Virtual Reality Meets Telematics: Design and Development of the Infinity Room

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The paper presents the findings of three years of experimentation in the use of compressed videoconferencing in international virtual design studios. Based on these findings, the authors elaborate on the development of a new videoconferencing interface: "The Infinity Room".

The Infinity Room is a design studio space containing a floor-to-ceiling rear projection screen wall that conceals a dark room equipped with 5 video cameras and 4 video projectors that reproduce, on one-to-one scale, the images captured in a similar installation at a remote location. Operationally, the video cameras feed a computer that eliminate image redundancies, codes all the sources into a single entity and sends it as a compressed video signal to a remote computer that decodes and decompresses the images for synchronized delivery through the video projectors. The tiling effect of 4 synchronized and fully interactive video images creates the illusion of an adjacent room.

The paper describes the design parameters used in the development of the Infinity Room and elaborates on the technology that makes it feasible. Requirements and constraints on physical space, hardware, software, and networking are discussed. The paper ends with conclusions that highlight the technical feasibility of building a small-scale prototype.

Keywords: *Virtual Design Studio (VDS), Virtual Reality (VR), Telematics, Videoconferencing, Collaborative Design.*

Background

Motivated by a trend towards the globalization of many design and development activities in the building industry (Holland, 1998), the College of Architecture at Texas A&M University has been implementing a sequence of international virtual design studios. The Tex-Mex Virtual Design Studio and the Las Americas Virtual Design Studio have offered valuable opportunities for research on the use and development of technologies that can better support international collaborative design activities (Vasquez de Velasco, 1998a, b). In this paper we briefly present our experience on the use of videoconferencing interfaces as background on the design of a new interface environment.

The Tex-Mex Virtual Design Studio was initially implemented during the fall of 1996 and offered without interruption until the fall of 1998. Every fall semester, a group of American students in Texas and a group of Mexican students in Mexico City worked together in the design of a project in Mexico. As an

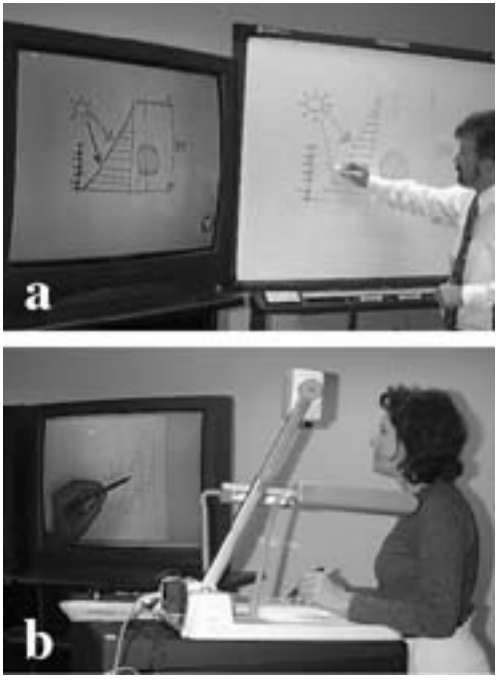

Figure 1 (right). (a) In Electronic White-Boarding the expressiveness of body language and hand motion is replaced by a cursor in the image that is transmitted. (b) The use of document cameras permits the transmission of hand expressiveness at the time of explaining a project.

alternative, during spring semester, a group of American students worked on the design of a building in Mexico under the supervision of 4 design instructors in Mexico (Vasquez de Velasco, 1997a, b).

In every case, the students were required to establish a web site in which an updated version of their project had to be displayed at all times. In addition to this, at least 5 times during the semester, all the students and instructors of the virtual studio participated in virtual reviews of the projects. The virtual reviews were mediated by room-to-room compressed videoconferencing technology. The network line linking the two videoconferencing sites was a dedicated T1 line offering a transfer speed of 1.5Mbps. In such a context the students made use of a variety of communication interfaces. We can divide these interfaces into three main categories:

a) Cursor-Driven Interfaces:
In this category we can place the use of Electronic White-Boarding and Electronic Project Presentations. In the case of Electronic White-Boarding the image that is transmitted is a blank drafting space supported by very basic raster editing functions (Figure 1a). The students and/or instructors can interact in real-time over the same drawing field making use of the raster editor. Each user is identified by cursors of different color. In the case of Electronic Project Presentations the image that is transmitted is a computer window in which the students can display project images and interact with them using CAD programs, presentation programs, and/or web browsers. In both cases, the users (the student and/or reviewer) are represented by cursors on the screen.

