Possibilities and Constraints of using Virtual Reality in Urban Design

Mostafa EL ARABY

Ph.D. Mostafa El Araby, Associate Professor, United Arab Emirates University, Department of Architecture, BO Box 17555, Al Ain, UAE, melaraby@aueu.ac.ae

ABSTRACT

This study aims at exploring the rapid growth of the use of Virtual Reality techniques in the field of Urban Design. Currently, Virtual Reality —the ultimate representation— and Virtual Environments are the most growing fields of information technology and have a great media attention. This research discusses the possibilities and limitations of applying Virtual Reality (VR) technology in environmental simulations for urban design practice. There is evidence to suggest that the use of such technology will enhance conceivable image of any proposed project at any urban setting for users, designers and clients. Therefore, city officials and administrators (clients) and the public (users) can reach better decisions regarding proposed projects within their towns and cities.

Specifically, this research structured in several interdependent parts: the first part is concerned with the definition of VR as well as a background of its history and current achievements. Types and components of VR systems are described and traditional simulation techniques are reviewd. In addition, a discussion of current attempts in incorporating VR in urban design disciplines are presented. This discussion raises the question of appropriateness of the VR techniques in urban design projects. An assesment of both potentials and limitations of aplying this technique, i.e. VRML (Virtual Reality Modelling Language), are discussed. This study defines potentialities, constraints and problems of using this technique, and recommends future research efforts in the field of using the Virtual Reality as a medium for delivering real content for those interested in the design of the built environment.

1. INTRODUCTION

Virtual Reality (VR) has received an enormous amount of publicity over the past few years. Potentials of VR applications have been realised in many disciplines. VR with its increasing dynamic, interactive and experiential characteristics becomes able to simulate real environments with various degrees of realism. The potential of visualisation in the planning and design of the built environment is very significant. The ability to represent, model and evaluate changes to the built environment on the computer desktop and over the Internet offers potential to enhance the planning and design process; and also help communicate ideas and developments to the public at large.

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1.1 Definition and Characteristics of Virtual Reality

There is almost no standard definition to the term Virtual Reality. Taken literally, the meaning of "Virtual Reality" from the "Shorter Oxford English" Dictionary definitions is "not formal, or actual, but something which is real, or has actual existence". It has been defined it as the illusion of participation in a synthetic environment rather than external observation of such an environment Regenbrecht & Donath (1997) have defined it as “…the component of communication which takes place in a computer generated synthetic space and embeds human as an integral part of the system…”.

Sherman and Judkins (1992) describe the characteristics of this technology as "VR's five 'i's : intensive, interactive, immersive, illustrative and intuitive." These critical characteristics of VR seem to be a good starting point for a definition of this technology. Moreover, without one or more of these characteristics there is no VR.

In order to expand on the above definition, the "VR's five "i's" will be briefly explored below.

Intensive

In Virtual Reality the user should be concentrating on multiple, vital information, to which the user will respond.

Interactive

In Virtual Reality, for the user and the computer to act reciprocally via the computer interface.

Immersive

Virtual Reality should deeply involve or absorb the user.

Illustrative

Virtual Reality should offer information in a clear, descriptive and (hopefully) illuminating way.

Intuitive

Virtual information should be easily perceived. Virtual tools should be used in a "human" way.

1.2 Development of Virtual Reality

Virtual Technology is not a "new" idea, rather it can be shown that it is a technology which has evolved from other technologies (Krueger, 1991; Sherman and Judkins, 1992). In late 1920s Edwin Link worked on vehicle simulation, arguably the first forerunner of Virtual Reality technology. By the 1940's Teleoperation technology began. In 1954 "Cinerama" was developed using 3-sided screens. Actual roots of virtual reality began at 1962s with the Morton Heilig's ill-fated "Sensorama" and the development of teleoperation displays using head-mounted, closed-circuit television systems by Philco and Argonne National Laboratory (Sherman and Judkins, 1992).

