Exploring the Possibilities for Computer Support for Collaborative Designing

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Design projects require a collaboration of individuals and a coordination of information and tasks. Computer support for design, more specifically CAD systems, have been developed to support a single user through a graphical interface and project teams through distributed data. This paper considers recent developments in computer support for synchronous collaborative design. The possibilities for developing a support environment for synchronous collaborative design cover a broad range of technical and personal considerations. We explore these possibilities by presenting several perspectives of the technical considerations and options, followed by a discussion of how such environments have the potential to enable a shared understanding among people as they are designing.

Keywords: collaborative design, groupware, shared CAD.

1 Introduction

Collaborative design has been supported by computers for many years. The use of computers to develop models and drawings of designs, to anal se designs for various performance criteria, and to organise and retrieve information, has been possible since CAD, computer programs for specific analytical tasks, database management, and word processing have been in widespread use. There has been a recent, renewed interest in computer support for collaborative design. This renewed interest has a dramatically different focus – the focus is on how such environments support designing. The attempt to move the computer onto the designer`s desk has had little success in the Architecture profession. Widespread use of computers on a design project has occurred, but not because designers are using them. The possibility of supporting synchronous collaborative designing has the potential to change this - we are beginning to see computers on designers desks. In this paper we look at how these changes are occurring by looking at recent research and developments. Based on this research we explore several technical and personal issues in the development of computer support for synchronous collaborative designing. The technology issues can be viewed from a number of perspectives, where each perspective can lead to a different implementation of computer support. In this paper we consider the technology from the perspectives of closed vs open applications, multiplexing or coordinating interfaces, single vs multiple applications, separate vs integrated video communication, and common vs multiple representations. We look at how these technologies have influenced the development of computer support for designing.

In addition to exploring the technology for supporting collaborative designing, there are ways of considering the nature of a shared workspace that can clearly identify the needs of a virtual design workspace. Shared visual interfaces can be provided through the current enabling technologies. A shared understanding among designers in a design team is possible through an explicit representation in the shared workspace. The shared workspace comprises the representation of the design project as data /information, as well

as the media through which communication and interaction between participants in a collaborative design occur. In a computer-supported environment for collaborative design, the shared workspace can serve different purposes and lead to different approaches to making the design information explicit. In this paper we consider various perspectives of the shared workspace according to information sharing, communication media, process management, and exploration space.

2 Exploring technology for multi-user applications for design

Group interaction or multi-user interface to information systems have emerged as an important factor in the development of collaborative and distributed design systems. Research in CSCW, groupware, and computer-mediated communication has been focussed on developing information systems that can support group work [1,2,3,4]. The application of this research to design support has taken several alternative approaches. To understand how these approaches differ, they can be considered according to different perspectives on the use of technology. For example, some of the common perspectives are: time-space matrix, shared information, implementation architecture, and interactivity and access control. Each of these perspectives can lead to the development of a support environment with a different emphasis. Time-Space Matrix. One popular approach to understanding how technology can support group activities is to consider two dimensions of support: time and space, that is when and where the participants are performing the collaborative work. This matrix has become a common platform for describing most groupware and distributed systems [3,4,5]. It describes:

(1) the type of interaction that a particular collaborative system can perform such as synchronous or asynchronous interaction,

(2) the geographical distribution of the participants such as co-located (same place) or remote (different place).

Figure 1 shows examples of collaborative design systems in the Time-Space matrix. The area in which computer-support for collaborative designing needs to be specialised is the part of the matrix labelled same time - different place. This does not assume that the other parts of the matrix are not relevant to collaborative design, but that there are existing technologies that can support that aspect of the collaboration. For the remainder of this paper we will focus on the support for collaboration when the people involved are working at the same time, but in different places.

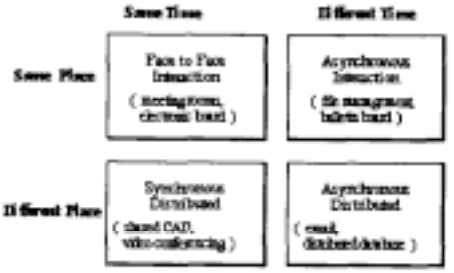

Figure 1

Shared Information.

