Requirements for Collaborative Design in Architecture

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ABSTRACT

The concept of collaborative design has recently come under renewed attention in the field of computer aided architectural design support. Although collaborative design deals with the same aspects of cooperation by various participants in the design process as previously studied in, for example, concurrent engineering and multi-disciplinary design, it nevertheless puts a different research emphasis. Collaborative design looks at how the process can be improved in such a way that collaboration –working together in a manner to enhance each participants contribution to the design– emerges from the process. In engineering design practice, this means a shift forward in the design process where engineers are asked earlier for their input in the design solution. For CAAD research, the phenomenon of collaborative design poses the question how design tools and environments can be made in such a way that collaboration will occur. In this paper, the aims is to describe the concept of collaborative design in architecture, and to give an outline of the perceived requirements in the organisation of design and Computer Aided Design Support to achieve collaborative design.

1 INTRODUCTION

Before a design process has been completed, and the (production) drawings are finished, a great many people have participated in the process. Designers from various disciplines, engineers and experts for advisory work, and stakeholders of the building, the municipality, and finance have been involved. From the very start of design methodology research, this aspect of numerous design participants has been acknowledged: see for example the compilation of (Gregory 1966). Various approaches under differing terms have been coined to organise communication and handling of information in this complex matter, such as: participatory design, multi-disciplinary design, co-operative design, and concurrent engineering. Attention has slowly shifted from technological and organisational approaches to an overall view of the design process and the quality of design and its managerial aspects. Design management has come into existence and is beginning to mature; (Oakley 1990) presents a good inventory. Collaborative design is the understanding from the CAAD research community how to support group design processes.

2 COLLABORATIVE DESIGN AND CAAD

The support of multiple participants in a design process by means of Computer Aided Architectural Design (CAAD) software has only gradually emerged. Until recently, the focus of most commercial CAAD packages has been on the individual designer/draftsman who is working in the final phases of the design process. This focus is changing however; see for example (Aish 2000). Within the academic field of CAAD research, emphasis with respect to design support for multiple design participants for a long time has been on information exchange throughout the design process.

From the late eighties onward, universities started to establish so-called virtual design studios. CAAD software had matured as a solid production tool for making final documents. The Internet became increasingly a medium for communication between academics and students, and the first tools appeared, such as Computer Supported Cooperative Work (CSCW) environments (first conference on CSCW, see ACM 1988; for application of CSCW in architectural design, e.g. Muller 1997).

As a parallel development to CSCW in architectural design, the virtual design studios were aimed to support architectural design of distributed groups by means of communication software over dedicated connections or via the Internet. Almost without any exception, all of these studios connected two or more universities from different countries and brought students to work on design projects. The main focus therefore, was on synchronous distributed, e.g. (Maher et al. 1993), and asynchronous distributed, e.g. (Wojtowicz et al. 1993) design work (see table 1).

Arguments for establishing such studios and research usually are based on the following grounds:

- Increasing number of participants in the design process.
- Increasing complexity of design problems.
- Increasing amount of design information.
- Increasing difficulty in finding, organising, and processing design information.
- And following from these, the need to teach students to work in groups.

As computers were having a ‘ubiquitous presence’ (Khemlani and Kalay 1997) at all participants involved, computational support was thought to address these issues. Most of the expected advantages (such as better information provision and exchange, improved and faster communication, more control on complexity, etc.) were caught under the label ‘collaborative design.’

Table 1: **Four Distinctions on Location and Mode in Distributed Design**

	Synchronous	Asynchronous
Same location	Classic studio	Design teams
Distributed	Distance working	Virtual design studio

The term collaborative design was introduced almost at the same time as the first reports about virtual design studios were made. (Sasada 1994) and (van Bakergem et al. 1993) count among the earliest implementations of architectural design tools to support collaborative design. Virtual design studios and systems for supporting collaborative design have been present in research and teaching since this starting period, and have become more and more sophisticated, adding new technologies such as VRML, e.g. (Yeung 1997), rapid prototyping, e.g. (Simondetti 1999), and incorporating various tools such as annotating and sketching on shared 3D models, e.g. (Jung et al. 2001) and documentation and retrieval systems, e.g. (McCall 1999).

Experiences with these systems led to an improved understanding of collaborative design. In the beginning, collaborative design was supposed to emerge when all participants in the design process would have equally access to all sources of information on the design task. Implementations of this approach looked at the organisational nature of the design process and tried to incorporate various participants in the information exchange. Later, this changed to a more technically oriented approach, which looked at the user interface and how participants could manipulate design information. Also, various ways of presenting the design information were studied. At the moment there is again reflection on the organisation and behaviour of groups in collaborative design environments (Cheng and Kvan 2000). New goals are being set for the future development of collaborative design: development of formal and informal means and processes of communication; a new collaborative design representation concept and technique; a prototype methodology that also accommodates social factors, and more (Stellingwerff and Verbeke 2001).

