MultiDCD Visual, an Asynchronous Visualization System for Managing the Debate of Ideas in Remote Collaboration

Alvaro Bonfiglio*¹ and Akira Fujii²

¹ Associate Professor, School of Architecture, University of the Republic, Uruguay
² Professor, Institute of Industrial Science, University of Tokyo, Japan

Abstract
Globalization of architectural practices and fragmentation of knowledge are driving contemporary design studios to work within a dislocated net of partners. Consequently, the main point for successful remote collaboration is the understanding of team dynamics. During the first stages of a design activity, team members work, discuss and communicate multiple proposals in a dynamic and unclear way. Available software for teamwork assistance is focused on real time sessions, following the approach used for Product Development. However, remote collaboration in architectural design requires a specific approach supported by asynchronous collaborative visualization tools. This paper presents the Multi-dimensional Collaborative Debate Visualizer (MultiDCD Visual), a client-server system for managing the flow of information in geographically distributed design teams. The system constructs a multi-dimensional model of the evolution of the design activity, allowing users to intuitively understand the debate of ideas.

Keywords: remote collaboration; asynchronic design; visualization; virtual reality

1. Introduction
1.1 Research Interest
Research into Remote Collaboration and Virtual Design Studios has been focused in synchronic tools since it began to be considered in the early 90’s (Wojtowicz et al. 1992). And over the years there have been many examples of successful real time collaborative work (Maher et al. 2000, Kalisperis et al. 2002, Hirschberg 2002, etc.) However, face-to-face contact among designers is just one part of the design activity, while the main workload is managed outside real time design sessions (Morozumi and Homma 2004.) Design teams produce most of the data and information locally and then distribute it via the Internet. Although Project Specific Web Pages and similar collaboration tools are being increasingly adopted by architectural practices, comprehensive research in collaborative environments is coming mainly from product design (Shen et al. 2008) and recent research in asynchronic collaborative visualization tools is being developed by Information Technology scholars (Heer and Agrawala 2007).

Software available on the market for remote collaboration in Architecture, Engineering and Construction (AEC) is basically oriented towards Value Engineering and targeted for the stages of Design Development or Construction. Therefore, it is used for finding the most economic solution to construction problems, rather than exploring broader design options.

In this paper the authors discuss and propose a structure for remote collaboration in architectural design through the presentation of an asynchronous visualization system for managing the flow of ideas in geographically distributed teams.

1.2 Methodology and research environment
The software presented here is based on the outcome of several design workshops conducted both in test-oriented and real-life scenarios. International competitions and distant teaching/learning exercises are the selected fields of this research, which is focused on the early stages of the design process. Evaluation questionnaires and written interviews were the primary sources of information.

During 2004 and 2005 two distributed design teams and one distant teaching/learning workshop were closely monitored. The design teams worked on the Ford Calumet Environmental Center International Competition, in Chicago, USA, and the ThyssenKrupp Architectural Prize, in Zaragoza, Spain. The distant teaching/learning exercise was called Virtual-Real Time and was conducted between Uruguay and Japan.

The monitoring of the flow of information among designers showed a series of shortcomings in the used software. In order to overcome these problems the authors developed the Multidimensional Collaborative
Debate Visualizer (MultiDCD Visual), an asynchronic system for managing the flow of information in geographically distributed design teams. The system was developed in two stages: first an alpha-version based on the exchange and comment of image files, and subsequently a more flexible and complete beta-version, which is presented here. This version was tested and fine-tuned in two exercises conducted in 2006; one was a professional workshop and the other was a distant teaching/learning exercise. The outline of these exercises and their evaluation are presented later in this paper.

Additional insight to the research problem was gathered from previous collaborative experiences in curricular exchanges between the University of Buenos Aires and the University of the Republic – Uruguay, and also during hands-on experiences at a Japanese design practice.

1.3 Article structure

The next section, chapter 2, presents the theoretical framework that supports this research: the general approach to the design process and the concept of object-oriented communication. Chapter 3 explains the details of the software architecture and chapter 4 deals with its key features. Chapter 5 shows the implementation of the system, describing interfaces and functionalities. Chapter 6 outlines the results of the use of the system; and finally, chapters 7 and 8 present conclusions and future lines of research.

2. Theoretical Framework

The present study is focused on the collaborative work of design teams distributed around the world. When team members are scattered across various time zones, only a narrow time frame is available for synchronic meetings and discussions. Therefore, asynchronic communication systems should supply a general understanding of the design process, providing the common ground and awareness of the team activity. Remote collaboration shifts the balance of information pooling from real-time tools towards more inclusive and stronger asynchronic communication environments.

