The Global Design Studio: Proceedings of the Sixth International Conference on CAAD Futures'95, M. Tan and R. Teh (eds.), Centre for Advanced Studies in Architecture, National University of Singapore, Singapore, 1995, pages: 659-666.
This PDF version contains the same text as the published version however Figure 2 and 4 are slightly different because the original images were not accessible.

TOWARDS DISTRIBUTED COMPUTER-AIDED DESIGN ENVIRONMENTS

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Abstract.

Computing in architectural design has followed a number of different visions, hopes and research agendas. One of the dominant themes in design computing seeks to support various activities of 'individual' designers acting within a 'personal' design realm. Parallel to this is another theme which seeks to blend computing aids into normal working environments of groups of designers. The recent interest in and resurgence of collaborative design tools are steps towards what we view as an emerging theme in design computing, namely distributed design environments. This paper describes experiments in collaborative design using computers, and their observations are used to suggest future directions for integrating computing and design in distributed environments.

Keywords: design computing, collaborative work, distributed processing, design services, design products.

1 Introduction

Computing in architectural design has followed a number of different visions, hopes and research agendas. One of the dominant themes in design computing has sought ways to support various activities of 'individual' designers acting within a 'personal' design realm, one in which designs are conceived and shaped primarily by a designer's largely solitary engagement. The vision set forth in systems such as Sketchpad [16] set the agenda for this theme that has been subsequently pursued in a number of projects and developments in the field of computer-aided architectural design (CAAD). Parallel to this has evolved another theme in design computing, one which seeks ways to blend computing aids into normal working environments of groups of designers. The recent advances in computing, networking and telecommunications encourage further interest in development and application of collaborative design tools. These separate technologies arc coming together in ways that suggest new design possibilities and roles for computing, especially distributed computing in this context.

The paper is organised as follows. In the second section, selected seminal influences in the development of collaborative computing are highlighted. This is followed by a description and analysis of two collaborative design studios that we conducted recently. The third section is exploratory and attempts to redefine the scope of current design computing agenda to accommodate distributed computing environments. Further, it is suggested that such distributed design environments will increasingly support not only designers but also the products of design. Thus the term 'distributed design computing environments' is used in this paper to encompass many aspects of future design environments- from development of designs to their construction and functioning, returning some feedback for subsequent designs. The fourth section is a summary of the issues raised in this paper.

2 Increasing Reach of Computing

The current developments in computing, networking and telecommunications offer a renewed opportunity to realise group-oriented computing tools in CAAD. Significant developments in this area have originated primarily from disciplines other than design. In the following are briefly mentioned selected seminal ideas and prototype projects that led to the developments relevant to the issues addressed in this paper.

One of the earliest group-aware computing environments was described by Evans in 1969 [7]. An "automated conference room" contained four consoles with input devices oriented to four different participants. The networked computer devices were meant to be used for individual note taking, sketching, information retrieval, and this information was transmitted to the console of each participant. Subsequent developments in this direction include the projects such as 'The Media Space' at Xerox Parc [9] that evolved around the notion of design as a 'social process' and sought to embed computing tools in the normal working environments of designers (rather than moving designers to special purpose computing environments).

Such group-oriented computer supported environments were developed using the rapidly evolving infrastructure of networks. A number of early projects sought to develop networks of computers using packet switching and dedicated telephone lines for communication [2]. Although they seem rudimentary by today's standards, the early networking technologies led to functional networked design offices. For example, dial-up and dedicated leased lines linked five regional offices of Hellmuth Obata Kassabaum, USA, in 1985 [131, and provided the backbone for asynchronous collaboration.

Earlier still, before any form of computing and networking infrastructure as we recognise it today was in place, the ideas such as 'Memex' [I] articulated what was to transpire subsequently with the development of digital information infrastructure. Associative documents and repositories of information that could be freely searched and accessed have been realised in various forms.

In retrospect, it may appear that networking, associative information environments and collaborative group environments were inevitable. It also seems that much of what these early projects envisioned and developed is reaching a significant level of sophistication and acceptance. In this context, it becomes necessary to imagine possibilities that may emerge in future CAAD systems**.** Before elaborating different possibilities in Section 3, we first recap and appreciate where we are in this unfolding developments.

