VIRTUAL REALITY IMPLEMENTATION IN THE ARCHITECTURE CURRICULUM

The experience of King Fahd University of Petroleum and Minerals

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Abstract. Following a recent curriculum revision, the Department of Architecture at the King Fahd University of Petroleum and Minerals (KFUPM) established a Virtual Reality (VR) laboratory to service its information technology courses and research. Two years after the establishment of the laboratory, utilization has not reached the level anticipated and the facility is yet to be fully integrated into teaching and research activities. The paper reviews the implementation of the laboratory with a view to identifying and examining the factors that account for its current utilization. Factors identified in the paper included inability to fully implement the proposal for the laboratory, inadequate implementation preparation, complicated procedure for producing visualization content, and computing resource compatibility problems. The paper concludes with general suggestions for schools trying to implement virtual reality in their curriculum and specific suggestions to improve the utilization of the KFUPM VR laboratory.

1. Introduction

Since the late 1980s, architecture and architectural education have witnessed an important transformation with the introduction of computers and information technology (IT) (Cuff, 2001). Computers and information technology have become pervasive in all aspects of architectural practice and education, challenging the traditional ways that architects have operated for a long time (Cuff, 2001; Laiserin, 2002). One of the most powerful changes brought about by computers is in the aspect of visualization. Computers enable the generation and experience of virtual environments with a profound implication on how we design and also interact with the product of design. The debate in the profession about the relative merit of the introduction of computers on architectural design that the transformation engendered has since given way to the exploration of its cognitive implication on design and to questions of whether it is engendering the emergence of new modes of thinking about architecture and space (Cuff, 2001). The pervasiveness of information technology in education and practice is also reflected in the growing proportion and importance of IT courses in the curricula of architectural schools. Many schools have increased IT content in their curriculum and are investing resources to acquire computing resources to ensure that they provide their students with the necessary skills and competitive advantage. In many schools investment in IT have also include the establishment of Virtual Reality laboratories to provide students with opportunities for enhance visualization aimed at improving design skills.

In the King Fahd University of Petroleum and Minerals (KFUPM), a recent revision of the architecture curriculum reflected the growing importance of Information technology in education and practice, and the need to position graduates with a competitive advantage in the professional field. The revision saw a change in the vision and mission of the department all emphasizing information technology. This emphasis was reflected in the course structure, where new information technology courses, including a virtual reality course were introduced. An initiative for the establishment of a Virtual Reality (VR) Laboratory was started to support the teaching of IT courses, studios and to support research activities. The Laboratory became fully operations in 2002. Two years after the establishment of the VR Laboratory, utilization is below the level expected and it is yet to be fully integrated into teaching and research activities. The paper reviews the implementation of the laboratory with a view to identifying and examining the forces that account for its current utilization. The paper is divided into three main sections. The first section explores virtual reality and its application in architecture and architectural education. The second section reviews the implementation process of the KFUPM VR Laboratory. The last section assesses the utilization level of the Laboratory and examines the factors that account for the observed level of utilization. The paper concludes with general suggestions for implementing virtual reality in architecture schools and specific suggestions for improving the utilization of the VR Laboratory at KFUPM.

2. Virtual Reality in Architecture

Virtual Reality refers to the act of generating and interacting with computer generated virtual environments (Vince, 1999). Virtual Reality refers to an attempt to create and convey a sensation of reality using artificial means, usually the computer. Virtual Reality is used interchangeably with Artificial

