An Experimental Study of Computer Mediated Collaborative Design
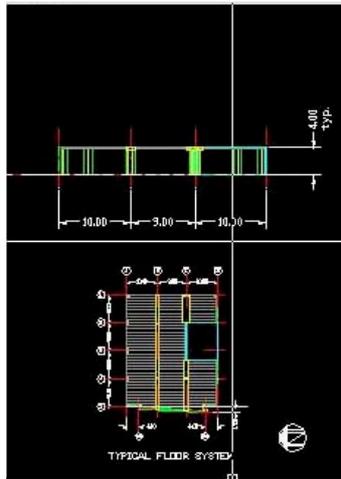## Background Research

There are three areas of research that provide the basis for our study:

- Representing Design Semantics
- Shared Understanding in Collaborative Design
- Design Protocol Studies

Representing Design Semantics

We broadly refer to design semantics as justifications of design decisions, and properties associated with performance and behaviour of designs. Most CAD systems help the designer document the geometry of the design only, as seen to the left. There has been some developments that link non-geometric, or design semantics, to the drawing. Typically, the object oriented paradigm is applied to integrate information across CAD systems by using a specific design schema. An example of such a schema is the design prototype (Gero, 1990), where each class of design objects is characterised by its function, behaviour, and structure. The project data can be stored centrally and accessed by separate programs, as in Fenves et al. (1994). Another approach is to allow users to link their interpretations to the CAD objects thereby capturing multi disciplinary interpretations (Clayton et al., 1994).

The issues raised by data modelling for integrated CAD are relevant to Computer Mediated Collaborative Design (CMCD) because CAD drawings alone are insufficient to communicate the design semantics needed for collaboration. However, the implications of CMCD go beyond the data models, where the focus is on exchanging information between computer programs, to the development of a shared understanding, where the focus is on how human designers communicate through the computer.

Shared Understanding in CMCD

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
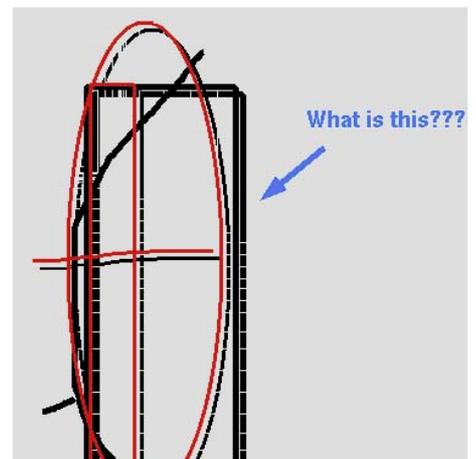
or formal group meetings, have to be carefully considered when the workspace is a distributed, electronic representation. During the collaborative design sessions we have observed, there are many questions among the designers regarding the meaning of the symbols drawn as part of the sketches - as indicated to the right.

Shared understanding implies an overlap of understanding. Each individual has an understanding of the design problem and their view of the development of solutions. This understanding is only partially shared with other individuals. This overlap in understanding is what we are trying to achieve in CMCD. 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, such as **information sharing, communication media, process management** (Saad and Maher, 1995).

Design Protocol Studies

Design protocols are formal studies of designers working on design problem during which data is collected and subsequently analysed. Typically a design protocol studies focus on formalising and understanding a specific aspect of the design process. The developments in methodology and analytical techniques for studying CMCD that influenced our study are:

- "Think Aloud" Method
- Studying Design Teams
- Sharing Design Workspaces

Think Aloud Method

As described in van Someren et al. (1994), the "think aloud" method produces a protocol which might be useful in describing how the thinking process works. The "think aloud" method consists of asking a subject to solve a problem, and to describe the process by talking aloud. During the session, the subject is provided with all the necessary information about the problem, and all the tools for a correct interpretation of the brief. The purpose of this methodology is to provide a transcript that gives insight into the process the subject uses to solve a specific problem.

A session in the "think aloud" method is audio (and often video) recorded, and subsequently coded using a coding scheme. Every word is transcripted as well as all interjections and exclamations, in order to reconstruct on paper what has been said during the session. The assumption made in this method is that the process of describing the

action doesn't seem to affect the design itself. According to Someren (1994), some subjects are not able to "think aloud" while solving the problem. In this case, these subjects are considered "not good" for the experiment, and the data is discarded. One limitation in the think aloud method lies in the "lack of thoughts" during the speaking session, rather than the influence of a loud description of the designing process. Another limitation of this method could be seen in how some subjects find it difficult to work and talk at the same time. They separate the two actions, and they switch from one to the other during the session, even if very frequently and suddenly. These subjects effectively use the think aloud method, but the presence of long silent pauses implies that much of the thinking process is left unspoken.