2.1 Collaborative Design Studios

In the context of evolution of user interface research, Grudin [8] identified the following five foci for interface development: at the hardware (I 950s), at the software (I 960-70s), at the terminal (I 970-80s), at the interaction dialogue (1980s), and at the work setting (1990s). It implies that, over the last few decades, the reach of computing has been increasing from the interaction between a machine and a single-user to encompass work settings. This is also demonstrated in collaborative design studio experiments that span time zones, geographic boundaries, and a spectrum of (a)synchronicity of collaboration. To develop a better understanding of geographically dispersed design teams working on a design project supported by collaborative software, we have initiated a series of collaborative design studios, two of which are described next.

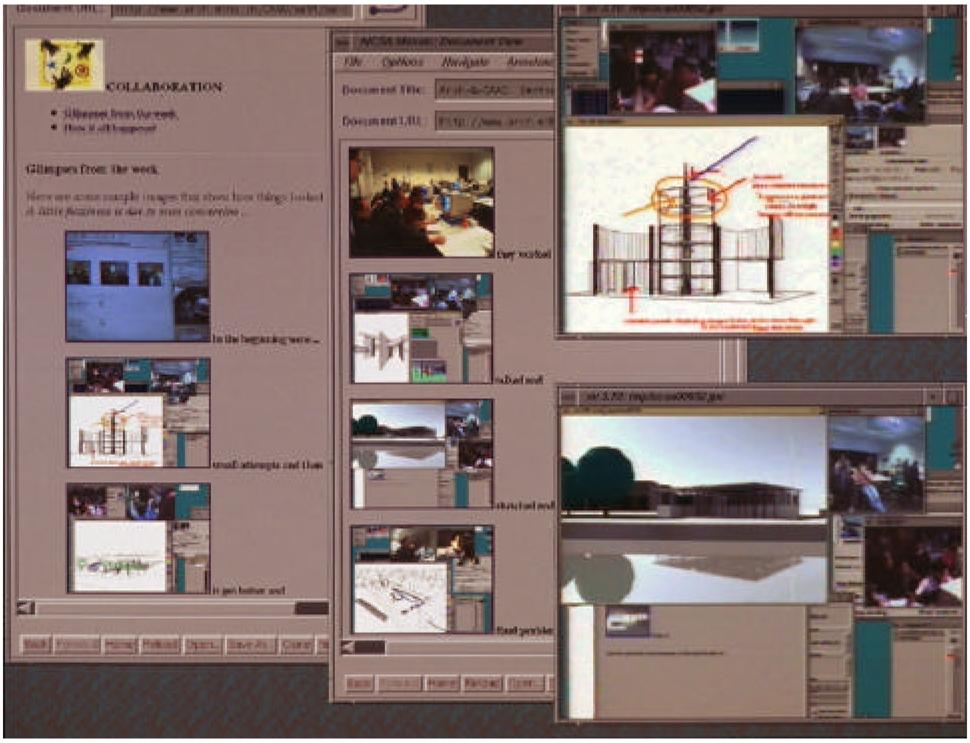

Figure 1. Snapshots of synchronous collaboration between ETH and NUS.

The first design studio involved students from the Swiss Federal Institute of Technology (ETH), Zurich, and the National University of Singapore (NUS), Singapore. The program brief called for a design proposal for an exhibition pavilion on sites in Zurich and Singapore. The students from Zurich were given a site in Singapore and the students from Singapore were given a site in Zurich. The students from ETH and NUS were teamed up, and each team was responsible for answering and providing all local contextual information to its remote partner team. The design projects from this studio (28th November- December, 1994) were documented on the World Wide Web (WWW or the Web). Daily sessions of synchronous conferencing were set up using a suite of computer software for audio and video conferencing, shared whiteboard, and the Web browsers (Figure 1). The entire process, the tools used, and the students' projects and feedback are comprehensively documented online [6].