2.1 General approach to the Design Process

One of the most important issues considered in this work is the avoidance of imposing limitations on creativity. For this reason, the study is based on a systematic approach to the design process defined by Morris (1997), which presents a structure for regulating the design activity without constraining innovation in the first stages or even during construction. Morris suggests the coordination of project reviews with all the stakeholders, in which the design objectives and future steps are discussed and agreed upon. In this way, the target of the meetings is switched from reducing costs (Value Engineering) to creating value (Value Management). The general schema is displayed in Fig.1.

In Remote Collaboration, real time communication tools support value management meetings, while asynchronic tools carry the whole process. Critical decision moments are limited and scheduled as far in advance as possible, allowing participants to gather the distributed information required for decision-making. Good information distribution avoids biased group decision-making (Stasser 1985).

Remote collaborative architectural projects entail several organization challenges. Usually, they are characterized by an unclear team structure that makes work division and effort allocation more difficult. However, a loose team configuration can be considered a positive characteristic, as overlapping responsibilities create a shared object or vision of the project (Buntrock 2001).

2.2 Object oriented communication

Activity Theory, as presented by Tuikka (2002) establishes the particular characteristics of communicative actions during the design process. Communication plays a very important role in collaborative work. It is a tool used by subjects (the designers) to perform an activity towards a shared object (the objective of design). Following the theory, communication does not come after a design is finished, but is a structural component of the design activity.

The shared object, however, is built in an iterative process that involves a multiplicity of design options, which are contrasted and discussed, and later discarded or accepted for further development or synthesis. The objective of the design activity is not one idea that evolves through time, but an array of design ideas that suffer a process of selection and adaptation. The object of the activity is transformed into a new tool during the process, as presented in Fig.2.
When designers produce an object, it usually becomes a tool for the next step: a new tool for a new object. This can be understood for example when the Outline Design is finished and architects face the Final Sketch Plan. Here the Outline becomes a reference tool for a new object. During the first stages of design the same sequence is verified in an unclear way when numerous options are considered simultaneously. Therefore, asynchronic collaborative tools have to support the creation and distribution of object-oriented messages. Design proposals are usually informed by sets of files of different formats, but they are to be managed as units of communication delivered inside a specific background by a particular user, in order to provide a context-aware interaction among designers.

3. System Architecture

The proposed tool is organized in a simple and easy to maintain two-tier structure. A dedicated server-based database managing system (DBMS) is remotely accessed over the Internet by client-run software through queries directed by uniform resource locators (URLs). An Oracle9i relational DBMS was selected as the most suitable for this development, based on its availability (under OTN Developer License terms) and reliability.

The application is built entirely in Java using Java Development Kits 1.4.2 and 5.0. The queries to the database are written in SQL embedded in the Java code. Also, the Java3D 1.3 API is extensively used for rendering 3D virtual environments. Although an OpenGL implementation of Java3D offered better cross-platform capabilities, a DirectX implementation was selected due to better hardware support. Java is by definition a platform-independent environment, but the system is designed for Microsoft Windows.

Java3D scenes have high memory requirements and the Java Virtual Machine (JVM) needs 128 MB of allocated space. For acceptable performances, client machines should have main processors running at 512 MHz or faster. Internet traffic and security are managed by the implementation of an Oracle Net client by the Thin driver.

The software was developed as a standalone application to work around security restrictions that affect applets. However, client and server are connected over TCP/IP using the Oracle Java Database Connectivity Thin driver (a pure Java driver that supports downloadable applets) in order to deploy future releases inside web pages.
4. Design Characteristics of MultiDCD Visual

Collaborative visualization systems present a wide variety of design challenges to solve (Heer and Agrawala 2007). The design of MultiDCD Visual specifically addresses issues that affect distributed teamwork in architectural projects: division of work; collaboration model; discussion and awareness; engagement; identity; and decision-making.

Design recommendations for those issues are reviewed and prototyped in the following key characteristics:

1- Modularization of work: The system supports a wide variety of contributions of diverse granularity (amount of effort involved in performing the task): from simply participating in the criticism of an idea by introducing a text string (a fine-grained task) to the most complex uploading of an original set of files (a coarse-grained task)

2- Sensemaking model: A content-based 3D model of the design collaboration that facilitates information foraging (looking for specific data), information schematization and problem solving. Also, it permits social navigation and the identification of trends or areas of interest by displaying traces of the users' activities.

