VIRTUAL REALITY IN ARCHITECTURE: ENABLING POSSIBILITIES

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Abstract. This paper examines the potential of Virtual Reality (VR) technologies for architectural applications. There has been a great deal of anticipation for its implications for architecture since Ivan Sutherland's first VR system in the 60's. The term VR was formalized and became popular in the main stream in the late 80's and became an industry by the late 90's. Although it has found good applications in Medicine, Flight Simulation, and Video Game Industry, its effect on architecture remains imperceptible. In the work that we review, we found that the success of VR in architecture has primarily been in the passive and exploratory applications. We also note that at the present time, the cost of VR systems is directly proportionate to the level of photorealism and immersion. We contend that photorealistic visualization and total immersion are not absolute prerequisites for making most design decisions. Hence, through this paper we bring to light the inherent promise of VR technology and the potential impact it could have with its current limitations, on the way we conventionally think and design our built environment pushing it beyond space and time constraints.

1. Introduction

What is VR?

The term Virtual Reality (VR) was coined in 1989 by Jaron Lanier of VPL research, to distinguish between the immersive digital worlds that he was trying to create and traditional computer simulations (Pimentel, 1995). For the purposes of this paper, we find Lingard's (1995) classification of VR as passive, exploratory, and immersive to be appropriate. Passive VR refers to such spectator activities as watching TV, seeing movies, reading books etc. Exploratory VR involves interactively exploring a 3D environment solely through the monitor of a computer. Examples include games like Myst, VRML architectural walk-through simulation etc. "Immersive VR (IVR) is the classic stage of VR, where the user can fully interact with the artificial environment, is provided stimulation for all the senses, and have their actions directly affect the computer generated environment" (Lingard, 1995).

1.1 WHAT IS ITS RELEVANCE TO ARCHITECTURE?

Ever since Ivan Sutherland developed (with support from ARPA) the first surprisingly advanced VR system during late sixties (Negroponte, 1993), there have been high expectations for the implications of this discovery for architects. For example, in 1968 Coons stated in his New York Times interview, "In a few years from now you (a group of architects) will be able to walk into a room and move your hand and have a plane or surface appear before you in light. You will be able to build a building in light so that you can walk around it and change it" (Herzberg, 1968). Van Dam (2000), a notable pioneer of computer graphics, observes that VR would offer a natural interface for architects to navigate through, make spatial judgements in, and manipulate three-dimensional physical environment. Thence, there is a good reason to be optimistic about its applicability to architecture.

In this paper we examine the current state of VR in architecture. We seek to understand if we have harnessed VR in Architecture by finding significant applications for daily productive use. We examine if VR has “enabled new possibilities” or “added value to the existing possibilities” in architecture.

2. Virtual Reality in Architecture

Although the term VR has a broader connotation, first image that comes to most people’s mind is probably that of an alien-like humanoid wearing a Head Mounted Display (HMD) tethered by cables and completely immersed in a fantasy world. Total immersion, photorealism, and real-time interactivity have been the Holy Grail of VR research community. Unfortunately, the technology is not even close to achieving these for practical purposes.

To understand if VR technologies have "enabled new possibilities" or "added value to existing possibilities" in architecture we conducted a literature survey as a methodology to find where the working VR systems are, if any, in the field of architecture. We used *Copernic 2001 Basic* and *northernlight.com* search engines for finding information on the web. We critically studied several magazine articles, conference papers, journal articles, scholarly essays, and books on VR. In analyzing the use of VR in architecture, and to understand the "enabling" aspect, we sought architectural design or products that were not possible any other way; and to perceive the "added value" aspect, we expected to see increased efficiency in daily productive use.

We considered the potential of Head-Mounted Displays (HMD), Computer AudioVisual Environment (CAVE) technologies, Single Wall Projection Displays / Power Walls, WorkBenches, Fish Tank VRs and WIMPs (windows, icons, menus, pointing) listed in the descending level of immersion for possible practical applications in the practice and education of architecture.

2.1 WHERE WE ARE SUPPOSED TO BE

In 1993, Negroponte expected that "within the next five years more than one in ten people will wear head-mounted computer displays while travelling in buses, trains, and planes" (Negroponte, 1993). In 1994, Bar-Zeev and Jacobson predicted that "some time towards the end of the 1990s, clients and regulators could join architects in the Virtual Design Environment (VDE) to evaluate design and constructions prior to the actual laying of the foundation" (Bar-Zeev and Jacobson, 1994).