By late 1960s Ivan Sutherland pioneered the development of synthetic computer-generated displays used for virtual environments. The cold war required numerous military investigations during the 1970s and added major contributions to the field of virtual reality by the development of flight simulators by NASA. In the mid 1980s "NASA" presented "VIVED" (Virtual Visual Environmental Display), and later the "VIEW" (Virtual Interactive Environment Workstation) (Gigante, 1993). In 1984 William Gibson published the term "cyberspace" in his book, "Neuromancer", and in 1989 Jaron Lanier, founder of VPL Research, coined the term "VIRTUAL REALITY" to encompass all of the "virtual" projects eg. "virtual worlds", "virtual cockpits", "virtual environments" and "virtual workstations". During the 1990s virtual reality was perceived as the 6th generation of computer evolution in which no barrier exists between the user and the machine.

During the last decade there have been continued research for the specific use of VR in modeling, communication, information control, arts and entertainment. Finally, One of the reasons that VR has attracted so much interest is that it offers many benefits to many different areas of applications. Examples include operations in hazardous or remote environments, scientific visualization, architectural visualization, design, education and training, computer supported co-operative work, space exploration, and entertainment. (Gigante, 1993). Recently, there has been a need to visualize ideas of planning and design of the built environment before establishment.

1.3 Virtual Reality Types

Virtual Reality could be classified into two main types according to the degree of immersion and interface in the synthetic environment (Mahmoud, 2001). The two types include Immersive and non-immersive Virtual Reality systems, Fig. (1). Morgan and Zampi (1995) have explained Immersive VR as "…*an application in terms of quasi-physical experiences*..." In such experiences, fuller contact between users and the virtual space is maintained. Examples of these VR interactive experiences could be achieved by using data gloves and multi-media head mounted display devices (HMD). Non-immersive VR, e.g. screen based VR or Desktop VR, enables users through screen interface using special tools, e.g. eye glasses, to feel the simulated spatial environment. Current screen based VR systems include "Division", and "Superscape" software.

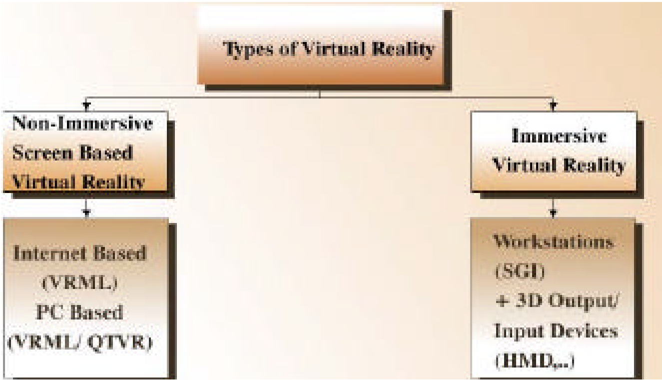


Fig. (1) Types of Virtual Reality Systems (Mahmoud,2001)

A recent emerging type of Virtual reality is the network VR. It is a result of the massive progress in the Internet and the World Wide Web in particular. Campbell (1996) indicated that the technology of Virtual Reality and the Internet continue to integrate, as the online culture is now the fastest growing demographic on the planet. The standard virtual reality format on the web is VRML (Virtual Reality Modelling Language) or (Virtual Reality Mark up Language) created by "Silicon Graphics Inc." VRML, as a phenomenon that is universally accessible, hyper-linked, is becoming common place on the World Wide Web. It is a file format for describing 3D interactive 3 dimensional virtual environments. It is capable of representing static and animated objects and it can have hyperlinks to other media such as sound, movies and images. (VRML 2.0, 1998)

1.4 Components and Construction of Virtual Environments

Components of a virtual reality system include effectors, reality simulator, application, and geometry. Effectors are any type of interface device that provides access to a virtual environment examples include head-mounted display devices and data gloves. Reality Simulator is the hardware that supplies the effectors with the necessary sensory (visual or acoustic) information. Application is the software that describes the context of the simulation. Geometry is the information that describes the physical attributes of objects in the virtual environment. Basically geometry is built by CAD software.

Construction of the virtual environment passes through three main phases: modeling, rendering, and real time interactive presentation using system effectors. Fig. (2). Modeling is the process of building the geometry and physical attributes of objects that constitute the virtual environment using CAD software. Rendering is defined as the process that includes applying texture maps, defining lighting parameters (Grabowiski,1996) and defining design materials. Time of rendering depends on quality of rendering, complexity of the model, and speed of computer hardware.