   Image previews and data-class labels simplify information foraging. The class system is the base for the construction of a non-biased 3D diagram of the information available. Distribution of existing information is considered fundamental to group decision-making.

3- Discussion: The first stages of architectural design are commonly based in imagery. Thus, discussion threads are placed directly within the images and sets of files. This embedded discussion model provides a good basis for establishing common ground among the users, facilitating mutual understanding.

4- Awareness: Users' actions are historically arranged and visually traceable. Every participant can follow the latest development of a project and decide what to do next.

5- Engagement: A highly visual, highly interactive, intuitive and game-like animated environment is built to encourage user participation.

6- Representation: Users' identification is fully supported by color-coded avatars, flags and activity traces.

7- Decision-making: The outcome of a design task is generally open-ended. The visualization system provides a series of milestones throughout the design process, establishing a natural structure without constraining the evolution of the activity.

5. System Implementation

A virtual model of the design collaboration is displayed in a 3D browser as a three-dimensional diagram (Fig.3.). Spheres represent users and their movements are shown by colored traces. Mapped cubes represent packs of data (ArchiPacks) and they are flagged and labeled following the same color-based identification principle. The background of the diagram shows general reference information about the relative position of packs and avatars. For example, a timeline axis presents the information about the workflow. Besides chronological information, the timeline also shows records and reports of the decision-making process. Users with upper-level privileges can post milestones (tagged as "Decision Point") containing minutes from meetings, general comments to the design or any written communication that affects the design process.

The composition of the virtual model avoids complex configurations and presents a clean and minimal interface. While filters control the amount of displayed information, the data itself is available through functions triggered by pointing directly to the elements of the model. Mouse-enabled navigation tools (zoom, pan and orbit) control the movements inside the 3D browser.

On avatars, left-clicks (principal click) display associated text comments, and right-clicks (secondary) launch a menu-based interface for uploading files, broadcasting comments, and, if the user has upper-level privileges, the menu also includes manager options for decision-making and scalability.

The avatar takes a new position every time the user makes comments on an existing ArchiPack or uploads a new one, drawing a line from the previous position. In this way it is possible to trace the actions of the different participants intuitively, simply by following a line.

Users build ArchiPacks by interacting with their own avatar. A right-click launches a utility menu that connects to the ArchiPack-Maker interface (Fig.4.). This interface assists users with the uploading of files to selected faces on a cube. Therefore, an ArchiPack can contain up to six different files in any desired configuration. The system accepts any kind of file, although it exclusively generates previews from image files. A secondary application helps with the creation of red marked areas and comments directly on the file. In this way, team members are able to compose and share very complex design ideas in a succinct and simple way.

The process of uploading an ArchiPack implements the collaboration debate algorithm (CD algorithm), which is partially controlled by the user as part of the information schematization tasks.

 Packs are sorted in x by the name of the idea (IDEAS) and in y by Level of Detail (L_O_D) following the CD algorithm as shown in Fig.5. A design idea A1 undergoes a reproduction (movement on z-axis) every time a user performs an action on it. Discussing or making comments about an idea simply moves the pack to a new date along the z-axis, keeping the previous alignment because the contained information...
remains unchanged. If the action consists of developing the existing idea towards a new level of detail, it is considered a crossover (the core information is basically maintained) and the new proposal moves along the y-axis to A2. But, if the new idea is qualitatively different, it will be a mutation (new core information is produced) and the idea moves along the x-axis to B1.

The information contained in Archi Packs can be visualized by orbiting around them with the navigation tools or by turning them automatically by clicking on the desired face as shown in Fig.6. Also, a right-click opens a sub-menu for making comments about the pack or downloading the associated files, and a left-click on the front face displays comments associated with red-marked areas.

Fig.4. The Construction of an ArchiPack from a Right-click on the Avatar

Fig.5. The Collaboration Debate Algorithm (CD Algorithm)
6. System Test & Evaluation

Design exercises in two different environments were proposed for evaluating the system. Architects and engineers participated in the first workshop (W1-Professional), and students and professors developed the second workshop (W2-Academic), a distant teaching exercise.

The theme for both exercises was the design of a networked series of tele-contemplation pavilions. The theme presented the following questions: "In times of mobile networks, Java computer language, Google and Wikipedia, is it possible to reflect about our cities and their connections? How do these connections affect our cities? How do they affect us?"

The proposed buildings would be nodes of a net of pavilions located in several cities around the world. They would have interfaces connected in real time, showing other cities and other realities. The motto for these pavilions would be cyber-contemplation.

