An Affordable Immersive Environment in Beginning Design Studio Education

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Abstract

This paper presents work exploring the potential of virtual reality (VR) within an affordable environment in the early years of architectural education has been limited. Through an immersive environment system in the studio, students create space by manipulating solids and voids while evaluating the anthropometric relations of the proposed solution. The students are able to study and test conceptual details in a virtual environment from the very beginning of their architectural design project.

We carried out a usability study in order to assess student perception of the usefulness of various system attributes for diverse tasks. Thirty-five surveys were collected from the students who had used the system. Observations indicate that within the architectural context, virtual reality techniques involving depth perception can convey relevant information to students more efficiently and with less misrepresentation than traditional techniques.

1 The Virtual Studio

Despite the fact that the use of virtual reality is increasing quickly in other fields, in architecture no one has yet attempted to utilize its great potential within an affordable environment in the early years of architectural education. The need is especially great in the beginning, because it could enable the student designer to move from simply observing through conventions to participating in the built environment. Through virtual reality, the students can explore the proposed space; they can immerse themselves in the designed space in a manner similar to the way in which it would be used.

At the present time, through a joint project with Penn State’s Information Technology Services (ITS), we are in the process of exploring the educational potential of immersive environments in the creation and understanding of space as a set of dynamic volumes that can be experienced virtually. The ITS’s VR-Desktop initiative and the Immersive Environments Lab have brought the salient features of projection-based VR to second-year architecture students in a way that is more generally accessible than the many canonical, first-generation, projection-based VR systems.
In the early 1990s the prototypes of projection-based VR systems performed well, but were so expensive that few could be created. Even now, although they are more durable and less costly, systems are generally restricted to use by the high-performance research community. It seems a fair assessment that projection-based VR has not achieved widespread use among users beyond the high performance community. It seems that the lack of acceptance by general users is due not only to the typically high cost of purchasing and maintaining such facilities, but also to the difficulties in utilization. There is a scarcity of VR-enabled applications to which general users can easily transition, a challenging programming environment for non-programmers who would attempt to use VR systems to develop unique applications. Our experience has been that for many potential users in a university community, the effort and resources required to bring VR techniques to bear on everyday research and teaching have been too great. The goal for the VR-Desktop project is to provide systems for a wider range of users in terms of their existing computing skills/work methods, budgets and physical proximity. The objective is to make the VR environment as easy, cost effective, and convenient as possible for users so that they can realize the benefits of big-screen VR. The principal goals in building the system were: 1) maintaining affordable cost by using "commodity" components; 2) ease of use by employing familiar computing environment (Windows) and support for applications with which the students are familiar (e.g. FormZ); and 3) continuous access by students, in proximity to their existing studio space.

2 The VR Platform

Currently and at the time of the student surveys discussed below, the Immersive Environments Lab display system included two six-by-eight-foot, rear-projection, passive-stereo, display screens, with the basis of the VR-desktop being the Navigational Loader program, written almost entirely in Java. The joystick input devices currently used are dependent on the Windows operating system; however, we have implemented devices independent of the specific operating system, such as the SpaceOrb. These system-independent devices are controlled by utilizing the Java communications API, whereas the system-dependent devices use the Java Native Interface (JNI) to communicate with the native operating system.
We are using the OpenGL implementation for Windows with Java3D as the basis of the application, utilizing the underlying graphics API to do the actual rendering. The high-end graphics cards used to produce the quad-buffer stereo image are inherently designed for OpenGL hardware acceleration. The stereo image produced is frame-sequential stereo that normally requires drawing at a monitor refresh rate of 100-120 Hz. Our systems use a CyViz device to split the frame sequential stereo signal from the graphics card into a projected image for the left and right eyes. With the addition of the CyViz box the monitor refresh rate can be reduced to 60 Hz, allowing for a greater choice of monitor resolutions and utilization of commodity LCD projectors.