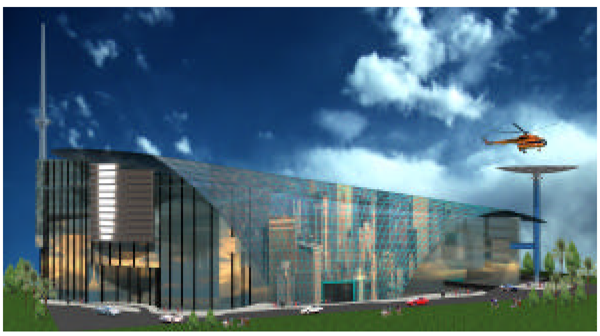


Fig 2: Construction of Virtual images for a residential complex and a shopping center (by author)

2. INCORPORATING VIRTUAL REALITY IN URBAN DESIGN

Urban Design is a multi-disciplinary area requiring an understanding of how to best use spaces in an urban setting, and taking into account the impact of traffic (people and all forms of transport). The success of "Virtual Urban Design" can be measured in the following ways:

- It's ability to convince the client (ie. the public, regulating bodies, and lobby groups), that the proposed urban guidelines can be successfully implemented.
- It's ability to convince the urban designers that models and simulations are realistic and accurate, and that VR can be used as a powerful and useful tool in urban design.

To do this "Virtual Urban Design" will be required to realistically simulate data including traffic flow of people and transport. Databases could be set up which include this constantly changing information.

VR and Urban Design could involve the use of "virtual models" in the following ways:

- To model proposed urban "guidelines" for newly developed areas. For example, different housing proposals could be compared for a vacant city block.
- To model existing urban precincts which require constant reappraisal.

For example, "Virtual Urban Designers" could walk through urban spaces and see how they might be better used. City commercial spaces may be replaced by urban dwellings and carparks with the changes brought on by "virtucommuting" (Sherman and Judkins, 1992).

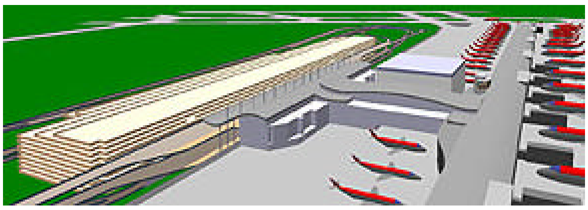
2.1 Current attempts to use VR in Urban Design

There is a flourishing of a substantial number of "Virtual Cities" on the web. There are two types of virtual city "non-grounded" and "grounded" (Aurigi, 2001). The main characteristics of the former are that they represent a space that is completely independent from real space (Okeil, 2001). On the contrary, "grounded" virtual cities present direct links to real cities. Amsterdam, London, Manchester, Berlin, Paris, Michigan, Los Angeles and others are examples of sophisticated cyber cities that are useful for planning education (Okeil, 2001) and design. As of upper July 2001, combined site searcing for the words city, cyber and virtual reality on major search engines returned 460 highly matching hits. The following table summarizes the results.

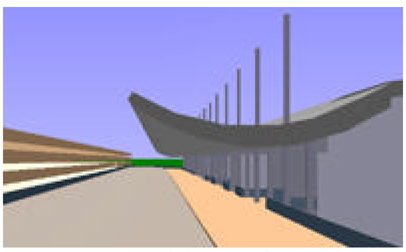
Site type	Number of cases
Document type source	287
Two dimensional sites with maps	132
Three dimensional model	41

Table 2: Type of Virtual Reality and Cyper City Sites of the Web

Other projects used virtual reality for visualization and modeling of small scale urban environments. Powerful computer graphics have already been used to model, for example, London city center, London Underground and Highways, Wolver Hampton Central city, Detroit Midfield Terminal Project and others (Dodge et at., 1997; UMVRL, 2001; Whyte & Bouchlaghem, 2001). These models would make it easier to communicate the more complex variables involved in urban design so that solutions can be tested more thoroughly. A major benefit of the virtual models Is the capability to navigate in real-time through the proposed design (walk, fly, drive, and look around) and explore the many aspects of the design in three dimensions. One of these examples is a virtual model for the Detroit Midfield Terminal Project (Fig. 3) that was developed by the Virtual Reality Laboratory (VRL) at the College of Engineering at the University of Michigan in cooperation with Northwest Airlines to assist in design evaluation and to support a complex decision making process.