Reality, Virtual Worlds and Virtual Environment. The concept of VR presupposes the existence of material reality. Humans sense and interact with reality or the material world through their senses; vision, hearing, touching and smelling. Human beings have a vision that is coloured, binocular, stereoscopic and wide angled. In human vision, the individual is also enveloped by the environment or image he sees. In hearing, human beings are able to distinguish different range of frequencies, direction and volume, as well as associate sound with external objects and events. The eye is also used for equilibrium for the body. Tactile sensation resulting from the human touch enables the differentiation of different types of objects. The human sense of smell enables odours to be distinguished and to be associated with events and places. The use of the combination of the senses creates the human perception of material reality. Virtual reality creates an artificial sensation of reality through enabling human sensation. The degree to which a virtual reality presentation enables the use of many or all of the human senses determines the reality or degree of immersion of the presentation. Technologies of virtual reality are differentiated based on the degree to which they are able to simulate reality particularly in their display. The technologies vary from fully immersive technologies where the user becomes integrated into an artificial 3-dimensional world with almost all his senses activated, to non-immersive technologies, which provide limited sensation of reality. There are various types of virtual reality equipment prevalent in the market. Among the most popular ones are screen based projection systems, Head Mounted Display (HMD), the Binocular Omni-Orientation Monitor (BOOM), and the Cave Automatic Virtual Environment (CAVE) (Vince, 1999). Screen based VR systems provide visualization through projections on screens. This can be as simple as projection on a computer monitor to Domes and large screen based systems. Level of immersion varies from simple projection of animation to stereo viewing of multimedia presentations on large screens or Dome systems using 3D polarized glasses. HMDs are the premier immersive VR technology (Vince, 1999). The device is head mounted and the user interacts visually with the image. This is sometimes combined with tactile systems to create a true feeling of immersion. BOOM from Fakespace is a head-coupled stereoscopic display device. The CAVE was developed at the University of Illinois at Chicago Electronic Visualization Laboratory. The CAVE consists of a room with graphics projected from behind the walls. The images on the wall are projected in stereo mode to give a sense of depth. Users are surrounded by the image giving a complete sense of immersion. Several people can also be in the room sharing the same experience.

VR application has grown to almost a limitless level with the evolution of the technology. Virtual Reality has changed the way people interact with technology, offering new ways for the communication of information, the visualization of processes and the expression and communication of creative ideas. VR is used to represent 3-dimensional worlds either real such as buildings, landscape, spacecraft, archaeological excavation of sites, human anatomy, sculptures, crime scene, reconstructions, solar systems, and so on, or abstract such as magnetic field, turbulent flow structures, molecular models, mathematical systems, auditorium acoustics, population densities, and information flows. These virtual worlds can be animated, interactive, shared and can expose behaviour and functionality. Architecture, by virtue of its experiential nature and the importance of visualization to it is one of the prime disciplines where virtual reality is having a significant effect. VR makes it possible to simulate buildings and explore them at a virtual level, making studies of such issues as function, construction technology, performance etc possible. As a tool, VR provides architects with the means to improve design quality through prior study and assessment of the design product. The use of VR by architects also improves the communication of design ideas to clients and users without the requirement of their understanding the notations of technical presentation (Maher et al, 1999). VR also enables the comparative evaluation of design alternatives based not only on technical and functional criteria but also on aesthetic impact and user needs (Maher et al, 1999). For the student architect, VR provides an opportunity to improve design skills through better mapping of abstract representations with the reality of the experience of form and space. Also the design teaching process is improved through the use of VR, as criticism and comments which might be hard to fathom from traditional abstract representations become more easily appreciated when a simulation of the building is experienced.

The potential of VR application in design education has made the technology the focus of acquisition by many architectural schools. The development of the technology is in part driven by research in universities, particularly in the United States, where the technology is most prevalent. It is not within the scope of this paper to develop generalized criteria for evaluating or analyzing success in VR implementation by schools of architecture. In the case of KFUPM four criteria developed based on the mission of the facility have been used to judge level of utilization and success in implementation; integration into teaching and research activities, ability to support the VR needs of the university community and use of facility for VR consulting to the wider community. Using the KFUPM criteria for an overview of VR implementation in the architecture curriculum, it is apparent that VR has been successfully implemented in many architecture schools, particularly in the developed world. Examples of successful VR implementation in Universities in the United states include the Cornell graphics laboratory established in 1974 (http://www.graphics.cornell.edu), The MIT Media Lab established in 1985 (http://www.media.mit.edu), University of Michigan Virtual Realty laboratory established in 1993 (http://www-vrl.umich.edu), The NCASA