b) Hand-Driven Interfaces:
In this category we can address the use of the document camera. The document camera is a high-resolution video camera mounted on top of a small format document display table (Figure 1b). In this case the students will print their CAD files in small format documents and place them under the lens of the document camera. As a result they can transmit the image of their document (i.e. a floor plan) and talk at the same time that their hands move over the surface of the graphic. In some cases the student will hold a pencil as he/she explains the project and will continue to draw on top of the image adding still more information to the design. Interaction between student and reviewer does not happen on top of the same drawing field. In some cases the instructor has followed the presentation with a hard copy of the same document (downloaded from the web page of the student's project), and can produce a crit by drawing on top of his/her own hard copy.

c) Body-Driven Interfaces
In this category we can place the use of Smart-Boarding and Video Feedback. In the case of Smart-Boarding the image that is transmitted is a room view in which the student stands in front of a large-format touch-sensitive Electronic White-Board and interacts

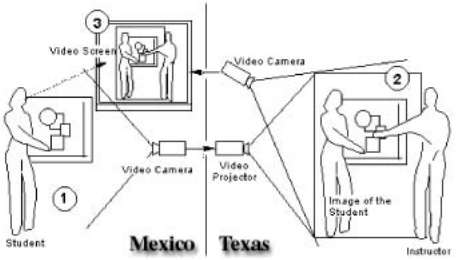

Figure 2 (left). Video Feedback as experienced in the Tex-Mex Virtual Design Studio.

with a raster editor or presentation programs. The most common case has been the display of project web sites but it is also possible to display an AutoCad file and even interact with a remote user that will be represented by a cursor. In the case of Video Feedback, the image of a student presenting a project with a Smart-Board is projected on scale one-on-one at the remote location where the instructor can approach the projection screen and interact with the image that is projected (Figure 2). The projection screen can actually be an Electronic White-Board.

Following the success of the Tex-Mex Virtual Design Studio, in the spring of 1999 the Tex-Mex Virtual Design Studio was transformed into The Las Americas Virtual Design Studio, this time with the participation of schools of architecture in Mexico, Guatemala, Peru, and Brazil.

Findings

Over the last 3 years, a total of 39 students and 8 instructors have been interviewed about their experience in the virtual design studios. These are some findings related to the use of videoconferencing interfaces:

- The level of interaction between students was substantially higher when the protocol of the videoconferences was lifted. For instance, during breaks and immediately after reviews, small groups of students stayed behind in the videoconferencing room in order to establish a more private, and in most cases very intense, debate about their projects.

- The use of a cursor-driven interface was not attractive at all. White-Boarding was easy to learn but the quality of graphics tools was far too basic. The students said that it did not matter how good their ideas were, the images generated on the white-board looked childish. In the case of using presentation programs, interaction between students was minimum. The main comment was that the cursor was not expressive at all and it was difficult to relate voice and cursor movements.

- The use of a hand-driven interface was very popular with students and instructors. The high level of expressiveness of our hands, as they interact with a drawing, was notorious. A number of students mentioned that during a conventional review they do not see the face of their instructors any way and that they have learned to read the attitude of their reviewers from their hand language and pencil strokes. In this case the students did miss the possibility of interaction in the same drawing space.

- The use of a body-driven interface was very promising. In one occasion we were able to manage a one-to-one scale video feedback session in which the instructor was able to stand next to the virtual student and display, by means of body language, the instructor's reaction to a floor plan provided as a virtual pin-up between instructor and student (figure 2). Despite the fact that the reviewer was not able to interact in the same graphic plane that the student, the level of transparency that was accomplished was distinctively superior to those achieved by the other interfaces. It was at the time of experimenting with video feedback that the idea of the Infinity Room was initially conceived.

The Infinity Room

The Infinity Room has been conceived as a telecommunications interface that merges telematics and Virtual Reality technology in the generation of a state-of-the-art virtual design environment. In practical terms, the objective of the Infinity Room is to support, with upgraded performance, collaborative design activities between design agents that are geographically distributed.

Design Concept

As a result of our research, we can identify four design parameters that need to be met in order to achieve substantial improvement on interface performance, namely: Flexibility, Expressiveness, Inmersiveness, and Non-intrusiveness.