The second design studio was set up between ETH and the University of Toronto (UT), Toronto. This studio (January- April, 1995) involved two design projects, each lasting about 8 weeks. The first project required a design proposal for an exhibition pavilion in Zurich and Ottawa, and followed a structure similar to our previous studio project with NUS. The second project- called 'Crossing', was aimed at seeking design proposals for an imaginary digital landscape. The design brief and the proposal developed by the student at ETH incorporated a digital exposition of various aspects of Switzerland. The developed design uses traditional architectonic volumes but contains sensitive black boxes which transport the visitor to digital image galleries representing selected themes of the Swiss culture. These design projects are comprehensively documented online [5].

2.2 Impressions and Issues

Unlike traditional design studios, there do not yet exist established traditions of networked design studios (other than a few references such as [18]). Under these circumstances, it becomes necessary to critically examine both the strengths and weaknesses of such studios not only in terms of the final products but also in terms of the entire process. Based on our observations of the studio experiments, in the following are described selected characteristics of networked design studios.

We noticed that the design process gets affected due to the peculiarities of given computing tools, e.g., making designs look more finished than they really are (or intended), or forcing designers to take decisions they might otherwise defer in traditional media. These problems may get inflated in networked design studios for the following reasons. First, in order to maximise the information exchange during synchronous sessions, design ideas may get articulated and presented at a faster speed than on paper. Second, if design ideas are not structured or detailed to a sufficient degree, it becomes difficult to express design intentions on the fly, especially if collaborative tools such as a shared whiteboard does not support dynamic display of three dimensional data. Consequently, a design collaboration session may get driven by what is possible within a suite of collaborative tools.

We encountered this phenomenon when students from ETH and NUS presented their design models to each other. The shared whiteboard we used supported import of Postscript plot files of a size less than 16 KB. Some students saw this as a limitation, and justifiably so. Some other students saw this as an opportunity to increase the information to byte ratio. These kinds of issues will probably become less of a hindrance in the future but they suggest that design representations get affected by the collaborative tools used and that designers need to become more expressive in using more than one representational technique (Figure 2).

There also exists a tension between the limitations imposed by a computing environment and apparently limitless amounts of information that could be generated. It occurred in our studios when students started documenting their design projects on WWW. Only a limited number of graphic formats and text layouts are presently supported in the Web pages. Some students found it difficult to conceive of balanced narratives comprising graphics and text to explain their projects. On the other hand, the possibilities for linking information came as a liberating influence from the static two dimensional restrictions of a screen layout Oust as it is also present in traditional media such as paper drawings). Even if students sometimes get carried away with either the limitations or possibilities, we think that it is a necessary learning experience. Our strategy was to show example narrative structures at the beginning of design studios which allowed an initial transition for students, and to let them subsequently explore their individual expressive styles.

A difficult issue to deal with (that arises even in single-user CAAD contexts) is that most computer based design models contain far more information than is visible at any one time on a computer screen. Static representations that mirror the techniques in traditional media such as paper provide only one way of representing such information. More dynamic ones in which three dimensional models may be developed, presented and explored- with and without the guidance of their creators, are needed for both synchronous and asynchronous collaborations. During the second studio with UT, we used tools such as CLRMosaic [10] that permit such three dimensional explorations (Figure 3 and 4) of design models including animations and links embedded on three dimensional objects.

Figure 2. Online design documentation and presentation of design proposals (Students: Mark Rosa, Andreas Vogler, Odilo Schoch).

The process of collaboration is an intriguing aspect of networked design studios. When design teams in distant locations have not met before, opportunities and means for socialisation become a necessity. In our studios, we made time and space available for such activities. During the initial synchronous sessions, students introduced themselves to each other and then were encouraged to talk their way through whatever interested them without any kind of prepared scripts. Gradually, they developed a rhythm of conversation and made wish-lists of information to be asked and delivered for the subsequent synchronous sessions. This process is very crucial for networked design studios as all participants need to feel a sense of interdependence which can only come about if they develop a sense of working together as a social group.