International/domestic departure Domestic arrival



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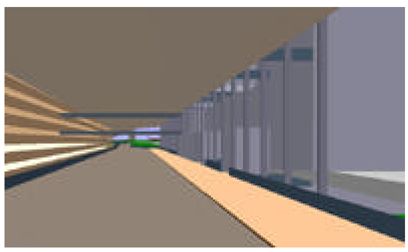

Domestic arrival

Fig 3: Virtual Images of Detroit Midfield Terminal (UMVRL, 2001)

A three-dimensional computer model that can be modified quickly and adapted to changing design objectives was recognized as an extremely helpful tool in assisting architects and project engineers with evaluation and analysis tasks. The virtual model is equipped with various controls allowing for an efficient generation of design alternatives. Once a three-dimensional computer model has been created, it can also be viewed using immersive virtual reality technologies like Head-Mounted Display devices or the projection-based CAVE system. Such systems provide a realistic, full scale representation of the environment and include stereoscopic viewing (UMVRL, 2001).

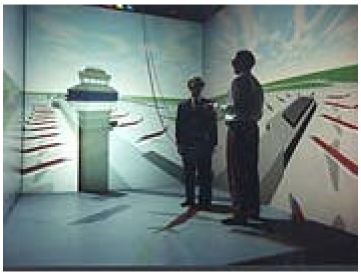

Fig 4: Viewing the Midfield Terminal in an immersive CAVE system (UMVRL, 2001)

In next example, some simple block buildings at Horse Gaurds Parade area, London, with trees and phone boxes have been sketched in 2D in Arcview. The building block outlines are stored and represented as 2D polygons in the GIS. Each polygon also has attributes that determine its colour and height in the 3D VRML model output. In the sketch as also trees (green stars) and phone boxes (red squares). These are part of a library of useful points features that is being implemented (CASA, 1998). The user can then view the 3D model in the VRML viewer of choice. The pictures below show the 3D model from different positions.

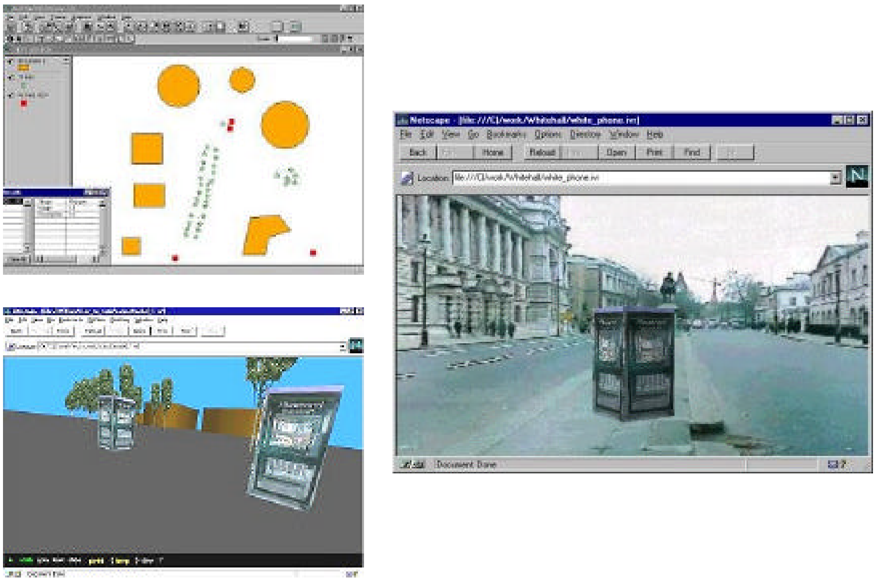

Fig 5 : RealVR / VRML object placement (Horse Gaurds Parade, London) (Dodge et at., 1997)

In the next example, which is developed by the Centre for Advanced for Spatial Analysis, University College London, a rather more realistic set of urban features are visualised in 3D. The building block outlines for the central area of Wolverhampton are shown in 2d in ArcView. These were derived from Ordnance Survey base data by removing building subdivisions and line vertex generalisation. This was necessary to produce a 3D VRML model small enough to be usable in PC-based VRML viewers (CASA, 1998).

