what they want from large and complex systems. Alias words are therefore essential in supporting text searching.

• In addition to selecting alias words, various user preferences can be specified in different user profile. For example, the user profile can include topics of interest, disciplines, and information types, etc.

Agent negotiation

• In order to identify the various software agencies, some properties have been proposed for cataloguing similar agent systems, for instance, ongoing execution, autonomy, environment awareness, adaptiveness, intelligence, and mobility, etc (Shoham, 1999).

• In the proposal, each agent representative will communicate with others for information sharing and knowledge transmission. As such, the mechanism of communication between agents should not be neglected. For example, Knowledge Query Manipulation Language (KQML) can be used to support run-time knowledge sharing among agents with a specific message format and a message-handling protocol (Finin, Labrou & Mayfield J., 1997).

Information delivery

• The presentation of results can be formatted in hyperlinked form. Related information can be presented in chronological order, by topic or frequency of word count.

• In a multiple agent system, the performance of different agents is unpredictable due to the various dependencies. This may affect the efficiency of a real-time system. Therefore, an evaluation of database size and programming algorithm should be done in advance.

We have outlined only a few of possible development strategies.

Concluding summary

The concluding observation of this paper is that text coexists with other media in design activities. Text also serves an important role as recording design intent, constraints, and customer requirements. CAD tools could not be completely successful without considering the interrelation of text and other media. This paper has pointed out an appropriate attitude of CAD tool developers to consider the support of design process before pursuing the high-end computer technology.

A main feature of the scenario described is that design information can be captured without additional data input procedure, in order to minimize the loss caused from any miss of design concept in a prolonged period of time. Based on this consideration, an agent system is proposed to support efficient design processes with low-bandwidth communication conditions. Text is a medium that takes a balance between data format, storage, ability to communication, and limitation of personal preference.

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