Sometimes communication and exchange of design ideas became problematic during synchronous collaboration when students switched to a wrong conceptual model of their actions. For example, quite often students tended to forget that software applications are not gaze-directed but need an explicit action such as a mouse click to change focus of input/output pipeline. When this was forgotten during conversations, all user input/output was directed to the wrong window.

At other times, the participants used elaborate body gestures, e.g., movement of hands and fingers, facial expressions, shifting in their seats, etc., just as they would during face-to-face meetings in a group. Some learning time is required to appreciate that finger pointing to some region on one screen is not visible on the other end, that video camera resolution may not pick out a raised eyebrow, that a smile may get transmitted and received at the other end after a lapse of some seconds, or that window sizes and their locations for a shared application on both ends may not be identical. These issues lead to situations in which some gestures get transmitted which were not intended, whereas some subtle gestures go unnoticed.

The online conversations took place initially as bursts of exchanges and then became smoother and flowing. This may be due to the fact that audio connections, introduce some lapse of seconds in signals between senders and receivers. Besides, all the participants have a different rhythm of conversation; some react immediately, some take time before responding, some others suggest their presence with brief confirmations. These patterns are similar to how they happen in telephonic conversations and it is better to let the group develop its own conversational rhythm. The only time some restraint in conversations was suggested was while making humorous remarks since humour from one culture does not always travel well to another culture.

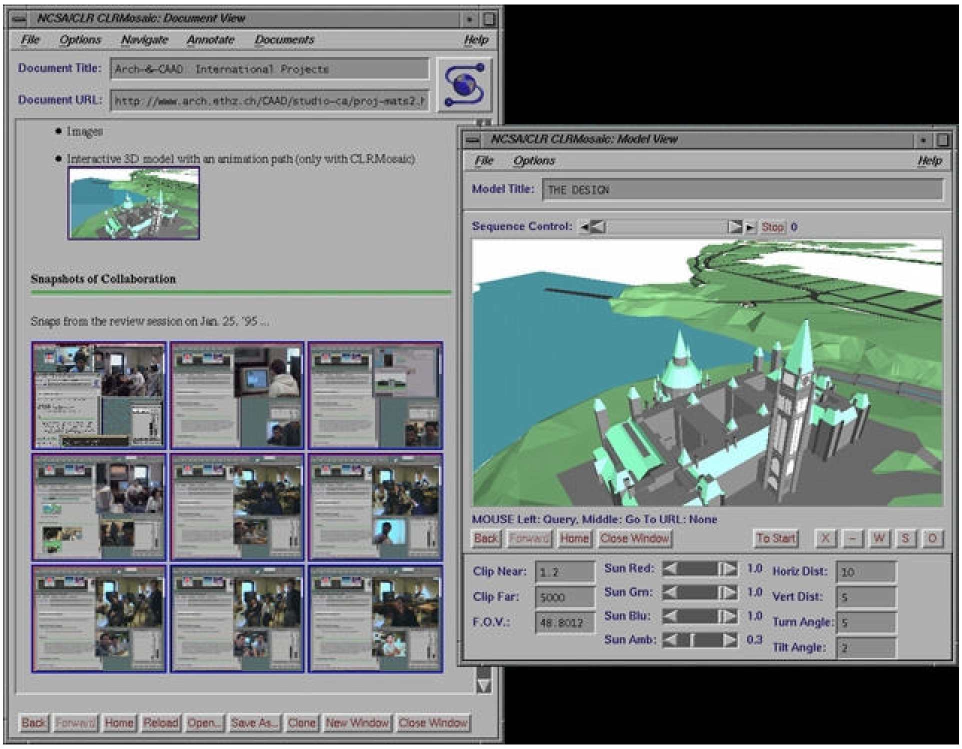

Figure 3. Online design documentation and exploration of design proposals using 3D models (Student: Matthias Leuzinger).

At one time or another, most participants felt insecure about whether their collaborators actually received and understood the information that was transmitted. Quite often, they asked each other for a confirmation in many different ways. This has an important implication for interface developers and collaborative software designers. A participant's own actions as well as actions of others should become transparently visible as much as possible otherwise much bandwidth is expended in simply acknowledging each other’s actions.

