

Cicognani, Anna and Maher, Mary Lou. (1997) "Models of Collaboration for Designers in a Computer-Supported Environment." In *Third International IFIP WG5.2, Workshop on Formal Aspects of Collaborative CAD*, Conference Proceedings, Jenolan Caves, Sydney, edited by M.L. Maher, J.S. Gero, and F. Sudweeks, IFIP, KCDC, pp.99-108, 16-19 February 1997.

Models of Collaboration for Designers in a Computer Mediated Environment.

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Abstract. The development of models for Computer Mediated Collaborative Design (CMCD) provides guidelines for the continuing development of technology and tools for CMCD. In order to develop models for CMCD, a range of experiments and research objectives needs to be developed. The current literature around models for CMCD is still quite informal and descriptive. In this paper, we define the roles and types of models for CMCD. We propose a framework for understanding the contribution such models can make that considers two phenomena in CMCD: communicating and designing. We present some descriptive models from design research, CSCW research, and CMCD research and show how these models address communicating and designing.

1. Introduction

Professional design requires some level of collaboration among people involved in the project, such as the designer(s), builders (or manufacturers), and users. Computer-support for collaborative design has recently become more available to designers who are non-computer professionals. The use of electronic communication and electronically shared documentation enables collaboration to take place among professionals that are not necessarily co-located in space and time. A Computer-Supported Environment (CSE) for designers that facilitates collaboration may include:

- *Electronic mail* in which messages can be sent from one person to another (or a group of people),
- *Electronic bulletin boards* in which messages can be posted to a location accessible to others,
- *Video conferencing* which allows a group of people to see a video of the other participants while talking and possibly drawing or typing on a shared window,
- *World Wide Web (WWW) pages* that record design information and project management information,
- *Networked applications*, such as CAD, 3D modelling, Virtual Reality, with shared databases or files,
- *Multi-User Virtual Environments (MUVEs)* that provide graphics- or text-based shared environments for multiple users.

These tools compose, define and support the collaborative environment. Others can be added in order to enhance and/or support specific aspects of collaboration. However, the use of some or all of the tools described above does not necessarily *facilitate* collaborative design. A better understanding of collaboration in design can inform us in developing and providing an appropriate computer-supported environment for designers.

We propose that models of CMCD are a result of such an understanding. In general, the roles of models are:

- to provide a framework for understanding a particular phenomenon,
- to enable us to explain a particular phenomenon, and
- to enable us to predict or project onto similar phenomena in the future.

Thus models for Computer Mediated Collaborative Design (CMCD) can provide a framework for understanding

CMCD, can enable us to explain what happens during CMCD, and/or can enable us to predict how such tools and technology will facilitate CMCD in the future. The current literature that refers to models for CMCD is still quite informal and descriptive. However, in order to improve our understanding we can start with informal, descriptive models and look for ways in which the models can be made more formal.

An example of an informal descriptive model of collaboration is given by Grosz (1996) where she characterises the difference between collaborating and interacting. Grosz describes collaboration as working jointly with another person/system where interaction only requires working on something. The example given is the difference between collaborating with another person or interacting with a pen while authoring a paper. The characterisation of collaboration goes further to propose that collaboration requires both planning and acting with another, and finally, collaboration assumes that the collaborators "share" intentions and goals. Grosz (1996) proposes that collaboration must have three elements:

1. the participants must have commitment to the shared activity,
2. there must be a process for reaching an agreement on a recipe for the group action, and
3. there must be commitment to the constituent actions.

This descriptive model helps us understand CMCD and its occurrence as a phenomenon when the designers have shared goals. However, it does not inform us regarding the development of CSE that facilitates CMCD. This is reinforced by the observations of Kvan (1994; 1995): "In general excellence is achieved when the designer knows the participants and the problem well and when this leads to a shared definition of the problem with the other participants." It appears, in general, that the most supportive framework may not succeed if there is not enough commitment by the participants. (Kvan, 1994; 1995) The potential of collaborative tools in CMCD may lose relevance when applied irrespective of the familiarity of the designers and the presence or lack of shared goals.