Rather absent in this recent attention on collaborative design is the incorporation of the future user in the design process. As (Maver and Petric 2001) note, this so-called participatory design which has been intensively studied in the seventies and early eighties, has not found continuation in the CAAD community because of the rare use of computers in the research period of participatory design. The basic notion that the computer can greatly facilitate collaboration of the future user in the design process is still valid however. This is acknowledged by such developments as user involvement (Kokosalakis 1998), community information (Ennis and Lindsay 2001), and user preference measurements (Orzechowski 2000). However, it is important to note that the extensive body of knowledge generated in participatory design, for example in (Beheshti 1985), is not often referred in current CAAD research. In this respect, there is still a major ‘translation step’ required to accommodate these findings in collaborative design, this paper not excepted.

3 WHAT IS COLLABORATIVE DESIGN?

Most authors, who report on collaborative design and virtual design studios, note that the quality of the design process importantly influences the contribution of each

participant to the design. This aspect of quality is more important than the availability of a prescriptive method or the presence of a technical infrastructure. (Cheng and Kvan 2000) remark that advanced technological solutions sometimes even hamper good development of a design.

Many aspects of designing with multiple participants from various disciplines have already been addressed by such approaches as participatory design, multi-disciplinary design, co-operative design, and concurrent engineering. A precise definition and focus area of collaborative design is still missing. However, the nature of collaborative design can be discussed by contrasting a number of aspects: cooperative vs. collaborative, technical vs. social, Human-Computer Interface (HCI) vs. Human-Human Interface (HHI), overall view vs. partial view, bandwidth vs. content, motivation inside vs. motivation outside, and design support vs. medium.

The aspects from this list are derived from experience with collaborative design collected from many authors (mentioned above) publishing in the field. This particular summary was first made at the Euro workshop {Accolade} in Brussels (Stellingwerff and Verbeke 2001). The workshop was particularly focussed on collaborative design in architecture, and featured 29 participants from fourteen European universities and businesses.

3.1 **Cooperative versus Collaborative**

In order to handle a design problem, the problem is decomposed in parts that are easier to solve. In cooperative design, participants get such parts to solve and later integrate in partial solutions that are again integrated in a whole design. Such activities of decomposition, task assignment, and solution integration occur throughout the whole design process. In collaborative design, the participants are not strictly bound to solve assigned partial problems, but are encouraged to engage in solving design problems from other participants as well or to contribute to their design work. Providing design participants insight in the design goals and problems of other participants also stimulates this. (Maver and Petric 2001) quote research findings showing that such approaches of mutual information tend to make participants look for solutions that are also beneficial for other participants.

3.2 **Technical Versus Social**

Although the interest from the CAAD research community is very much technically oriented, it has been noted by CAAD researchers that awareness of the presence of other participants in the design medium is an important aspect of collaborative design. There are many degrees of presence possible in collaborative design environments, ranging from static and non-interactive (image or name of different person is visible), direct communication (via voice or typed text), indication of focus and action (by redlining and showing where a participant is looking to) to full representations by means of avatars in

virtual reality environments. Almost each of these categories have been implemented in (prototypical) systems of some kind: ICQ by (Mirabilis 1996); CUSeeMe by Cornell University; ClearBoard by (Ishii, Kobayashi and Grudin 1993); Immersive redliner by (Jung, Do and Gross 1999); Eduverse by Activeworlds; and Blaxxun by Blaxxun Interactive, but rarely in design environments.

Another social aspect concerns the context of the design participant (whether he or she is occupied, nature of the design context, present or absent from the workspace, what he or she is currently interested in with respect to the design, etc.) This so-called peripheral awareness of a participant (Gavin et al. 2001) is present in a synchronous-same location session, but lacking in any other time or place distributed design process. For collaborative design it seems necessary to maintain this sense of awareness of other participants.

3.3 **HCI Versus HHI**

The Human Computer Interface (HCI) is still a limiting factor when it comes to stand-alone design applications. For collaborative design however, it is more important to look how a design medium can facilitate the Human Human Interface (HHI). This applies in particular to information retrieval, sharing, and handling, as well as recording of design processes and managing design histories. It is also important how the various participants can engage one another in the design medium (what their own representation looks like, how information is afforded, how they can interact with one another).