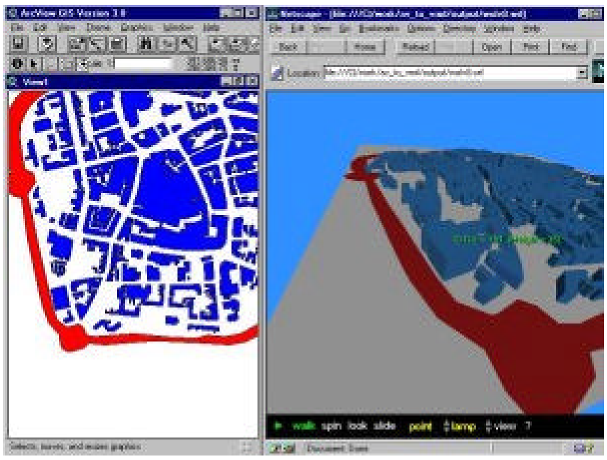

Fig 6 : 2D / 3D sketch design and visualisation of urban form of central Wolverhampton (Dodge et al., 1997)

Each block was assigned a height attribute in ArcView. The red polygon around the outside is Wolverhampton's ring road. The two other pictures below show views of the 3D model in Live3D (CASA, 1998). Fig. 7.

Fig. 7: Developing visulaization images for the central area of Wolverhampton (CASA, 1998)

The previous examples showed that the use of GIS and web-based VR technologies have significant potential as visualisation tools for use in the planning and design arena. As these powerful software visualisation tools become widely available on the WWW the potential exists to undertake networked urban planning and design, which may be particularly applicable to widening public consultation and participation in development projects (Dodge et al., 1997).

2.2 Appropriateness of Using VR in Urban Design

The previous sections of this paper depicted that using an appropriate Virtual Reality, with its potentialities in visualization, can provide urban designers with a powerful tool to enhance the design process.

Potentials

The new technique has the potential to enable designers to increase their imaginations by visualising their hidden intentions and thoughts. It can help both clients and users to understand what designers invent, hence to communicate easy with professionals (Mahmoud, 2001). The use of GIS and web-based VR technologies have significant potential as visualisation tools for use in the planning and design arena (Dodge et al., 1997). Using the Internet-based VR can make design process universal, as many designers can collaborate in one project regardless their place on the planet. The use of internet-based VR also enhance public participation in the planning and design processes.

Clients and users can explore their buildings and cities while they are at home using the Internet network or a CD-ROM. The promise of VRML is still not totally discovered and further research is still needed. As the VR technology develops, the interfaces will become more simplified, and VR will achieve its goal to become "…a transparent medium of communication…" (Campbell, 1996).

Encountered Problems of using VR in Urban Design

Many attempts were made in discussing how to apply Virtual Reality in urban design (Campbell, 1996; Campbell & Davidson, 1997; Dodge et al., 1997; Reeve et al., 2001; Whyte & Bouchlaghem, 2001 and others). Encountered problems include high cost of adopting the technology, display realism problems, limitations of hardware and the need for physical constraints (Campbell, 1996; Dodge et al., 1997; and Papper & Gigante, 1993). Furthermore, the new technology has psychological, behavioural, and social effects on societies. Nevertheless, most of these studies agree that the potential of using Virtual Reality for visualization of the built environment planning and design is significant.

One of the major factors that affect the feasibility of Virtual Reality is cost. Until recently, Virtual Reality manipulation has been almost private for powerful high-end workstations like "Reality Engine" from "Silicon Graphics". The problem is that it may be too expensive to be widely used outside large universities' labs. Most of the mentioned above studies used such expensive hardware. The visualization and modeling of urban environments needs extensive use of integrated softwares to include geographical information systems (GIS), digital drawings (CAD), multimedia data and World-Wide Web based virtual reality techniques (Dodge et al., 1997). The question is how can ordinary urban designers make use of Virtual Reality. In a survey conducted by the University of Loughborough into using VR in United Kingdom (between 1994 and 1997) it was clear that the majority of VR systems are desktop PC based - Fig. 8 (cited by Mahmoud, 2001).