In order to provide more focus towards models for CMCD we consider *what* can be modelled. In general a model of collaborative design in a CSE provides an abstraction of something too rich or complex to be usefully described completely. For example,

- a *process model* is an abstraction of the phenomena of collaborative design, possibly described as the design tasks followed to reach the final design;
- a *product model* in a CSE is an abstraction or computer representation of the design being developed;
- a model of the *architecture of the computer environment* is an abstraction of the CSE itself.

In this paper we look at descriptive models of collaboration in design research and CSCW, focusing primarily on process models. We propose a framework for understanding the contribution of existing and typically informal models of collaborative design in a CSE that identifies two major phenomena as: *communicating* and *designing*. The identification of these two phenomena is based on our observations from an experimental study of CMCD (Maher et al., 1996) and on our development of architectures for CMCD (Maher and Rutherford, 1996). The framework reflects the difference between the application of CSCW to a meeting where the focus is on communication and CMCD where there is a dual focus on designing and communicating.

2. Models of Collaborating Designers

Design research that focuses on process models of designers is often done using the techniques of design protocol analysis (eg. Cross et al., 1996), the "think aloud" method (Someren et al., 1994), and the "retrospective analysis" method. (Suwa and Tversky, 1996) There are two approaches to describing models of collaborating designers: quantitative and qualitative. In the quantitative approach, information is processed and selected on the basis of fundamental categories decided by the "coders". This methodology often results in a statistical analysis of the design activity as articulated by the designer. The qualitative approach selects categories of functionality through which coders can analyse results. In this approach, researchers focus their attention on the quality of the results, trying to understand the design in a broader sense of how effective a specific information was compared to others, and to the whole design results.

A qualitative description of design activity in a collaborative session is promoted by Berenton et al. (1996) while analysing the collaborative design process in the Delft Protocol Workshop:

"We took a qualitative approach focusing on describing designer interaction, rather than a quantitative approach focusing on counting design acts or design content. [...] In the quantitative approach, which is most common in design protocol analysis, the researcher develops a coding scheme that categorizes the design activity by topic and then spends the bulk of the research effort coding, quantifying and analysing the data looking for interesting patterns in graphs or informative statistics. We considered the design activity to be so rich that reducing the activity down to a set of categories without considerable qualitative analysis of the raw data would make considerable assumptions about what was important and run the risk of overlooking interesting aspects of the activity."

A qualitative model of the collaborative design process is presented by Ostwald (1995), where the collaborative process is characterised by "*action-reflection-critique*", first developed by Nakakoji and Fischer (1995) as a general model of design:

"The action-reflection-critique model is proposed as a model for collaborative design. The model synthesizes design theory with theories about how people collaborate to solve problems [...] The action-reflection-critique model calls for stakeholders to incrementally develop an understanding of design problems and potential solutions through construction of external design representations that ground communication of design intent and design critiques. [...] Design theory suggests that designers solve problems incrementally by creating explicit design representations which "talk back" to the designer, revealing new understandings of the problem. Human-human collaborative problem solving theory suggests that people construct and maintain an understanding through dialogue, in which meanings are accrued incrementally, along with evidence of what has been understood so far. The action-reflection-critique model calls for stakeholders to incrementally develop an understanding of design problems and potential solutions through construction of external design representations that ground communication of design intent and design critiques. Mutual understanding is constructed through creation, discussion and modification of design representations."

From the above, we notice that the focus in the "*action-reflection-critique*" model is on the externalisation of the design problems and potential solutions. This model fits within our framework for models of CMCD because it addresses the needs for both *designing* and *communicating*. The three stage *creation-discussion-modification* process reflects a process through which each designer develops his/her own understanding of the brief and finds support and/or critique in the collaborating group by creating explicit design representations.

Collaborative design has also been described using organisational paradigms. These paradigms describe both how information is shared, and how participants regulate and organise their behaviours in the collaborative design. Caneparo (1995) finds four different ways for participants to adapt their behaviours to a collaborative design:

1. *Hierarchy*: one member of the design group establishes the outline of the design and gives tasks to the other designers.
2. *Individual initiative*: each designer acts independently and aspects of the design are developed according to individual inclinations and talents.
3. *Participation*: the group converges on a design solution through consensus and comparison.
4. *Collaboration*: after comparison and consensus, the group goes more deeply into the agreed design solution.