3.4 **Overall View Versus Partial View**

In many project-supportive CAAD software, teamwork is coordinated via allocating specified parts of the design to partners in the team (by means of locking mechanisms). A person is able to work on specified parts of the design, and perhaps see the intermediate results of other participants. Results can be submitted usually only after a check of conflicts after which they are released to the final document. The lock mechanism that is currently used mostly in CAAD systems is helpful in conflict identification and resolution (Aish 2000), but it interrupts the natural flow of conversation that takes place between design participants. In collaborative design, assignment of participants to design tasks is more implicit and should not be as strictly enforced as people can give their attention to a wide variety of issues in the design problem. The participants themselves, supported implicitly by either a locking mechanism or a versatile design history management system, must solve the resulting problems of conflict resolution through the medium.

3.5 **Bandwidth Versus Content**

In the development of virtual design studios there has always been a push towards high bandwidth connections so that as much data as possible could be transferred between participants on various locations, e.g. the Texas A&M Infinity Room (Vásques de Velasco and Hutchison 1999). This facilitated for example live video feed of design participants "as if they were present". From this experience it appeared that the amount of realism of participant representation matters less than what data or information is actually exchanged and in which manner and representation. For collaborative design, careful consideration of design representations and information provision is necessary.

3.6 **Motivation Inside Versus Motivation Outside**

When design participants become motivated because of the design task (the motivation lies inside the project), then the result could get a better quality than when the motivation is more external (which can occur with strict task division). Most authors claim that this elusive point of internal motivation is the distinguishing mark of collaborative design. However, most authors fail to provide mechanisms or principles to achieve such motivation. (Cheng and Kvan 2000) as well as (Brown and Berridge 2001) suggest small exercises or starting games to make participants comfortable with the notion of collaborative design and the design environment that is being used. In general, we can state that any collaborative design environment must strive to make this commitment by design participants possible.

3.7 **Design Support Versus Design Medium**

The classic CAD system offers design support in various ways: by allowing quick drawing and modelling, by automating repetitive tasks, by simulating and evaluating design performance, etc. A collaborative design environment requires additional functionality to become useful. The aspects have been mentioned above: information retrieval, sharing, and handling, recording of design processes and managing design histories, and the way participants are present and present themselves to others. When these aspects are realised, they form more a design medium. Design support follows from using such a medium.

3.8 **A Tentative Definition of Collaborative Design**

In most of the systems described in the summary above, it seems an article of faith by the authors that something like collaborative design might occur. Generally speaking, all authors claim that collaborative design occurs when:

- There is more than one participant working on the design.
- There is an awareness of other participants in the environment.

- All participants can manipulate the design at a certain moment.
- There is information sharing possible between participants.

In the {Accolade} workshop the participants noted that technical aspects are just one aspect of a long list of characteristics. A good collaborative design process, according to participants of this workshop, consists of:

- Communication behaviour, aimed at consensus, understanding of mutual goals, and ongoing communication.
- Identification of conflict of interest between parties, aimed at identification, resolution, and understanding intention of others.
- Communication environment, supporting the processes above.

For a tentative definition of collaborative design, we can state that collaborative design is a process in which the participants work together in a meaningful way, not just working together efficiently, but stimulating each other to contribute to the design task. They act towards mutual understanding and maximizing outcomes that satisfy not only their respective goals, but also those of other participants.

From the CAAD research perspective, this means that environments need to be created that function as a medium in which collaborative design can take place. There is no full-proof method that will automatically generate collaborative design, but it is possible to identify factors that can facilitate it. In the next section, an outline of requirements for such environments is presented.

4 COLLABORATIVE DESIGN SUPPORT

In the {Accolade} workshop, five main headings for further research in collaborative design were identified. These headings identify which aspects of collaborative design need improving:

- Communication language. A better understanding of communication between design participants as well as the used (design) representations between participants (e.g. shared language, differences, knowledge of other disciplines, etc.).
- Communication environment. Technical support and structures to enable the communication language aspects (e.g. data structures, access, available communication tools, exchange of information, etc.).
- Communication behaviour. All activities of communication that enable collaborative design (e.g. effective participation, group momentum, awareness, sharing viewpoints, etc.).
- Goals and roles. Ways to understand goals and roles how to get there (e.g. goal consensus, clear goals and roles, goal and result revision, etc.).
- Education. Learn from educational experiments and apply later developed tools and concept in education (e.g. pedagogical framework, learning to collaborate).

The requirements for successful collaborative design environments can be listed more

specifically (see table 2) according to the list of aspects used in the previous section.

4.1 **Outline of a Collaborative Design Environment**

There is not one singular way in which a collaborative design environment can be developed. In this section we list some functions that a collaborative design environment should have to support the required aspects listed above. Obviously, this outline is not a definitive one, but it serves to get an impression of the necessary parts.