Figures 1 and 2 show the two eight-by-six-foot screens are positioned in a wedge that is offset from the typical flat screen at the middle by 30 degrees. This offset produces a feeling of immersion similar to that of a CAVE® when both screens are projected with stereo images. To create separate viewing frustums for each screen a Java3D View Object is created with two Canvas3D Objects attached to it, one for each screen. The Canvas3D Objects each have an associated Screen3D Object containing an image plate, which can be configured to match the physical positions of the screens. In the Java3D View model space, screen positions are defined relative to a fixed frame of reference in the physical world by the tracker base. The tracker base is used to define a fixed frame of reference, even if no physical tracking hardware is being used. Coexistence coordinates provide a frame of reference that can be defined by the user in the manner that is most convenient for positioning the physical configuration of the image plates, the tracking hardware, and the eye positions in the virtual world. The Java3D renderer then performs the projection of the virtual world onto the physical display surfaces automatically.

The program works by first loading a VRML file and parsing that file to obtain the scene graph information. The ability to load the full VRML97 specification is in the beta-testing stage and will be implemented when the loader is completed. The scene graph is then traversed to load in the views created in FormZ and then saved as VRML View nodes.

3 Implementation of Virtual Reality Simulation in a Second-Year Studio

During three semesters in 2001 and 2002 a component of our design studios introduced students to the use of computers in enhancing design possibilities. Students spent one-half of each semester using the VR-Desktop environment to design their projects as part of the normal rotation through four different instructors. The projects were not specific to the fifteen-student computer studio as they were the same assignments as for the other three sections of second-year. Over the three semesters this program involved approximately thirty-five students, from the second-, third-, and fifth-year design studios. Integration of computers directly into the design studio took place in a physical environment that united the traditional drafting table with the computer. Through the use of digital design media, 3D modeling, and virtual reality, students in the studio developed a critical design sense of fundamental architectural form, systems, and vocabularies. They examined the relationship between order and idea and developed their analytical and design capabilities through this exploration of digital technology.

The undergraduate architecture design students are not advanced users or programmers so they provide a nearly ideal user community for the development of more accessible VR tools. In order for the students to be successful, any tools that are deployed must be straightforward and in keeping with existing workflow. The students' design work is such that the potential benefits of the human-scale interaction with their designs are readily apparent. The resulting independence and enthusiasm of the student users and the feedback they provide on software development have been invaluable in our success.

4 System Implementation and Evaluation

Through the VR-Desktop environment in the studio, students immediately start working in a VR environment. They create space by manipulating solids and voids while evaluating the anthropometric
relations of the proposed solution. The students are able to study and test conceptual details in an immersive environment from the very beginning of the project, increasing the creativity and success of their designs.

The Immersive Environments Lab (IEL) system was initially envisioned as a surround screen or immersive 3D environment for use in individual design development and personal visualization of models. The students, however, quickly adopted the system for use as a multi-modal presentation space, in addition to its use as a personal and immersive system as envisioned by the designers. Due to the familiar desktop computing environment employed, several students have been able to identify useful software additions for the system, such as stereoscopic multimedia tools, and communicate their applicability to other users, thereby enhancing the usefulness of the lab and increasing the quality of work for everyone. It has been interesting to observe how different students use different software tools to analyze or present various aspects of their projects. In this sense, one can think of the system as integrating the VR experience within a continuum of multimedia approaches or applications. Examples of student work produced by the design studios using the new visualization technology are used to illustrate the success of this studio. (See Figures 3 and 4)

Recently we have begun a usability study in order to assess student perception of the usefulness of various system attributes for various tasks undertaken. This assessment will continue and will be reported on periodically as the design of the lab evolves and new information is available. Initially, thirty-five surveys were collected from the undergraduate students who had used the Immersive Environments Lab. Thirteen surveys were submitted by students enrolled in second-year architectural design studio. Nineteen were from students enrolled in an advanced undergraduate studio in Digital Design Media. Three were from fifth-year students who independently used the system in the development and/or presentation of their thesis design projects. The surveys were similar in content except that studio and thesis students were asked a series of questions regarding use of the system for "architectural design" development and presentation, whereas the digital design media students were asked the same with regard to "artistic and digital media" development and presentation.