This view of group design activity distinguishes collaborative design as having aspects of consensus and design development. This characterisation can be seen to fit within our framework for CMCD and indicates that collaborating designers require both facilities for communicating (in order to reach consensus) and designing (in order to develop the design further).

Aytes (1995) reports on the result of recording meetings which involve both verbal and visual communication. He finds two ways in which designers used drawings in a collaborative session:

- *action-oriented*: drawings to enhance communication
- *representation-oriented*: to improve documentation

These two purposes of drawings fit within our framework for CMCD where the action-oriented drawings provide information for communicating and the representation-oriented drawings are the results of designing.

In particular, referring to the framework for process models, the analysis of these two kinds of drawings can point out specific variables (eg. quantity/quality of accessibility related function, or personal communication) which may well be studied to support a particular activity.

3. Models of collaboration in CSCW

Much of the development of tools to support computer-mediated collaboration focuses on the general needs of people while they are holding group meetings, for purposes such as: writing, taking a strategic decision, discussing a topic, finalising a decision. Research in CSCW studies how people work together, their behaviours and results, in a Computer-Supported Environment. Both models of collaboration (how people behave and react in a CSE) and system architectures are studied by researchers in this field.

Since a major application of CSCW is the development of tools for group meetings where effective communication is the focus, it is not surprising that tools for CSCW are characterised according to two types of communication: synchronous and asynchronous:

- Synchronous communication occurs when the participants are available at the same time, eg. groupware, talk and video conferences; here information is exchanged and extended in real time and feedback is available immediately.
- Asynchronous communication occurs when the participants are available at different times, eg. email, hypermail, shared documents, World Wide Web. Asynchronous communication has the disadvantage of delayed feedback and possible noise amplification. On the other hand, it has the advantage of leaving to the participants the time management of the information sharing.

Identifying these two types of communication provides a model for the further development of CSCW. The tools for synchronous and asynchronous communication can be studied in terms of how and when they are used, and which kind of results it is possible to obtain from their use. However, this distinction is not very useful in studying the *designing* phenomenon in CMCD.

Lebie et al. (1996) comment on the difference in communication patterns in face-to-face collaboration and computer-mediated collaboration:

"although there was extensive variation among groups within a given medium, we did find some consistent patterns of behaviour for groups within each medium [...] The FTF (Face-To-Face) Groups communicate more than the CMC Groups [...] They also tend to have both proportionally and absolutely higher rates of off-task interaction, compared to CMC Groups [...] According to our perspective, the effects of the text-based communication system may hinder the groups[Otilde] ability to perform two of the three essential functions of groups: maintaining group well-being and providing effective member support. This limitation may, in the long run, have negative consequences for group members[Otilde] ability to work with one another effectively on the group[Otilde]s important task." (p.151)

This study shows that the effect of communication is important in maintaining the collaborative effort but does not address CMCD because there is no mention of the shared understanding of the goals being achieved.

Condon (1993) presents models of the control of the collaborative process in CSCW:

- *fascist*: one chairperson is always in control, having the right to decide who can use the keyboard at any one time.
- *communist*: the system is in control. Although it can only reflect the activities of other users, the system

becomes the ultimate authority.

- *anarchist*: is a "free-for-all". Each user has the capacity of controlling and modifying the system.

Condon argues that the third model, anarchist, is "the only viable model for the design of CSCW systems." He also argues that "the main problem of groupware from the point of view of the system designer [is] the lack of a clear owner." (p.176) These models of control can provide the basis for both communicating and designing in CMCD.

Sharples (1993) proposes three models of behaviour in collaboration as a basis for understanding CSCW:

- *parallel*: the collaborators all work simultaneously and send their products to each other or to an editor;
- *sequential*: the writers divide up the task into stages such that the output from one stage is handed on to the next writer in line;
- *reciprocal*: the group members work together to create the material, mutually adjusting their activities to fit the evolving documents.

These models describe how information is passed from one collaborator to another but do not distinguish between information related to communication and design documentation.