Finally, the design projects developed by students (Figure 2, 3, 4) are qualitatively acceptable given the time frame and the computing environment in which they were produced. One measure of this is, of course, the projects as documented and presented. Another measure is the kind and number of design related questions it generates from the distant collaborators. In this regard, we were quite fortunate in having good students in both studios who repeatedly attempted to bring back the conversation to design issues from the supporting technological issues.

Our experiences from both these studios suggest that networked studios are a good vehicle to educate the next generation of designers as well to develop tools that are appropriate for distant collaborating design teams.

3 Distributed Design Environments

As the technologies to support group work mature, a new set of circumstances and opportunities arises for research and applications in design disciplines. Collaborative design settings of the kind described in the previous section still need further refinement of collaborative tools. Solutions from data (de)compression and transmission techniques will add a degree of refinement to these tools. Other issues in collaborative tools such as control, concurrency, knowledge modeling, negotiation modeling, and emergence of shared understanding, offer additional opportunities [15] [41 for future work. But the following propositions are aimed at viewing and extending the scope of collaborative computing technologies from a different angle.

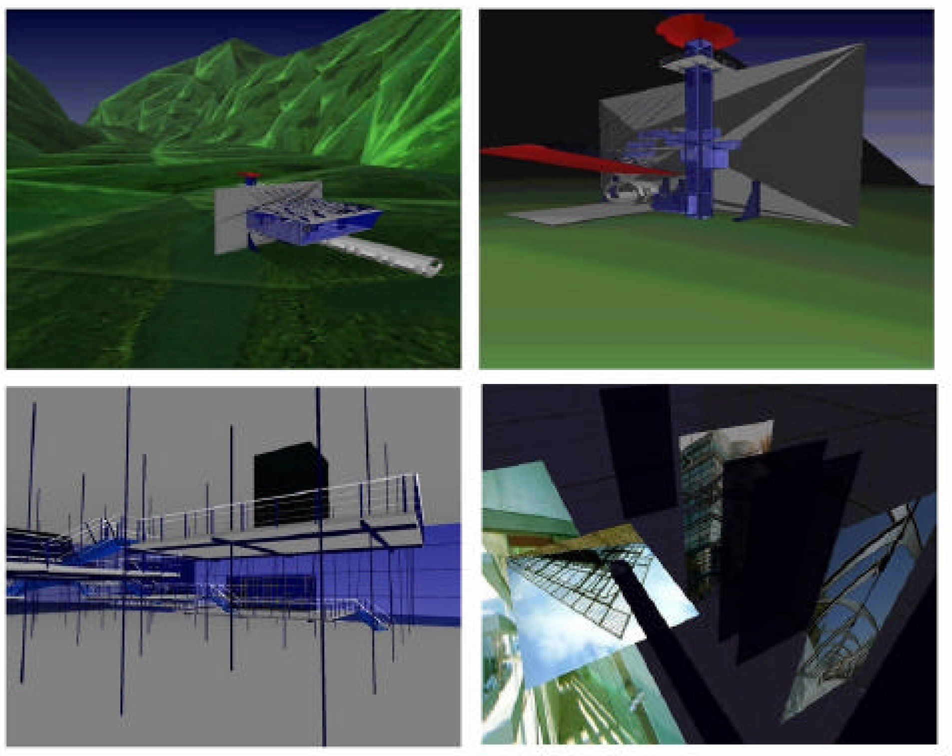

Figure 4. Online exploration of 3D design models, the darker lines represent links to models, images, and other digital data (Student: David Mizrahi).

The current developments in computing, networks and telecommunications bear out Grudin's observation that computers are reaching out into the social and work environments. In fact, if the pace of developments continues at the current rates, the notion of 'ubiquitous computing' [171 will come to fruition. It suggests that microprocessors become so pervasive and numerous that they blend into day-to- living and working environments, and more importantly they will be able to communicate with each other. Since the factors affecting and driving future developments in these areas are diverse and diffused, at best we can suggest an emerging pattern of a class of new design problems and solutions. Briefly described, these developments will affect not only the process of design but also the very products that result from design activities and that a new kind of design environment will emerge that is truly distributed in nature. The following are some of the first signs of this emergent environment.