2.2 WHERE ARE WE?

In our research and analysis of relevant work in progress at selected US research universities, we note the following trends in the use of VR for: (i) walkthroughs for visualization, analytical simulation (e.g. energy, circulation, facilities management) and virtual reconstruction; (ii) design decision making;(iii) collaboration;(iv) marketing;and (v) construction.

We found architectural walk-throughs and distant collaboration to be the most widespread productive use of VR which are however limited to *passive* and *exploratory* VR. Most of the IVR projects we reviewed were done in the mid-nineties and they seem to have been either halted or spun-off into another application area. Beyond a few demonstration prototype IVR systems in select research facilities, we did not find any systems in daily use in architecture or efficient enough for practical use. Our findings are consistent with Brooks' report on the state of IVR (Brooks, 1999). Brooks estimates that there are about a hundred installations in daily productive use worldwide, mostly in entertainment and vehicle simulations.

Table 1. Table summarizing architectural applications of VR in the US as we found in our survey (Appendix A). The numbers in parentheses refer to the listing in the Appendix. The costs of the systems are our best guesses based on product information we found on the web.

		HMD	CAVE	Power wall	Work-bench	Fishtank VR	WIMPy VR
Applications	Cost in $	.4–90K	295K–	1–200K	70K–	10K–	3K–
	Walkthrough	(7)	(6), (11)	(6)	(10)	(2)	(2), (11), (4)
	Design	(8)	(12)		(10)		
	Collaboration			(5)			(1)
	Marketing	(3)		(3)			(3)
	Construction	(9)					

2.3 WHY ARE WE NOT THERE YET?

Andreas Van Dam's (2000) comprehensive progress report on the state of VR technologies identifies the major bottlenecks and hurdles that need to be overcome. "Immersive Virtual Reality is still in an early stage of development, due to significant deficiencies on many fronts, including input and output hardware performance and ergonomics, interaction techniques, application software, development environments, cost, and reliability" (Van Dam, 2000).

Bill Hibbard (2000), a visualization expert at National Center for Supercomputing Applications (NCSA) in University of Illinois at Urbana Champaign observes that the three conditions that need to change before IVR can become widely used are the high cost factor, the apparent latency in tracking and user intrusive equipments. Polly Baker (2000), an NCSA CAVE expert, agrees that to justify the research work being conducted on CAVE, a million dollar installation, the factors laid down by Bill Hibbard needs to be resolved first. Having realized this, they are now experimenting with designing more economic and smaller footprints of CAVE like VR installations that are less immersive, easy to use and suitable for workspace environments in terms of size and cost.

Until IVR systems become affordable, dependable, and offer high value over alternative approaches we do not foresee their widespread application in architecture. Even after this happens, appropriate application software for architectural design and interoperability will be the next big issues to be resolved before VR systems can become design tools. Until then, we have to contend with *passive* and *exploratory* VR systems, which we found in our study to be becoming increasingly popular in daily productive use.

2.4 WHAT CAN BE DONE TODAY?

At the present time, the cost of the VR systems is directly proportionate to the level of photorealism and immersion. Costs of a sophisticated VR system with a high degree of photorealism and immersion are not yet practical for use in architecture. If we remove these aspects which we contend are not absolute prerequisites for making most design decisions, real time interactivity becomes achievable which we argue to be more beneficial.

In the virtual wheelchair project (Appendix A, 2) navigability of the space was a chief concern, hence real-time interactivity being more important than photorealism and immersion. Several simulation projects of this nature are being carried to make design decisions based on temperature, humidity, air-flow and lighting simulation of spaces in buildings. Design evaluation using the three-dimensional interactive interface on a WIMPy VR proves to be more effective than looking at regular two-dimensional drawings. Reconstruction of demolished or inaccessible or preserved archeological sites is another noteworthy walkthrough application of VR in architecture. The Temenos project (Appendix A, 11) uses VR to provide a more precise and efficient means of acquiring valuable insight into the project for the students, scholars and others interested, which may not be possible through traditional means of representation alone.

The GreenSpace II project at HIT Lab at University of Washington (Appendix A, 1) applies the concept of distributed VR (distant participants present in shared virtual environment) to architectural design, facilitating a remote discussion of the architectural space. Projects like this are proving to be a great asset in getting one's ideas and thoughts across to the service consultants, most of whom are not trained to think spatially like architects but nevertheless, need to have a good understanding of a building for coordinating its service requirements. Virtual design studio based on similar collaborative notions using WIMPy VR with networked connections are being carried out successfully in several academic design institutions and design firms. In all these projects the simultaneity of response and feedback, in other words the real-time interactivity, has been more important than photorealism or immersion.