Virtual Reality Laboratory at the University of Illinois at Urbana Champaign established in 1991, and Columbia University Computer Graphics and User Interface laboratory (http://www1.cs.columbia.edu/graphics/projects/virtual-worlds.html). A review of these facilities appears to suggest certain common recipes for success. First of all, there is no single VR technology that predominates across all the laboratories. HMDS, BOOM, CAVE and projection system VR were found across all the laboratories. Most of the laboratories developed as a result of research initiative by either a department or a group of people. Almost all the laboratories use external funding usually from industries. The external funding allows the laboratories to acquire a broad range of VR facilities and to ensure that their facilities are updated. The laboratories all have a strong research focus, in addition to teaching. Almost all of the laboratories are at the forefront of the development of VR technology, both hardware and software. The laboratories are also situated to support multi-disciplinary research bringing together many disciplines such as architecture, computer science, engineering and manufacturing. Many of the laboratories have teams dedicated to research in specific areas and many have a core team of people that also manage their VR facilities. In the Gulf region, other than KFUPM, the other case of a prominent implementation of VR is that of the Department of Architecture at the United Arab Emirates University (UAEU) (www.engg.uaeu.ac.ae/a.okeil/uaeu-cave). The UAEU system is an immersive CAVE that was developed in-house. The project was initiated in May 2001 and the first student project and course taught using the CAVE were carried out in January and February 2004 respectively indicating that it has successfully taken off and is already being integrated into design studios and the courses of the Department.

3. Virtual Reality Implementation in KFUPM

The process for establishing the Virtual Reality Laboratory at KFUPM started immediately after the completion of the review of the curriculum of the Department in 2001. The process for establishing the VR Laboratory was initiated by the then Chairman of the Department to support new information technology courses in the revised curriculum. A proposal for the VR Laboratory was prepared and forwarded to the University administration. The proposal highlighted the mission and purpose and, equipment and staffing requirement of the laboratory. Included as part of the objectives of the Laboratory are to support teaching and research, to support the educational use of VR in other departments and to offer consulting services to public and private sectors of Saudi Arabia. The proposal called for the laboratory to be partially funded by the University and partly by a corporate chair endowment in Virtual Reality. The University ultimately funded the laboratory as the Department was not able to finalize the arrangements for the endowment of the chair. Prior to the preparation of the proposal for the laboratory, the Department had initiated a search for suitable VR technology to use. In choosing equipment, commercially available systems were opted for to ensure the quick establishment of the laboratory and because of the lack of internal capability and time to develop a system. Two companies offered products that were judged most viable; Imagetek corporation (www.3dimageteck.com) and Elumens (www.elumens.com). Both companies were asked for literature about their systems as well as for quotation. Imagetek Corporation offered a choice between a 3DI Telejector shown in Figure 1, and a 3D video encoder/decoder combination along with projector, stacker brackets and mounts, and a film screen. The 3DI Telejector has the capacity to project both stereoscopic 3-D video, watched using polarized glasses, and 2D video. The 3D encoder/decoder combo has the additional ability of encoding and outputting a single field sequential video signal from two cameras for recording, transmission or display of 3D video. It can also take encoded field sequential video and decode into left and right eye views for projection.