In the survey the students were asked an open-ended question about describing three aspects of using the Immersive Environments Lab that they felt were most convenient, useful or successful in their work. Specific functional or formal attributes that most often were cited as beneficial were stereoscopic or 3D projection (17), large screen size (15), and the ability to navigate and/or view the scene from different viewpoints (13). Several students (7) specifically commented on psychological dimensions, such as envisioning being in the project or the ability to show others is seen in your imagination. Similar dimensions may be implied in many of the less specific comments along the lines of the ability to walk through assists showing of designs. The nature of the work undertaken by different groups also appears to have a bearing on students' ratings on the design versus presentation scale. Students enrolled in the digital design media class (which focused on digital media creation and presentation) rated the facility more useful for presentation (M=7.82) than did students enrolled in second year architectural design studio (which focuses on architectural design development with subsequent presentation thereof) who offered a more neutral rating on the design versus presentation scale (M=6.38), t(30)=-2.06, p<.05.

The combined indices also yielded some interesting results. The Perceived Immersiveness index, which combines the ratings for Large Screen Size and Stereoscopic Display, varied significantly by task, F(2,61)=11.74, p<.01. The means for Presentation and Audience being nearly identical but significantly higher than for the design task, suggesting that either the novelty or the compelling presence afforded by these attributes had greater perceived utility in presentation situations than for designing, per se (which perhaps could happen just as well offline, on a smaller display, etc.). For the Perceived Navigability and Capacity for Complexity indices, no significant variation was found on the task variable alone.

It would seem that initially, at least, that the utility of the key VR ingredients of wide field of view, stereoscopic projection and interactivity have been validated by the students. Student responses often discriminated between useful functionality of the system and its awkward implementation. For example, several students positively commented on the ability to move around the scene, while at the same time mentioning that system response made navigation awkward for large models or that they did not like
using the joystick to do so. The authors suspect awkward movement is confounded by poor system response for large models, which contributes to the difficulty in navigating with the joystick. Several comments pertained to access and spatial layout of the facility. For example, convenient, unattended continuous access was cited as a plus, as was useful presentation space, whereas limited audience capacity was cited as a drawback. Such observations have been useful in deciding where best to focus future efforts to improve system functionality, room layout, scheduling, and other issues that will influence acceptance by users.

Overall, the students rated use the system positively, although most rated the system at least somewhat more useful for presentation purposes than for making design decisions. The degree of such perception appears to be influenced by instructor and/or the extent of use of the system, which also are correlated to overall enthusiasm. In continuing this research, additional questions and correlations with regard to instructor focus and access patterns may yield useful information for improving teaching that utilizes such facilities in the future.

One student pointed out that the novelty of the system was counterproductive as it caused the lack of useful critiquing because critics seemed amazed by the environment. Indeed, novelty may be a significant factor in these initially favorable reviews by the students. Issues surrounding the design and acceptance by users of VR systems are inherently subtle and multifaceted.

5 Conclusion

With the virtual studio students are encouraged to design in three dimensions from the beginning of conceptualization. Through simulation and testing of the building design it is hoped that students will go beyond convention and explore movement in both time and space. The virtual reality visualization techniques should allow the students to understand space and form, as well as texture, contrast, and color, as they explore spatial and temporal movement. We expect that within the architectural context, virtual reality techniques involving depth perception can convey relevant information to students more efficiently and with less misrepresentation than traditional techniques. Hopefully through VR techniques architectural education can be improved.

6 Acknowledgements

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7 References


Figure 3. Examples of Student Work in the Immersive Environment.
Figure 4. Additional Examples of Student Work in the Immersive Environment.