Shared information raises issues concerning: (1) the degree of sharing required, and (2) the kind of information being shared. The granularity of shared information depends on the application domain of collaborative systems. Shared editors, for example, are used to share some textual-based information. In addition to textual-based sharing, group. drawing tools enable participants to share graphical information. Peng [4] identifies two knds of information that should be captured and exchanged in collaborative work: action-oriented and representation-oriented information. Action-oriented information which is useful to group interaction in synchronous collaboration such as gesture, movements, etc. Representation-oriented information is useful in sharing some formal

representation of the design project. The use of technology for sharing action-oriented information assumes that video and audio data is transmitted between the participants in the collaborative session, such as a video conferencing system. The technology for sharing representation-oriented information is commonly referred to as groupware, in which more than one user can see and modify the representation during a collaborative session.

Implementation Architecture.

Communication or the exchange of information is a major concern of collaborative design systems. The ability to quickly exchange various types of messages for communication within a group is essential. The challenge is to apply appropriate technologies to increase the support of direct communication channels amongst participants. This classification addresses the nature of the implementation architecture. There are two main architectures for multi-user applications: centralised and replicated [6]. A centralised architecture runs a single copy of the shared application on a central server and the graphical input and output is shared among several screens over a network. A replicated architecture is based on executing a copy of the application for each user. These alternative technologies have implications for supporting design activities when the volume of information being shared is potentially very large, indicating a centralised architecture may be more efficient, and when the amount of information in a user transaction is very large, indicating that a replicated architecture may be more efficient.

Interactivity and Access Control.

The floor control mechanism provides a mechanism for enabling interactivity and access control in a multi-user environment. Floor control becomes important in groupware sytems in which there are more than two users and the users are all actively making changes to the representation. The floor control helps to resolve interpersonal conflicts. One approach is the master/slave style in which one master user is allowed to interact with the application and the other users may only watch. This approach is clearly limited since users are discouraged from participating in the collaborative process. Another moderated approach can be used in which the floor control is passed between users through a special access interface. The interface is based on token-based model that allows users to request and pass the floor control to each other. This is similar to passing a pen in a meeting. The current pen holder can interact with the shared application enabling a task to be completed without intervention. Control is then passed to other users by releasing the pen to the group. Figure 2 illustrates an interface for establishing user control of a collaborative design application [7].

Observational studies of computer support for group activity has led to the development of specialised support systems that address the above considerations [1,8,9,10]. However, future research and development in CSCW and collaborative and distributed systems in general requires the contributions from a range of disciplines including sociologists, cognitive scientists, designers, and computer scientists. Another important aspect of collaborative applications is to explore the impact of technology on group and individuals within a specific discipline.

Focussing of computer-support for collaborative designing provides a potentially complex set of problems that raise several technological issues regarding both communication and representation. Multi-user applications for design usually reflect the current role of CAD and how it can be extended and used within a multi user environment. Considering the possibilities from the perspective of designing, a different way of exploring the possibilities can be found. Based on our experience in developing prototype environments for collaborative design [7,11,12,13,14] and running virtual design studios for architecture students [15], we have developed several views of the technology that lead to different implementations of computer support. We have seen that the effectiveness of a collaborative design environment to support designing is based on the type of applications (closed versus opened), the approach to distributing interaction (multiplexing versus coordinating), the type of applications (single versus multiple), the use of real-time video (separate versus integrated), and the representation of design objects (common vs multiple). We discuss each of these views below.

Figure 2

2.1 Closed versus open applications

When people work together they often use a variety of computer supported Es stems that are available to the group. These normally belong to two extreme categories. In first category, the group has access to utilities that enable them to share an existing application. Some existing applications are closed in the sense that the user interface cannot be modified. In order to develop a multi-user application from these existing single-user applications, the data generated by the application must be intercepted and sent to several locations. The user interface of the application may be duplicated on each site by an intermediary agent. For example, the keyboard events and the mouse movements may be captured from all participating sites and can be sent back to a centralised application.

In the second category, more comprehensive and open design applications are normally used. Application development systems and interface enhancements that are offered by open applications aim to provide a foundation for clear understanding of the application engine and for developing and extending the functionality of existing applications. As a result, systems which support collaborative work and multi-user interactivity can be evolved.

New applications have been developed specifically to support group activities. Examples of such applications are: shared white-boards which provide support for drawing, listing, indexing of electronic documents; co-authoring tools to support the joint writing of documents; and groupware development environments that provide support for building multi-user applications. These could be considered open applications since the multi-user interface is integrated to the application.

Figure 3 illustrates the two categories:

(a) a multi-user interface is specifically developed for a closed shared application with which users can interact,

(b) the multi-user interface is provided and integrated into an open shared application.