1. Integration of computing and networks in design offices is happening at an increasing rate. What is more that it connects design services with other professionals and services thus effectively increasing the geographic reach for offering their individual and combined services. The global networking connectivity thus puts the pressure on regional design offices to compete at scales that are no longer regional. For example, one study recommends the formation of 'virtual organisation structure' for engineering services in Scotland [14]. The recommendation is based on identification of comparable skilled services that could be obtained in different parts of the world while taking advantage of disparities in earnings between various locations.

2. A relatively simple addressing scheme now puts users on the Internet in touch with information that is available online. The Web browsers enable not only creation of new information delivery services such as digital libraries but they also shed many intermediaries that are traditionally involved in storing, distributing and accessing information.

3. Another manifestation of information and skills delivery services visible on networks is what could be termed 'algorithm servers'. In essence, they offer highly specialised information processing tasks that are long associated with either in-house or in-the-neighbourhood services. Examples of such information processing nodes on the Web are: drawing scanning and conversion, rendering, animation, documentation of projects and slides making, product brochures distribution, and others. One may ponder the quality of results but there are sites on the Web that offer custom-built house plans complete with their materials specifications. Perhaps one

day there will be shape grammar servers and plan generators accessible on the networks, and more exploration they support, more usable they will become. After all, if network bandwidth and processing capacities keep rising, it won't matter if design teaching and practice are carried out using a local computer or the one miles away.

4. Home automation products industry is steadily growing, offering automated products and controls for lighting, ventilation, security, heating, electrical, entertainment and other building subsystems. Due to the emerging standards and protocols such as X10 greater ease of operation and affordability of such diverse products working in tandem with home computers are to be expected. The projects such as the TRON House [11], comprising of many computerised distributed components controlled by a Real Time Operating System Nucleus, are indicative of such developments.

5. The rate at which the number of work-related telecommuters is growing in U.S. is estimated at about 20%, currently at about 3 million [12]. Networks and computing make these new living and working patterns possible. Once in place, they make possible smaller office spaces, which in turn cut down costs on building investment and maintenance. A few signs of future working environment are already visible in 'virtual office' projects [3]. The one striking feature of such projects is an integration of networking and computing technologies with design expressions. They indicate that new technologies are disappearing into the building fabric and that the new spatial patterns of design and usage are evolving governed by these technologies.

The selected indicative patterns described above suggest that, on the one hand, at least certain classes of building designs are undergoing changes, and that many of their components have micro-processors in and around them. On the other hand, design practice too is changing with professionals who have an opportunity to design and explore designs using information and skills that may be beyond their immediate surroundings. In other words, design processes, designers, design descriptions, manufacture and construction of design products, and their maintenance- they all are becoming more distributed in nature, and increasingly rely upon computing and networking technologies. A new class of designs and designers need tending in such a context.

These observations lead to implications (possibly different ones depending on an individual frame of reference) for educators, researchers and practitioners alike. To us, it suggests that so far much effort has been invested in CAAD in focusing on and supporting a designer (leading to significant results) but too little effort has been invested in shaping the products of designs that are rapidly changing. It follows then that new design expressions and computing tools both need to be developed that address the needs of electronic workgroups of designers, and that perhaps we need also to imagine designs and computing tools that are not measured in terms of designs of the decades past.

4 Summary

Based on collaborative design studios of varying duration, a number of issues that need to be addressed in future collaborative computing environments were highlighted. Further, it is suggested that while there are likely to be measurable advances in improving (a)synchronous data exchange and throughput, new research and development opportunities now arise in developing computing responses to spatial designs that arc themselves manifestations of as well as supported by distributed computing and networking technologies.

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Acknowledgements

For the collaborative studio experiments, thanks are due to all the participating students in Zurich, Singapore and Toronto. And special thanks to the colleagues, in Zurich: Gerhard Schmitt and Eric van der Mark; in Singapore: Milton Tan and Sambit Datta; and in Toronto: John Danahy and Rodney Hoinkes.