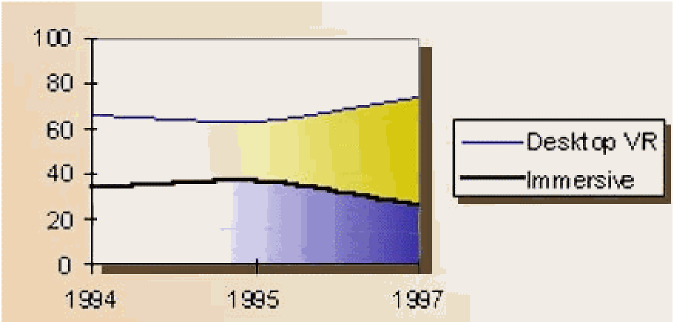

Fig. 8: The use of VR Systems in United Kingdom (Loughborough, 1997 after Mahmoud, 2001)

It was suggested that a powerful PC based system could produce VR if we eliminate the need for a stereo-scopic system and use a mono-scopic system instead. It could be concluded that Desktop VR tend to be more appropriate in terms of affordability and possibility of wide use (Loughborough, 1997). VRML could be suggested as a future Desktop VR simulation technique (Mahmoud, 2001). VRML browsers, e.g., “CosmoPlayer 2.0” from “SGI”, are available on the Internet for many different platforms.

Social and physiological side-effects of using VR in urban design

Campbell (1996) thought that social relationships and interactions would be dramatically altered as the transfer of information and images comes to substitute the movement of mass. People may come to communicate with others around the world with a realistic medium. VR will serve to shift from personal to electronic communication (Mahmoud, 2001). Principles of environment behavior including cognitive maps and territoriality are well-researched areas that are fundamental to one's perception of space and place. Socio-cultural perceptions, symbolic meanings of form, and “…the degree to which the formal and metaphysical character of a space can influence one's mood or behaviour in a space…” are all issues that could emerge from the physical realm to the virtual one. (Campbell, 1996).

2.3 Future Applications of VR - The Built Environment

The ability of VR to persuade and convince authorities could potentially be much greater than the presentation means currently used by architects, developers and builders. Planners could adopt this technology for shaping the built enviorment. It is worth remembering that VR technology is a synergy of many other technologies, including Computer Aided Drafting (CAD) and Human Computer Interface(HCI) technologies. One effect of VR on the built environment will be the reduced need for buildings due to more people tele/"virtu"-commuting (Sherman and Judkins, 1992). Commercial buildings in particular will be reduced because tele-commuting, or even better, "virtucommuting" will bring the workplace to the user. Already a large amount of banking is carried out via telecommunications. Administrative and consultation work, sales and writing/publishing are obvious examples. Design and architecture are also suited to this application (Sherman and Judkins, 1992).

Service oriented buildings such as shops will be reduced since these services have the potential to be carried out in the convenience of your own home on "home reality machines" (Sherman and Judkins, 1992). In theory, the number and size of service buildings, including colleges, churches, medical buildings, banks, travel agents and theatres could potentially be reduced by the commercial use of Virtual Reality. Another impact on the built environment would be in the area of domestic design. Today residential plans tend to include a space for the computer, however VR will probably have special requirements relating to provision of space for different VR activities. VR is already been utilized for evaluation and commersializtion of residential development in the United Kingdom (Whyte & Bouchlaghem, 2001).

3. CONCLUSION

As has been shown on this paper, Virtual Reality could have a tremendous impact on the future of urban designers, cities and society in general. This paper has demonstrated several academic research projects in the field of planning and design where the technologies are being applied. As these powerful software visualisation tools become widely available on the WWW the potential exists to undertake networked urban planning and design, which may be particularly applicable to widening public consultation and participation in development projects (Smith & Dodge 1997).

Some of the possible benefits of Virtual Reality on the design process and practice of urban design are:

- The ability to test ideas in "real time" in a "three-dimensional" space during the design process.
- Communication of ideas, and the power to convince authorities.
- The elimination of much of the guesswork in design.
- Braver and better designs.
- The integration of the design process.
- Increase public participation and involvement of designing urban settings.

Some of the foreseeable problems of Virtual Reality in urban design could be:

- The computational power required might be so great and expensive that very little might be achievable in urban design practice.
- High cost of adopting the technology might hinter the ability of small firms and ordinary urban designers to use the VR techniques in their designs and projects.
- Technical shortcomings of various VR systems could be a problem. At present "desktop VR" does not fit the definition of VR as described in this paper, mainly because of technical problems which have yet to be solved.
- It may never be a medium which offers the speed of hand sketching to visualise in 3D.

Virtual Reality requires future research to answer many questions before it can be used effectively in urban design or any field. These questions are technical, conceptual and social. Further research is needed in the field of visual perception of the virtual environment. Systematic research is needed to prove the reliability and validity of the new technique.

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