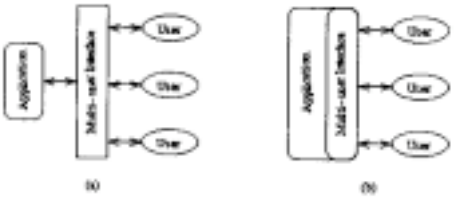

Figure 3

2.2 Multiplexing versus coordinating

Another aspect of multi-user development is the distribution of input and output of shared applications. In the X Window system, for example, an X Protocol Multiplexor can be used to distribute the data from the application and collect the events from the remote

locations, as illustrated in Figure 4. While this approach may be applied to most X Window applications, it has some problems. First, some applications may ignore some user events or communicate directly with the hardware workstation for efficiency purposes. These actions are hard to capture by the multiplexor and the applications would have to be modified.

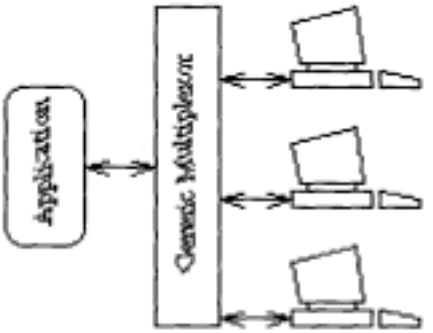

Figure 4

One of the design and implementation issues of a multiplexor is the floor control. The floor control policy is the technique that the multiplexor uses to determine who can access what and in what manner. The default assumption in the design of multiplexors is to pass all users actions generated by any user to the client. This approach tends to deviate the collaborative work and is potentially confusing to the users and also to the application. If three users simultaneously select the same object in a drawing program and try to move that object in three different directions, the resulting activity is unpredictable. Coordinating the input and output of the shared applications allows developers to manage and distribute users' interactions. This approach might be viewed as a process of filtering and distributing users' event at the high level of the application interface instead of the hardware level provided by the multiplexors technique.

Figure 5 shows an illustration of sharing an application through coordinators.

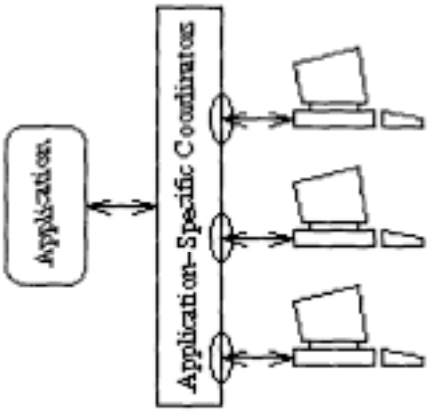

Figure 5

Coordinators can communicate between each other and the shared application through an application-specific coordinator. The disadvantage of the coordinator approach is that it requires a large development effort to build the coordinator and it is specific to each shared application.

2.3 Single versus multiple packages

The goal of groupware and multi-user systems is to assist groups in communication, in collaborating, and in coordinating their activities. Collaborative design may require the use of a variety of applications. Users often use different tools to work on the same global task. As an example, two designers might work on the same building project using two different applications. The first designer (an architect) uses a CAD system to display the layout of an office building. The second designer (a structural engineer) uses a structural package to analyse the structural system of the floor plan. Although the two designers work with two different packages, their results should be shared to maintain consistency. Therefore developing a multi-user architecture for design should not only provide access to one shared application but also to the variety of tools that designers use to do their specific task (multiple packages), as illustrated in Figure 6.

Computer conferencing systems such as XShare [16] or MMConf [6] provide a shared display of groupware applications. A shared display allows participants to view static or dynamic information (such as text and graphics) through the use of various shared applications. While these systems support various forms of interaction between the shared applications, the exchange of information is still restricted to a specific application activity. In practice, designers use of a wide range of applications to address a specific design activity. The development of computer-support for collaborative design requires a model for the interaction among the various applications.

2.4 Separate versus integrated video capability

The effectiveness of the communication is enhanced by the addition of several communication media such video and audio transmissions. One approach is to use a separate communication channel to carry the video and audio signals to the multiple workstations. While only one copy of the shared data /application is displayed on each participant's workstation, video images of all participants are displayed in separate windows. This approach allows the progress of informal discussion and helps in situations involving negotiation amongst participants.