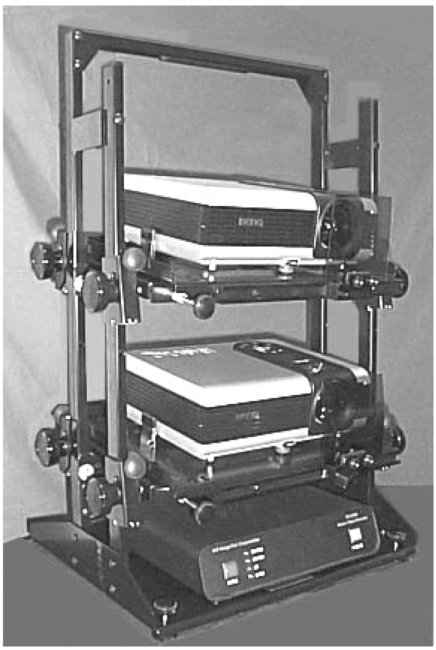

Figure 1. 3DImagetek 3DI Telejector

Elumens on the other hand offered a series of Dome VR equipment built on spherical projection technology. The Dome Series shown in Figure 2 are large spherical projection systems offering immersive VR through the use of a 180 degree field of vision. The Series consist of a Vision Station for a single user and the 3, 4 and 5 meter Domes capable of holding a larger number of people depending on Screen diameter.

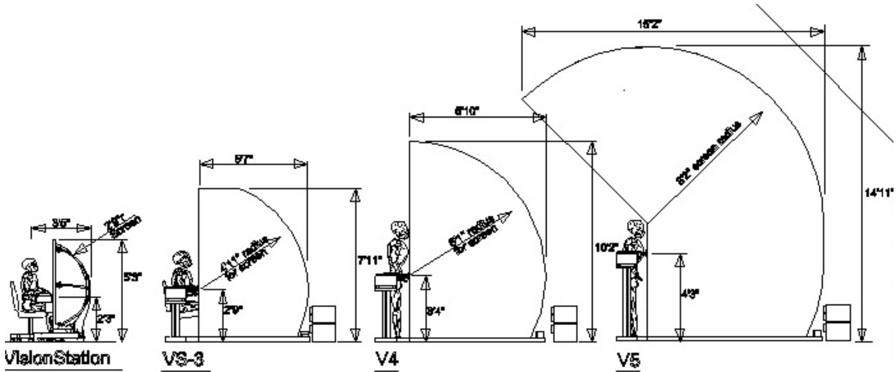

Figure 2. elumens Dome Products (Source- Elumens)

On assessing the submissions of the two companies, the Dome product from elements was judge more suitable. The dome products were scaled to enable us purchase a vision station which could be used in the Design studios, where students could generate animations and virtual display of their design products in the process of creation thereby improving the design process. The four meter dome was judged suitable for the laboratory by virtue of its ability to hold up to 10 persons viewing a virtual reality presentation. It therefore had the capacity to support student presentations to a jury of the department faculty. Factors which counted against the Imagetek product included the fact that it was a simple stack stereo projection system which meant that all content had to be recorded into a media that is compatible with the project system and then encoded to display both left and right eye which is viewed with polarized glass. The elumens system offered the opportunity of viewing with out any additional gadget.

Once the elumens system was selected, the vendor was invited to make a presentation of the technology to the school, which they did. The system was well received and there was a vivid enthusiasm for the implementation of the technology. The process of ordering the equipment was initiated in early 2002. A vision station was first ordered and situated in the design studios. Subsequently the four-meter vision dome was ordered and delivered. Computers were ordered for the laboratory, comprising of a Dual Xeon Processor IBM machine with Nvidia Quadro4 xgl graphics card to be used for running the 4meter dome and five single Xeon Processor IBM machines intended for networking to create a rendering farm to support content production for the laboratory. The Elumens 4-meter dome was installed by agents of the company, who also gave three days training on how to prepare and visualize content. This was attended by almost all the faculty as well as a core group of senior students who were selected to work on it.