Brooke (1993) considers user interfaces and defines two main ways of using a Computer Mediated Collaborative Tool:

- "each to his own", where every participant gets a different (appropriate) access to the shared information; and
- "my way", where participants are allowed to map their preferred ways of working and sharing data.

In the first, the participants are driven by the tools, but information may be accessed and used with more order; in the second the access and use of the database is left to the users' capacity of co-operating and collaborating. This characterisation shows how a particular view, or model, of the collaborative process influences the development of the CSE.

4. Models of collaboration from Computer-Mediated Collaborative Design (CMCD) experiments

Most of the research towards understanding collaborative design conducted in CMCD attempts to both qualify and quantify some observations of CMCD. Cummings et al. (1996) found that:

"computer-mediated groups produce essays with higher integrative complexity than those of face-to-face groups [...] The greater complexity of computer-mediated groups' essays in the later weeks of the study is partly accounted for by their use of more scribes and their inclusion of more unique member ideas."

This observation comments on the effect of CMCD on the resulting design, ie on the complexity of the final product, but does not comment on the effect or effectiveness of communication during CMCD.

Gary et al. (1994; 1995) examined the communication resources that students during a CMCD process, developing a description of what is best for supporting design activities among students. This study addresses the communicating needs of designers in a CMCD, but not the designing needs.

The ROCOCO project (Maziloglou et al., 1996) 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 were 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. Again, this study focuses on the communicating aspect of CMCD and not the designing.

Maher et al. (1996) (1996) studied Computer-Mediated Collaborative Design by formulating an experiment in which two designers worked on a design problem in a two hour session using computer support for synchronous communication and shared CAD. The study comments on the relative lack of documentation of design semantics, indicating that there is little support for recording the shared understanding of the design in a CMCD.

Overall, there are few formal studies of CMCD that have led to models of collaboration. Many of the studies focus on either communication in CMCD or designing in CMCD and report on observations.

We believe that the reason of this lack lies partly in the youth of the research field, and partly on the complexity of the design analysis joint to the computer-supported environment.

5. The role of models in Computer-Mediated Collaborative Design

Models of Computer-Mediated Collaborative Design (CMCD) can be studied in order to abstract, explain and predict how designers' performances will develop a collaboration in a Computer-Supported Environment. A model of the collaborative design process in CMCD will help to develop effective models of:

- the architecture of the CSE, and
- the information available to the designers about the design project.

We propose that such models of design collaboration should include two major activities: *communicating* and *designing*. These two activities are also required in a Face-To-Face environment, only their necessity to be performed in a Computer-Supported Environment changes the levels and qualities of accessibility to information. Also, changing the nature of the collaborative tools, from FTF to computer-mediated, may change the level of familiarity and comfort of the interaction among the participants.

The two major activities, communicating and designing, are not distinct in the sense that they occur at different times, they are only distinct in the sense that they impose different requirements on a CSE. A difficulty in keeping the elements of design collaboration separated, especially in a CSE, is that people use collaborative tools in an unusual way, suppressing or enhancing some of the qualities which were designed for specific purposes, adding noise to the experiment, and sidestepping technical aspects which the researchers thought of as complementary to the collaboration. Other times, the environment itself (it could be the technological environment) introduces noise and disturbing elements, such as interruptions in the flow of information through a channel, or reduced accessibility to the tools.

Some models of the shared design workspace have been proposed in the development and use of tools for CMCD. For example, Saad and Maher (1995) propose that the shared design workspace must have four aspects:

- *information sharing* in which the representation of the design objects are shared using a language that can be understood by all the participants,
- *communication media* in which the participants in the collaborative design can communicate their intentions, planning, actions, etc.
- *process management* where the participants can determine the stage of the process and what is to be done next,
- *exploration space* in which alternatives can be proposed, trialed, changed.

We can see how each of these elements of the design space can support communicating and designing. Information sharing and exploration space provide formalisms for designing. Communication media and process management provide formalisms for communicating.

When we look at the tools that make up an environment for CMCD, we see a predominance of tools to support communicating and little to support the act of designing. Designers require tools for describing their designs as sketches and/or as proportioned and dimensioned geometric models. The confluence of tools for communicating and designing can begin to provide an environment in which CMCD can be enabled and studied.

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