The first workshop took 3 weeks in total, from February to March 2006, and it included one week for testing the software before launching the exercise. Three architects and one engineer integrated a team distributed in Japan, Spain and the Netherlands.

The exercise simply allowed designers to broadcast some original ideas. However, comments and discussions developed as expected, as shown in Fig.8. between the user identified by the red color and the one identified by the green color. In this case, the discussion is centered on the access to the pavilion and its general mass.

The test W2-Academic was a distant teaching workshop and it took two weeks, from May to June 2006. One instructor and four students from Uruguay and one instructor from Japan participated in the exercise.

Fig.9. shows the participants activity patterns. The exercise evolves in time from right to left. An instructor (red) follows a very crooked path, making comments and discussing every idea proposed by the students. In contrast, students follow a simpler pattern, focused on the development of their own idea.

The use of MultiDCD Visual generated a very vivid environment for the exchange of design ideas. At the beginning, it was occasionally complemented by synchronous communication, mainly chat, but as users got used to the system (and students did it faster than professionals) it became the core support for the design process.

After the workshops the participants received a brief questionnaire (Fig.7.). The questions targeted three main topics: general impression of the virtual environment, ease of use of the new tools, and quality of the information exchange.

Considering that almost every participant had previous experience with three-dimensional modeling, it was expected that they would be comfortable with the virtual environment. In the same way, the general dynamics of ArchiPacks and avatars were easy to follow with the provided navigation tools.

Filtering was a utility not extensively used, and it did not help participants for speeding up connections to the
In future releases, either a better approach to connection capabilities or a clearer design of the utility should be addressed.

In general, the use of the system and the display of information were considered fine. The time required for understanding the new tools was appropriate, and the functions for marking-up, file exchange, and accountability of the process were also positively evaluated.

7. Conclusions

MultiDCD Visual was developed in order to supply a necessary asynchronous visualization computational tool for virtual design studios. The software manages the presentation of the design-related data, allowing users to have a knowledge-based approach to the flow of information.

Modules of design information (ArchiPacks) constitute the basic units of communication. A series of applications for marking-up and grouping files assist the user during data uploading, simplifying the construction of packs. Then, the ArchiPacks are presented in a shared three-dimensional environment where the dynamics of collaboration take place.
The system allows users with manager privileges to introduce new participants at any time, following the growing complexity of any architectural project.

A genetic algorithm sorts the Archipacks in a simple and intuitive arrangement. Packs are located along the x-axis according to the name of the idea or folder created by the user. Its y-value, the Level of Detail is automatically assigned in relation to the number of previous uploads, and its z-value follows the timeline of the project.

Two different workshops tested the performance and adaptability of the software. The first test was a professional design activity, and the second was a distant-teaching exercise. The software was positively evaluated in almost every considered point. The navigation tools were considered useful as well as the structure of the elements presented in the shared environment. Also, there was good acceptance of the tools for uploading and downloading information. However, the Filters utility had some negative reception, which requires attention in future developments.

In sum, the decision-making process within a distributed team is enhanced by better information pooling inside this integrated environment. The visual representation of the debate of ideas unveils the internal logic of the process, simplifying its comprehension.

8. Further Research

During the testing period some of the scalability attributes were not used. In particular, the possibility of managing multiple design parameters was not launched, due to the limited amount of time allocated for the proposed workshops. Besides the default parameters IDEAS and L_O_D, new dimensions for the x and y can be created at any moment. Basically, these dimensions can be of two types: numerical and qualitative. Usually useful for comparisons, numerical dimensions are for example Cost, Area, Strength Resistance or any other characteristic that may be expressed by numbers. Qualitative dimensions could be Location, Material or any other feature that is typically indicated by a name. By assigning different dimensions to each axis it is possible to retrieve a graphic representation of particular aspects of the project evolving over time, for example the evolution of area allocated in relation to site, or the evolution of cost in relation to air-conditioned volume.

Future versions of the MultiDCD Visual will address techniques for speeding up connection time and utilities for presenting and marking-up three-dimensional models. In addition, the integration of real-time (and band-consuming) communication gadgets is another line for future work.

Acknowledgements

This research was funded by the Ministry of Education, Culture, Sports, Science and Technology of Japan, and conducted at the Institute of Industrial Science, University of Tokyo.

Part of the background research was co-funded by the University of the Republic - Uruguay, Commission of Education (Comisión Sectorial de Enseñanza - CSE). Special thanks to Salvador Schelotto, Eduardo Ramos Barañano and Marcelo Payssé from the University of the Republic, Uruguay.

References