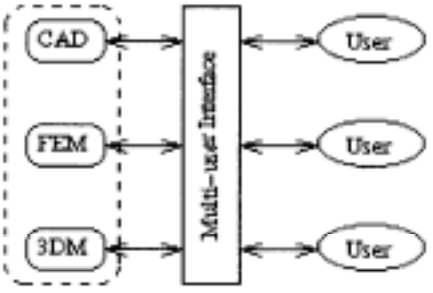

Figure 6

The second approach is to integrate several media within the shared workspace by bridging the gaps between the computer and the desktop. The ClearBoard [17] utilises a video overlay technique which permits two people to see each other through the image they are changing. The ROCOCO project [18] uses a similar approach in the development of a shared drawing system in which a team of two designers can generate design concepts. An image of the remote partner is displayed on the screen and a transparent shared drawin surface is also displayed on the same window. The metaphor behind ClearBoard an

ROCOCO is the open shared workspace which provides a smooth transition between individual and shared workspaces.

2.5 Common versus multiple representation

Most groupware applications are based on sharing visual objects. Visual objects can be constructed from graphics primitives or strings of characters. The complexity of manipulating- visual objects depends on the structural representation of these objects within the system. he representation of visual objects in shared drawing systems varies from paper-based of freehand sketches, to surface-based or object-based graphics, knowledgebased graphics. These systems tend to focus on the common representation of visual objects and simultaneous interaction in the shared systems.

In addition, collaborative engineering systems focus on the representation of an object model that provides a basis for sharing design or product information. SHARED model is an example of a conceptual framework for representing the content and structure of product information. A collaborative design system requires the support of multiple representations and modelling of design concepts while maintaining the flexibility of interacting with a visual representation of design objects.

2.6 Summary of technology issues

To summarise the above issues, Table 7 shows how a number of recent research and commercial projects have applied or developed the technology to suit there goals. Columns describe the issues whereas rows correspond to specific projects. A tick in a cell indicates that the corresponding project uses the technology indicated by the column heading.

Table 7

3• Developing a shared understanding using electronic design workspaces

A collaborative design environment provides a shared workspace through which the various people involved in a design task can collaborate. In a computer-based design environment, this shared workspace is an electronic and distributed space. Some of the issues that are taken for granted in a shared physical workspace, such as access to the person who produced the design idea or the familiarity of informal or formal group

meetings, have to be carefully considered when the workspace is a distributed, electronic representation.

The shared workspace comprises the media through which communication and interaction between participants in the collaborative design occur. In a computersupported environment for collaborative design, the shared workspace can serve different purposes and lead to different approaches to making the design information explicit. In order to clarify the role of the shared workspace, we consider the nature of a shared workspace as: information sharing, communication media, process management, and exploration space.

3.1 Workspace as information sharing

A fundamental role of the shared workspace is to share information. Collaborative design may be conducted in a distributed and indirect way. In building design, for example, architects are responsible for architectural design, engineers are responsible for structural design, builders are responsible for developing a plan for the construction process, and so on. In order to collaborate, these professionals share information about the geometry and function of the building. In addition, different types of computer applications are used by each designer. A collaborative design system should support the representation and access of shared design information as required by each of the participants and their respective computer applications. One approach to sharing information is to store the information in a distributed database accessible to the various participants in the design project. Figure shows a view of the shared workspace as a shared database from which different application programs store and retrieve information.

The advantage of centrally storing shared information is that it allows participants to access information at any time. Shared information facilities are becoming an important feature of collaborative work. Maher & Rutherford [7] explore the enabling technologies and the implications of shared databases for distributed design sessions. The major problem with centrally stored information is agreeing on a formal representation scheme of the design.

3.2 Workspace as communication media

Collaborative design involves a significant amount of communication among design participants. Communication leads to the sharing and exchange of design information, both formally and informally, during the design process. Communication in collaborative design serves a number of purposes and exists in different modes. One mode of communication is the exchange, or sharing, of a design solution state generated by one designers activity among others. In order to ensure consistency, designers need to refer to the solution information in order to update their own solution states.

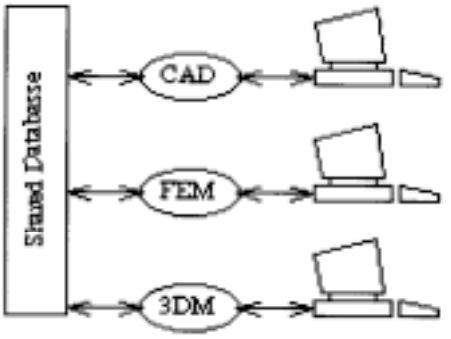

Figure 8

Figure 8 shows an illustration of the use of video conferencing in collaborative design session, where a graphical model of the design is displayed along with the video images of the participants in the design. The focus in this view of the shared workspace is

on the visual interaction of the designers and the graphical representation of the design solution. Alternative approaches to communication include email, talk programs, and annotated drawings. Without a consideration of the shared workspace as a communication medium, the ability to collaborate diminishes.