4. Utilization of Virtual Reality Resources

By the October 2002, the VR Laboratory was up and running with all computers and visualization equipment installed. The visions station that was initially stationed in a design studio was later moved to the VR laboratory as it was found to have occupied significant studio space. Almost two years after the establishment of the Laboratory, however, assessment of its utilization points to a level far below anticipation. The Department was able to get the first core set of students who were trained during the establishment of Laboratory to master it and undertake a number of visualization exercises for university projects. They were also able to use the laboratory for the visualization of some of their past studio works. They were, however, unable to use the laboratory for the visualization of on-going studio projects. The Department was less successful with the next set of students co-opted to work with the laboratory. Only a few of them were able to master the process of creating content and the group was unable to undertake any significant visualization exercises. Faculty research using the Laboratory is yet to take off and there is still no attempt to formulate core fundamental research based on the Laboratory's facilities. The laboratory is also yet to be fully integrated into academic courses and design studios including the VR course and the computer based Design Studio. The proposal for the VR Laboratory to serve as the core of a multimedia service to other University Departments, though approved, has not generated the request anticipated and even if requests are generated, there is limited capability to undertake such task. The general assessment points to utilization that is below the level anticipated. The need to act to improve utilization calls for examining and understanding the forces that are contributing to the current utilization of the laboratory. A set of interrelated forces have been identified as accounting for the current utilization. These have been classified into five as follows.

4.1. INABILITY TO IMPLEMENT THE PROPOSAL FOR THE LABORATORY

One of the factors shaping the utilization of the VR Laboratory is the inability to fully implement the proposal for the Laboratory. The proposal called for the purchase of diverse VR equipment as well as dedicated staff support in the form of the holder of a chair in Virtual Reality and a Computer Aided Design Technician to oversee the running of the laboratory.

The dedicated staffs are supposed to be in charge of managing facilities in the Laboratory, scheduling use, providing training and courses in use of facilities etc. The inability to diversify equipment means that the performance of the Laboratory is hinged on understanding and using the single range of equipment in the laboratory. Absence of supporting staff has left the Laboratory without key people to guide its development and promote its use.

4.2. INADEQUATE IMPLEMENTATION PREPARATIONS

On hindsight, it also appears that the process of computerization and implementation of VR might have moved too quickly in the Department, combining the introduction of computers with the introduction of Virtual Reality. The quick and simultaneous introduction of information technology and Virtual Reality engendered a debate among the faculty on the relative merits of the digital revolution on design skills, the so called digital versus tactile debate taking place in many schools of architecture. The debate shifted focus from trying to understand and utilize the potentials of the facilities available to trying to justify the implementation of information technology in the curriculum. Such a situation, it appears, might have been avoided if implementation of information technology had been carried out in a gradual and sequential manner. Implementation was also not preceded by the adequate preparation of the academic faculty. Initial training offered by the supplying company was inadequate to impart the necessary skills needed to manage the production of content. Academic staffs were also constrained, by teaching, research and other activities, from devoting time to master the operation of the VR facility and in some cases, conflicts in computing platform interest precluded academic staff from investing the time to learn. While quick implementation was motivated by the availability of funding for the laboratory, a gradual implementation backed by a well though out strategy of implementation for both computing and virtual reality might generally have led to better earlier acceptance and a faster integration into the teaching and research process.

4.3. PROCEDURES FOR PRODUCING CONTENT AND LACK OF SUPPORT

The complicated procedure and requirement for generating content for visualization on the Dome has also been a major disincentive to the optimal utilization of the VR laboratory. The Dome series product uses the Spherical Projection Interface method, sometimes combined with stereoscopic vision. The preparation of content follows a particular set of steps or process illustrated in Figure 2. Content development starts with the modeling and assignment of materials for the object to be visualized. The model has to then be animated using software programs that support a four camera set-up. Elumens recommends 3D StudioMax because of its support for 4-camera setup. It appears, however, that only Maya is additionally able to effectively support a four camera setup for generating Dome content. The animation process produces four different images for each frame. The images are then stitched using the elumens proprietary TruFrame program to create a single image with 180°x180° field of view (FOV) for distortion free viewing on a hemispherical viewing screen. The stitching process also involves correcting the image for offset viewing and projection on the different Dome series. The projector and viewer positions are largely arbitrary and flexible in Dome projections. Elumens systems require very high-resolution playback to take full advantage of large screen area. The Vision Station displays at a resolution of 1024x768 while the larger systems display at a resolution of 1280x1024. The large display resolution means that the final visualization file is large, and has to be compressed. Elumens provides another proprietary product TruMotion for the compression and playback content files on the Dome. The complexity of the procedure means that adequate time is needed to address all process problems and prepare content for visualization. Significant computing resources is also need for content production particularly in the rendering and stitching of output from four cameras and also in the visualization of the huge files that are generated. The complexity of the process, inadequate computing power and excessive glitches that were face in the initial experimentation in the use of the laboratory appears to have served as a disincentive to the full utilization of the laboratory.