In our study of CMCD we borrow the idea of coding and analysing the data of the collaborative session, but we do not consider the data to be the verbal utterances of the subjects. Since we are not trying to reconstruct the collaborative design process, but to understand how the designers document their designs differently when collaborating, the verbal utterances would not provide the correct data. Rather, we have taken the data to be the information that is recorded using the computer to document the design. A further consideration of design protocols and the alternative coding schemes is necessary.

Studying Design Teams

There is an evident difference between design methods used by **teams** of designers and a designer by him/herself. Whereas a single designer does not have to deal with negotiation mechanisms and mutual agreements, s/he will not have the advantage of collaboration. It would be interesting to know, for instance, how the fixation issue in design, as described in Purcell et al (1994b), can be resolved/dissolved inside a team of designers.

Cross and Cross (1994) describe studies of teams of designers. In these studies, roles and relationships, planning and acting, information gathering and sharing, problem analysing and understanding, concept developing and adopting, conflict avoiding and resolving provide the basis for observing teams of designers. Planning the design activity seems to be a common procedure followed by designers working alone or inside a team. What changes can be seen quantitatively in the amount of information gathered. In a team, even if made by two, circulation and sharing of ideas is more substantial.
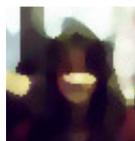
A comparative study of designing alone or in a team has been made by Günter et al. (1994) using a three phases process of analysis: clarification of the task, searching for concepts and fixing the concept. Another comparative study is reported in Dwarakanath and Blessing (1994). Often, the working alone issue is presented as an action of a single composed team (Dwarakanat and Blessing, 1994; Goldschmidt, 1994). In a single designer brainstorming, the same person formulates questions and gives answers, considering at the same time different aspects of the problem, from aesthetics to functionality.

In these studies the focus is on the collaborative design process, where we want to focus on how the design is documented and on the possibility of computer-mediation for collaboration.
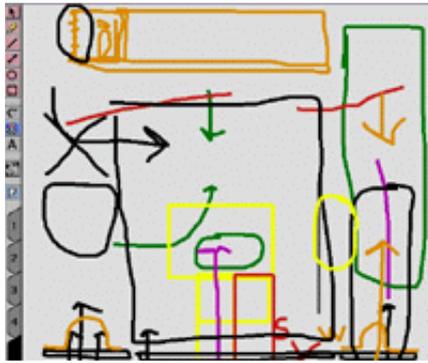

Sharing Workspaces
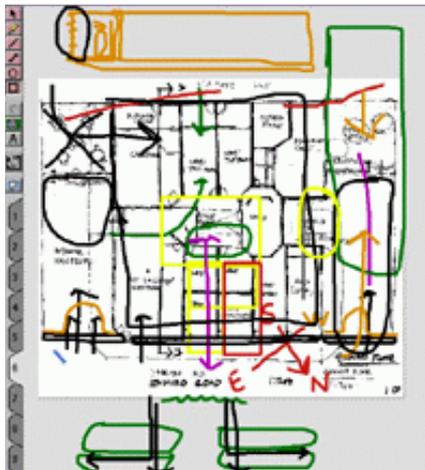
Recent studies on sharing workspaces demonstrate the complexity of introducing computers in a design session. Tang (1989; with Leifer, (1991) studied design activity in a computer supported environment in order to improve and understand the tools used during a CMC session. A framework of actions (listing, drawing, gesturing) and functions (storing information, expressing ideas, mediating interaction) is used to study the activity in the drawing space. Hand gestures, intermixing among drawing space actions and functions, spatial orientation are also considered in analysing shared workspaces. As a result, the system VideoDraw (Tang and Minneman, 1991) has been developed for supporting a collaborative activity.

Maziloglou et al. (1994) define workspace as both interpersonal space and shared workspace. The ROCOCO project investigated "the communication channel usage of product designers as a means of establishing the requirements for a computer system to support geographically separated designers". In the **first phase**, designers were observed while collaborating face-to-face, trying to negotiate a solution to the problem. In the **second**, designers where observed collaborating in an impoverished computer environment, achieved by suppressing some of the software features. As a result, designers adapted themselves to the new condition very quickly, and subsequently researchers didn't notice a significant change in design results.
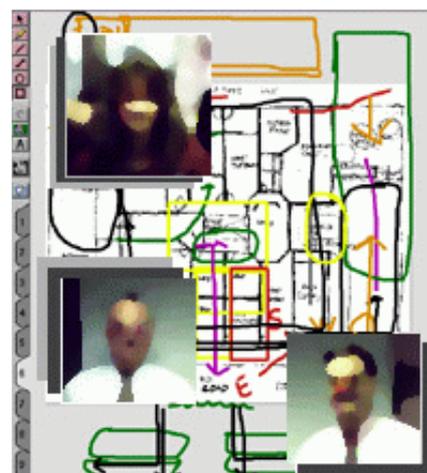
In our study of computer-mediated collaborative design we are looking for the amount and content of documented design semantics. In this way the study complements previous studies on human interaction and human computer interaction.

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