3. Conclusion

The inherent promise of VR technology in architecture lies in its use as *passive* and *exploratory* systems today. In the examples cited above, it has not only "enabled new possibilities" as in the Virtual Wheelchair project and the GreenSpace project but also "added value to existing possibilities" in architecture as in the virtual reconstruction projects. VR's use in architecture may not be as convincing as the real, due to the present software and hardware technology constraints, however it does enable us to perform tasks that were not possible before or facilitate us to do them more effectively. While much can be expected from future technology developments, such problems are not likely to disappear anytime soon.

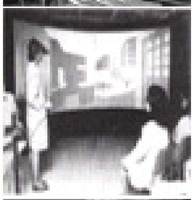
Hence, from our research we found that even with its current limitations, VR has a potential impact on the way we conventionally think and design our built environment, pushing it beyond space and time constraints.

Appendix A:

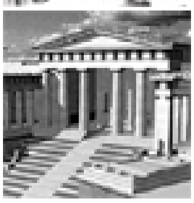
1. Greenspace II, 1993–
http://www.hitl.washington.edu/projects/greenspace
The objective of the project GreenSpace II at HIT Lab at University of Washington was to apply the concept of distributed VR (distant participants present in shared virtual environment) to architectural design facilitating a remote discussion of the architectural space.

2. VirtualWheelchair Simulation, 1994
http://www.cgrg.ohio-state.edu/accad/re-3.html
The project at Advanced Center for Computing in Arts and Design of the Ohio State University proposes to examine the negotiation of spaces by the wheelchair users in a building before it is constructed, hence ensuring design of barrier free environments in order to assure handicapped accessibility to these spaces.

3. Matsushita's Kitchen system, 1994
[Bertol,1997. p. 125]
The project under the Virtual Space Decision Support System was an attempt to include the customer early in the design giving them a realistic estimation of the final kitchen product. The customer could choose from different designs, colors, or materials for the kitchen. This gave prominent publicity to VR and the company, despite mixed results with the product marketing.



4. The Temenos Project, 1995
http://www.reconstructions.org/frames.html
The project is a digital reconstruction of the Athenian Acropolis in the 5th century B.C., using cutting-edge 3D computer modeling methods, done by the Museum of Reconstructions in collaboration with archaeologists at Princeton University and the Greek Ministry of Culture.

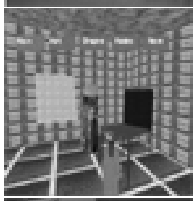


5. ALIVE Project, 1995
http://lcs.www.media.mit.edu/projects/alive/
The project, though of entertainment value, has significant implications on the collaboration and communication process in architectural design, practice and education. With the aid of virtual reality system, the project enables communication between people separated by physical distance on the same lines as ‘teleimmersion’.

6. Lascaux Project, 1996
http://www.daap.uc.edu/CERHAS/benb/lascaux.htm
LASCAUX was the first PC-based heritage reconstruction project undertaken by Prof. Benjamin Britton of the College of Design Architecture Art and Planning at the University of Cincinnati. It is a virtual reconstruction of the famous ancient, painted, French cave at Dordogne, France.

7. Sitterson Hall Project, 1996
http://www.hitl.washington.edu/scivw/EVE/II.C/
VR was used to design better environments for disabled wheelchair occupants and other users of the Sitterson Hall building at Graphics and Visualization Centre, University of North Carolina, Chapel Hill.

8. Conceptual Design Space, 1996
http://www.cc.gatech.edu/gvu/virtual/DVE/DVE.html
The project undertook the creation of conceptual building designs through real-time, interactive virtual environments while being immersed in the virtual world at the Graphics, Visualization and Usability Center at Georgia Institute of Technology.



9. Augmented Reality for Construction, 1996–
http://www.cs.columbia.edu/graphics/projects/arc/arc.html
The project at Computer Graphics and User Interfaces Lab at Columbia University is a demonstration testbed for building construction, maintenance and renovation. Augmented reality construction system is designed to guide workers through the assembly of a spaceframe structure, to ensure that each member is properly placed and fastened.