A virtual design studio needs to be perceived as a large room with flexible layout. The students should be able to meet across the network without the protocol of waiting for their turn to talk. Ideally, some students may be showing their projects to a virtual instructor, other students may be comparing design solutions in a small group and yet other students may be engaged in a private conversation. In a design studio with 12 students at each side of the network we believe that the availability of 4 open channels at all times will permit the level of flexible interaction that is typical of a work session in a conventional studio.

Four open channels and 4 television monitors are certainly better than a single one but yet the level of inmersiveness we have experienced at the time of interacting with full scale images of our interlocutors would be missing. In order to replicate that level of inmersivenes in a multi-channel environment we will need to replace the television monitors of our conventional videoconferencing rooms with video projectors acting upon the back of floor-to-ceiling rear projection screens. Beyond that, and as an obvious design inductive inference, we can imagine all four projection channels generating a panoramic tiled video screen that could be used as a single interactive frame or as a sequence of independent, yet visually synchronized frames.

In the case of an apparently conventional room in which all the technology is concealed behind a rear projection screen, the level of technological intrusiveness will be minimal.

Requirements and Constrains

The concept of the Infinity Room, as outlined above, implies a number of requirements that need to be satisfied within the constraints of current technology and feasible cost. The three main brackets of requirements that we need to address are: Physical Space, Hardware & Software, and Network.

Physical Space:

In order to comply with the concept of a flexible space, in which technology is not intrusive, we need to think on the need of two adjacent rooms. One will be the actual studio where students should be able to move freely around the studio without the need of constant supervision. The other room will be the equipment room where all the cameras, projectors, and computer equipment will be installed on a permanent basis. All corners within the studio will be rounded to eliminate problems in the simulation of virtually extended perspectives.

The interface between both rooms will be a floor-to-ceiling rear projection wall that will receive the projection of remote images generated by video projectors in the equipment room. At the same time, in the equipment room, each panel of the rear projection wall, 4 in total, will hold a high-resolution video camera calibrated to cover a fraction of the actual studio space. It is understood that in the middle of each projection panel there will be a one-inch circular opening where the lens of the cameras could be fitted (Figure 3)

Hardware & Software

Four computers will contain hardware based CODECs that provide connectivity and interoperability between other design studios with similar equipment. A CODEC is a hardware, or software, solution that COmpresses

and DECcompreses the video and audio signal into a format that can be easily transmitted across a network. Interoperability between "The Infinity Room" and other videoconference-based systems is accomplished by utilizing a CODEC that operates on the ITU H.320 standard.

Instead of traditional television monitors, four rear-mounted projectors are placed behind four flat panel rear projection screens. The projectors have multiple video inputs to accommodate the video from the remote studios as well as any local video source that needs to be displayed.

A variety of cameras are located throughout the studio (Figure 3). First, a primary camera is outfitted with a wide-angle lens located at the front of the room which captures the entire room. Second, a camera is located directly above a work surface at the center of the studio mounted within the ceiling. The camera acts as a document camera with a viewing area larger enough to accommodate drawings or models. Third, a small, portable camera on a flexible shaft is utilized to get inside models. Finally, four individual cameras are located behind each of the projection screens to provide close-up shots, as well as providing an individual camera source for small, individual videoconferencing sessions.

Electronic whiteboard sensors are attached to each of the four projection screens which assume the role of traditional whiteboard. All of the equipment is directly controlled by a touch screen pad that is connected back to a computer within the equipment room. In addition to the touch pad, each individual unit has a remote controlled keyboard and mouse. These tools provide a control device for when the units are operating in an individual meeting mode.

Network

For the purposes of "The Infinity Room", the minimum connection required is a T1 line. A T1 provides 1.54Mbps. of bandwidth which is divided into four 384Kbps. videoconferencing channels. An inverse multiplexer is the device used to divide the bandwidth. If the design studio at College Station would have several studios that it would need to work with, an ISDN PRI (1.54Mbps) would be used instead of T1 to give the studio the functionality of being able to disconnect from one studio, and dial another.