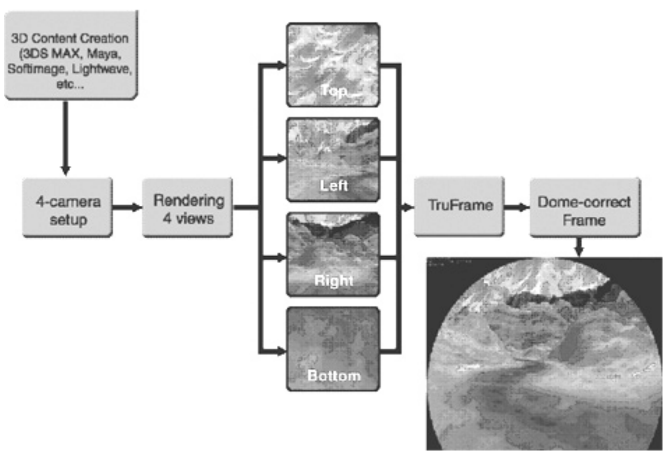

Figure 2. Content Preparation for Elumens Dome Series Display

The disincentive resulting from the complicated procedure for producing content was further exacerbated by the inadequacy of training manuals and support. The Domes were supplied without adequate training manual or step by step manuals explaining the procedures for producing and visualizing content. Support for the products was provided through a single web location, where users have to post their questions and wait for response or search for response to similar enquiries from other users. The situation expanded the learning curve for the operation of the Dome and discouraged people from utilizing the VR facilities.

4.4. DESIGN STUDIO SCHEDULE AND NEED FOR NEW COURSES

The structure of the design studio schedule of the Department also contributed in part to the level of utilization of the laboratory. Studios are structured so that students undertake 2 to 3 design projects within a fifteen weeks semester. This makes the average duration of a project to range from 4 to 6 weeks. The limited time given to design projects means that students are always under pressure to meet scheduled bench mark requirements and have little or no time for experimenting with new technology. The combination of a complicated content production process and limited project durations has combined to limit the utilization of the laboratory. Additionally also, the inability to offer new courses that explore the potential of the VR laboratory, means that students are not very clear about the benefits of the use of the VR facilities.

4.5. LIMITED COMPATIBILITY WITH OTHER COMPUTING RESOURCES

Part of the disincentive for using the laboratory also arises from the limited compatibility of computing resources. The Dome series equipment uses a four camera setup, thereby requiring that virtual models be compatible with the 3D StudioMax computing software. Prior to the introduction of the dome, however, FormZ was the most prevalent rendering software of choice among the students, and the teaching of IT courses dealing with Modeling, Rendering and Animation was done using FormZ. The lack of full compatibility between FormZ and 3D StudioMax meant that attempts to transfer virtual models from FormZ to 3D StudioMax, always resulted in glitches that required substantial time to resolve. This increased the time dimension needed to create content for visualization on the Dome and further discouraged the use of the Facility. There was also the question of appropriate browsers to use for real time virtual reality. The hemispherical nature of Dome display means that browsers have to have the capability of supporting spherical display at the large resolution required by the Domes. So far only one experimental browser has been identified and even that is at a rudimentary stage of development. This lack of compatibility of browsers with the Dome series limits the ability to cut the time of preparing content by engaging in real time virtual reality.