Table 2: **Requirements for Collaborative Design Environments**

ASPECT	REQUIREMENTS
Cooperative vs. collaborative	Make participants enjoy interaction; give them the ability to tackle all design problems
Technical vs. social	Provide (peripheral) awareness of the presence of other participants
HCI vs. HHI	Allow participants to present themselves in various manners
Overall view vs. partial view	Provide means for conflict resolution. Allow flexible and open access to the design data
Bandwidth vs. content	Provide representations of information and participants that are specific for collaborative design
Motivation inside vs. motivation outside	Make participants aware of the shared goals of the project
Design support vs. medium	Make the design environment such that it resembles more a medium than a tool (compare e.g. web browser with word processor)

A collaborative design environment can consist of the following parts:

- Workspace. An area where a participant can manipulate the design under consideration. This can be completely integrated with design software (such as what commercial packages like AutoCAD or Microstation are trying to achieve), or a more separated platform for redlining, making comments, etc. on derived documents from the design work, as in the work of for example (Jung, Do and Gross 1999, 2001).
- Storage. Relevant documents, additional data, and records of participant interaction and dialogue need to be stored and accessible through a storage facility. Documents need to be time-stamped and annotated (if possible in an automated way). (McCall 1999) gives an example of a tree-like storage of design data, as well as a means of viewing documents along a time-line.

- Communication. Multi-modal communication facilities such as speech, text, and sketching, preferably with means for conference possibility to communicate with more than one person at a time. Data exchange between modes should be quick and easy to use (examples from industry are Yahoo! Messenger by Yahoo! Inc., CUSeeMee by Cornell University, or ICQ by Mirabilis).
- History recorder. An automated means that records the chronological events in the collaborative design environment. (Hirschberg et al. 2000) and (Madrazo 2001) show such a structure for documents and objects.
- History reviewer. A tool that enables participants to browse through the history of the design project, if possible with quick search possibilities on keywords or iconic tools; (Gross 1996) provides a sketch interface for quick browsing.
- Design viewer. A tool to show all relevant documents of the design project at the current state. Such a tool is separate from the workspace functionality since it will only allow participants to overview the project, and perhaps make annotations, remarks, etc. without any editing of the project itself.
- Linkage tools. Tools for connecting the documents to other design software. This is particularly necessary when the various participants use private software to work on the design. A dynamic locking mechanism is required for access and changing parts of the design and publishing them back to the storage.
- Avatar system. Various representations to show presence of own and other participants in the collaborative design environment (many VRML-based Internet worlds such as Blaxxun and Eduverse allow easy switching of avatar).

The collaborative design environment should function in such a way that a participant who uses it is aware of the presence of other participants. This puts special emphasis on how participants can contact each other through the use of the system, and how they can keep track of each other's activities and (informal) comments and work.

The outline leaves open the question whether parts or the whole environment should use two-dimensional or three-dimensional metaphors (desktop versus virtual environment). A future scenario for a 3D environment is described in (Achten 2001). Two-dimensional approaches are also conceivable, as is demonstrated by non-permanent graphic marks in the NetDraw prototype (Qian and Gross 1999), where the marks indicate gestures by other participants.

5 ADVANCING COLLABORATION IN ENGINEERING DESIGN

Within the design community, engineers often have an advisory role. In collaborative design processes, they are expected to act earlier in the design process, when ideas are still in their formative phase. Genuine collaborative design environments that support this are not yet in existence. However, technology alone will not be enough to make this change happen. In particular, two interrelated issues need to be addressed in this manner:

- Fostering a designer's approach to the engineering task. The particular

characteristics of design problems have been acknowledged in engineering design (see introduction above). However, in the earlier design phases, these characteristics such as ill-definedness, lack of evaluation tools, poor criteria, become even more apparent. It has to be noted also, that any judgment made in such phases is well-informed at best at those moments. Therefore, the engineer's work needs to be differently appraised by the other design participants.

- Develop knowledge management for wicked problems. Knowledge structures, problem solving strategies, and knowledge representations that can deal with incomplete, inconclusive, and changing information in the design process need to be developed. Also, it has to be acknowledged that earlier on in the design process a design problem is more difficult to assess. Therefore, new levels of confidence need to be established in the professional assessment of the engineer.

With respect to this article's subject, these themes address both the content and context of the engineering practice that should be supported by a collaborative design environment.

6 CONCLUDING REMARKS

Collaborative design has become subject of study in the field of CAAD. Currently there is a predominant technological focus to achieve tools and environments that will promote collaborative design. Through the advent of virtual design studios and new techniques in ICT, numerous separate steps are taken towards such environments. Developed systems in the field highlight new possibilities that have not been conceived before in methodological/design research oriented research. However, the more managerial and method/process-oriented experiences also need to be incorporated so that both research areas can benefit from these findings. The engineering practice will probably change towards a more pro-active, design-oriented approach in which engineering knowledge is applied earlier and in the formative stages of the design process. This requires changes in design support tools, design process, and knowledge management.

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