10. Responsive Workbench, 1997
http://www-graphics.stanford.edu/projects/RWB
The workbench is being used at Stanford Computing Graphics Lab at Stanford University for site planning and design detailing. A virtual model derived from CAD plans for a new building is displayed on the workbench where existing design can be evaluated and new design aspects can be investigated.

11. Detroit Midfield Terminal Project, 1997-
http://www-vrl.umich.edu/NewMidfield/index.html
In cooperation with Northwest Airlines, the Virtual Reality Laboratory (VRL) at the College of Engineering at the University of Michigan developed a virtual model for the Detroit Midfield Terminal Project to assist in design evaluation and to support a complex decision making process.

12. Virtual Architecture Design Tool, 1999
http://www.vrac.iastate.edu/research/architecture/index.html
The project at Iowa State University's new Virtual Reality Applications Center (VRAC) examines the prototype of an immersive environment for interactive architectural design. This new approach allows architects to gradually build models in a virtual environment at various scales enabling direct design exploration as it is being developed.

References

Anders, P.: 1999, Envisioning Cyberspace : Designing 3D Electronic Spaces, The McGraw-Hill Companies Inc., New York.

Baker, P.: 2000, Visualization Spaces, Computer Graphics, November, Vol 34, No.3, 8-10.

Bar-Zeev and Jacobson.: 1994, Looking Back: A Retrospective Of Virtual-World Industry From The Year 2010, Computer Graphics World, May, 30-35.

Benedict, M. (ed.): 1991, Cyberspace: First Steps, The MIT Press, Cambridge, pp. 243.

Bertol, D.: 1997, Designing Digital Space, John Wiley and Sons Inc., New York.

Betsky, A.: 1997, Machine Dreams, Architecture, Vol. 86, No.6, 88-91.

Brooks : 1999, What's Real About Virtual Reality, IEEE Computer Graphics and Applications, Vol. 19, no. 6, Nov/Dec, 27.

Chesher, C.: 1994, Colonizing Virtual Reality: 1984-92, *Cultronix*—Volume 1, number 1. retrieved 14 September 2001 http://www.eserver.org/Cultronix/chesher/

Engeli, M.: 2001, Bits and Spaces: CAAD for Physical, Virtual and Hybrid Architecture at ETH Zurich, Birkhauser Architectural.

FakeSpace: 2000, Product Line, Domestic 48 states and Canada, Educational Price list. Sept.

Herzberg: 1968, Architects Open Computer Dialogue, New York Times, VIII, 1:7 April 21.

Hibbard, B.: 2000, Confessions of a visualization skeptic. Computer Graphics. August. Volume 34, No3, 11-13.

Jain, R.: 2001, Digital Experience, Communications of the ACM, March 2001, Vol. 44, No.3, pp. 40

Lanier, J.: 2001, Virtually There, Scientific American, April.

Lingard, B.: 1995, Human Interfacing Issues of Virtual Reality, retrieved 14 September 2001, <http://www.cs.wpi.edu/~matt/courses/cs563/talks/brian1.html>

Mitchell, William J.: 1995, City of Bits, MIT Press, Cambridge.

Negroponte, N.: 1970, The Architecture Machine: Toward a More Human Environment, MIT Press, pp. 35.

Negroponte, N.: 1995, Being Digital, Alfred A Knopf, New York, pp. 92.

Ohta, Y. and Tamura, H. (ed.): 1999, Mixed Reality, Mixing Real and Virtual Worlds, Ohmsha Ltd., Tokyo.

Pape, Dave.: 2001, CAVE Users guide, retrieved 14 September 2001 <www.evl.uic.CAVEGuide.html >

Pimentel K. and Texeira K.: 1995, Virtual Reality Through the New Looking Glass, 2nd edition, Intel/McGraw-Hill.

Schmidt, G.: 1993, Virtual Reality in Architecture, in Virtual Worlds and Multimedia, John Wiley and Sons Ltd., pp 85-97.

Sherman, B. and Phil J.: 1992, Glimpses of Heaven Visions of Hell. Virtual Reality and its implications. Hodder & Stoughton, London.

Steve, A., Blatner, D.: 1992, Silicon Mirage The art and science of virtual reality, Peachpit Press, Inc., Berkeley.

Van Dam, Forsberg, et all.: 2000, Immersive VR for Scientific Visualization: A Progress Report, IEEE Computer Graphics and Applications, Vol. 19, no. 6, Nov/Dec, 26-52.