5. Conclusion and Recommendations

The paper reviewed the experience of KFUPM in establishing a VR laboratory and examined some of the forces that account for the less than expected utilization of the laboratory. From the literature, it is apparent that many universities have successfully implemented virtual reality laboratories. Schools have to be on the edge of technology to remain competitive and provide graduates with the skills necessary to survive in the professional industry. Introduction of technology must however be optimized to ensure the efficient use of resources. In KFUPM, VR implementation was driven by visionary leadership coupled with the availability of opportunities for funding. Such leadership is absolutely necessary for introducing innovative technologies. The KFUPM case has however shown that the introduction of such innovative technologies must be tempered by well developed strategies to ensure optimal success in implementation. Examination of the KFUPM experience suggest certain strategies that may generally improve the potential for success in introducing computing as well as virtual reality to the curriculum of architecture schools. To start with, computerization should be gradual moving from a systematic gradual introduction, acceptance and integration of computers into curriculum to investment and introduction of high end systems such as virtual reality. Gradual introduction should be complemented by training and faculty development and training on computer application in architecture. Virtual reality introduction should preferably be initiated by the academic faculty and a core team of dedicated people with technical know how should be identified prior to implementation. Virtual reality should not be implemented as a departmental resource but as a university wide resource integrated into teaching and research across different disciplines. New and specific courses that seek to explore VR and its applications have to be introduced along with VR adoption. Computer based studio projects should include dedicated projects aimed at using VR to explore and shape the design process. The Choice of systems for implementation must reflect technical capabilities and ease and ability to use systems. Research, especially basic research, and collaboration with industry is critical to the success of virtual reality facilities. It enables the generation of funds for modernization and provides the motivation for full utilization

In the case of the KFUPM VR Laboratory, concerted actions are needed to improve the utilization of the laboratory. There are several specific actions that are recommended to improve the utilization of the laboratory. Urgent action is needed to identify a core group of faculty and assign them the responsibility of developing strategies for incorporating laboratory into teaching and research activities. Such faculty should develop adequate technical knowledge of the available equipment. The University may also consider appointing dedicated staff for the laboratory as was contained in the initial proposal. There is also a need to develop a multi-disciplinary research framework which seeks to exploit the capabilities of the facilities of the Laboratory. Adequate training in the use of the VR laboratory facilities is critical to the optimal utilization of the laboratory. There is a need to develop user friendly training manuals as well as a proactive support regime to promote the use of the laboratory. This should be complemented by the introduction of special courses that seek to explore the potentials of the VR laboratory. There is also a need to link the VR Laboratory to design courses and to exercises in IT courses, especially the Virtual Reality course. Finally, there is a need to work on setting up the initial rendering farm intended for the laboratory as a means to ease the time required to produce content.

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References

Cuff D.: 2001, Digital Pedagogy: An essay, *Architectural Records*, 09, 2001, 200-206

Laiserin J.: 2002, From Atelier to e-telier: Virtual Design Studios. *Architectural Records*, 01, 2002, 141-142

Maher M. L., Simoff S. J. and Cicognani A.: 1999, *Understanding Virtual Design Studious* Springer, London

The Cornell University Program of Computer Graphics, (http://www.graphics.cornell.edu)

The UAEU Immersive CAVE (UAEU-CAVE), www.engg.uaeu.ac.ae/a.okeil/uaeu-cave

University of Michigan Virtual Reality Laboratory, (VRL) http://www-vrl.umich.edu)

Vince J.: 1999 *Virtual Reality*, Springer, London

Virtual Worlds Research at Columbia University's Computer Graphics and User Interfaces Laboratory, (http://www1.cs.columbia.edu/graphics/projects/virtual-worlds.html)

Welcome to the MIT Media Lab, (http://www.media.mit.edu)