3.3 Workspace as process management

The process of planning, managing and controlling design activities has been identified as a key requirement for the development of computer-integrated design applications [19]. A number of control policies for coordinating the participants of the design process has been developed including modelling tools for representing patterns of group communication. In a shared workspace environment, the organisational structure of the design domain affects the administration and control strategy used during the execution of design activities. The shared workspace contains information required by the participants to determine the current state of the development process.

The use of the shared workspace to manage the design process determines the content and organisation of the information. As shown in Figure 9, the design data is organised according to the generators/ users of the information: the information generated by the architect is stored near the top of the information hierarchy so it is available to the structural engineer and the HVAC engineer. The focus in this view of the shared workspace is in the coordination and management of people and information through the use of a blackboard architecture [20]. The blackboard architecture _provides a computational environment for sharing the problem solving among agents. The agents can be computer programs or people. The blackboard system provides a syntax for developing a structured representation and a structured approach to interaction and negotiation. The effect this has on the nature of the shared workspace is a consideration of the process model and the information needed to support the various processes /participants in the collaborative design environment.

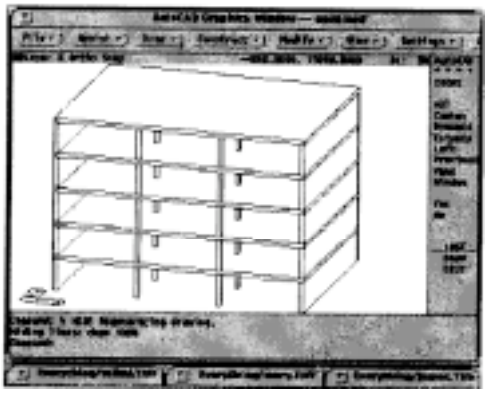

Figure 9

3.4 Workspace as an exploration space

In contrast to the above considerations, the shared workspace can be seen as a team interaction that explores and can potentially expand the explicitly represented design space. The process of exploring various versions of the design solution can occur through the interaction and feedback of the participants. Gero [21] defines exploration in design as a process for defining or producing a state space within which to explore. Rather than viewing design as a search process where the design space and goals are predefined, this view of design considers the space and the goals to be evolving as the design proceeds. Figure 10 illustrates state space exploration and is based on the paper by Gero [21]. In the figure, each coordinate system shows the state space S. as viewed by each participant. Each participant contributes to the design space, introducing changes over time. Therefore, the representation of the shared workspace should allow multiple views of the design space and allow changes to occur as the design process proceeds.

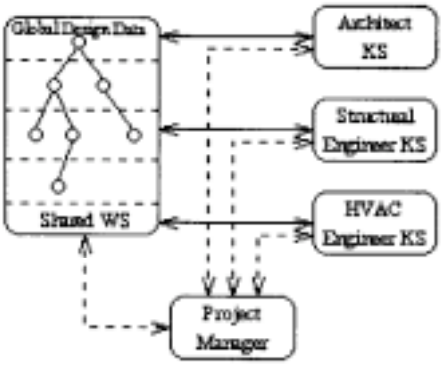

Figure 10

4 Conclusion

This paper has explored the potential of computer-support for collaborative design by considering the technical issues in developing computer support and the representation issues in developing a shared understanding among the individuals in the design team. The technical issues provide some insight into how such environments have been and can be implemented to provide a broad range of technical support to design teams. The representation issues raise the question of how such system can enable the development of a shared understanding among the people that use them. The majority of research projects and prototype implementations have focussed on the technology issues [12]. A growing number of experimental projects, in which a group of people use such environments, are beginning to explore the difficulties in developing a shared understanding [15]. The widespread acceptance of multimedia communication and the advances in virtual design workspaces will be important in the future development of multi-user applications for collaborative design. These developments should ultimately allow both a seamless integration of the technologies used to support designing and enable a shared understanding to be developed and maintained through computer representations.

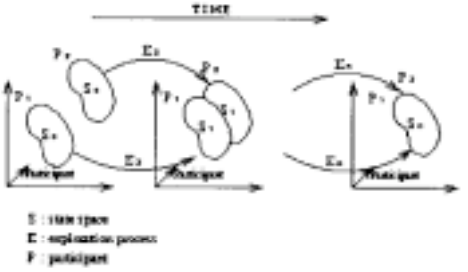

Figure 11

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