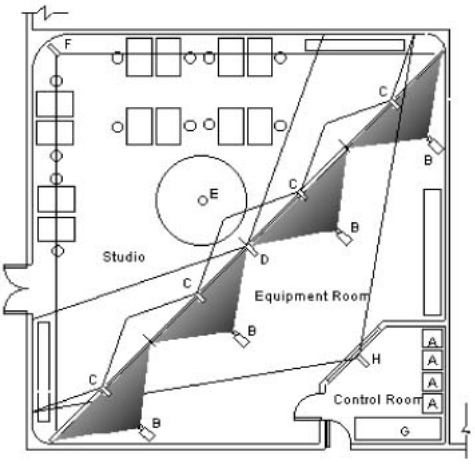

Figure 3 (left). Floor plan of the Infinity Room. A= CODECs, B= Video Projectors, C= Wide-angle Cameras, D= Main Studio Camera, E= Ceiling Camera for Physical Models & Drawing Boards, F= Video Feedback Camera, G= Audio and VCR Equipment, H= Future Main Camera (in case of Electromagnetic Shuttering Glass Screen)

If greater bandwidth is required, and available, the network connectivity could easily be upgraded to multiple T1or ISDN PRI lines, or a single DS3 (45Mbps) or OC3 (155Mbps) telephone line. However, a single line solution is preferred to eliminate issues of timing and synchronization between the four CODECs.

Conclusions

The Infinity Room is flexible because:

- It is not restricted to a fixed functional layout. Students can modify the room layout with almost the same flexibility they experience in a conventional studio space.
- It is not restricted to a single dynamic of interaction. Students and instructors can participate in different communication dynamics simultaneously. A single group gathering, several gatherings of small groups,

and individual/private meetings. At least 4 communication channels are available.
- Collaborative design activities can be supported by any media the students or instructors wish to use. Voice, body language, analog images, digital images, physical models, digital models can be used seamlessly.

The Infinity Room supports expressiveness because:

- It permits bilateral communication making use of the same design medium. This is different from current practice where the local classroom gets to see the instructor drawing on an electronic whiteboard but the students at a remote location only see a cursor that generates the drawing.
- It permits the display of body language in interaction with graphic material.

The Infinity Room is immersive because:

- It provides a main interface that simulates the existence of an adjacent room where the virtual studio resides. In accomplishing this it is of fundamental importance that the images of the virtual studio are projected on a scale of one-to-one and that the rear projection screen covers a complete wall.
- In a future it may be possible to replace the rear projection screen with a wall of electromagnetic shuttering glass (of at least 60 cycles per second) this will permit the projection and filming of images simultaneously (at 30 frames per second each) from the back of the equipment room. This will improve the effect of matching perspectives, eye contact between interlocutors, and will remove the need for small openings (blind spots) on the projection surface.

The Infinity Room is non-intrusive because:

- All the technology is concealed in the equipment room. Only few openings in walls and ceilings will give away the location of cameras.
- No especial gear is required. In some instances the students or instructors may wish to use a wireless lapel microphones in order to improve audio performance. In the future it may be possible to add the alternative use of individual shuttering glasses in order to permit stereoscopic perception of projected images.

In terms of feasibility, all of the equipment utilized within the design is currently available in today's marketplace. A major benefit of selecting equipment that is currently available is that the room is able to operate with the current communication standards, (ITU H.320, ITU H.323, and ITU T.120). By utilizing the current standards, the studio can communicate with the existing equipment utilized by the commercial, public and academic communities. The equipment cost for the room is approximately $300,000.

References

N. Holland and G. Vasquez de Velasco, The Internationalization of Undergraduate Programs: A Model Program Using Reciprocal Distance Education, Traditional Study Abroad Programs and International Internships, Conference of the American Society of Engineering Educators "Frontiers in Education" FIE 98, ISBN 0-7803-4762-5, (Arizona, 1998) 595-599

G. Vasquez de Velasco and N. Holland, International Virtual Design Studios and Reciprocal Distance Education, Third International Conference of the Ibero-american Association for Computer Graphics, Sigradi 1998, ISBN 987-97190-0-X, (Argentina, 1998a) 399-405

G. Vasquez de Velasco and N. Holland, Reciprocal Distance Education in International Design & Construction Studios, International Conference on Research in Design Education / ARCC - EAAE, 1998, (North Carolina, 1998b) 34-39

G. Vasquez de Velasco and Javier Jiménez, Compressed Video Technology in International Architectural Reviews: An instructional application, ED-MEDIA/ED-TELECOM 97, World Conference on Educational Telecommunications, ISBN 1-880094-26-6, (Canada, 1997a) Vol-II 1040-1045

G. Vasquez de Velasco and Javier Jiménez, The Tex-Mex Virtual Design Studio, Sixth International Conference on the Application of Computer Networks in Architecture, ISBN 2-909285-07-3, EuropIA Productions, (United Kingdom, 1997b) 167-180

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