Real Teaching and Learning through Virtual Reality

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This paper addresses an articulated vision of Virtual Reality, which lends itself to design collaboration in teaching, learning and communication of architectural design ideas among students, design professionals and client bodies during the early stages of the design process. Virtual Reality (VR) has already acquired a new degree of complexity through development of network-based virtual communities and the use of avatars. A key intrinsic quality of VR technology is to support collaborative design experience.

The design tools developed for this experiment are capable of creating 3D objects in a shared VR environment, thus allowing the design and its evolution to be shared. The choice of programming language (JavaTM) reflects the desire to achieve scalability and hardware independence, which in turn allows for the creation of a VR environment that can co-exist between high-end supercomputers and standard PCs. The prototype design environment was tested using PC workstations and an SGI system running in a Reality Centre.

1. Introduction

In recent decades the design profession has been deeply affected by the digital revolution, and the use of Computer Aided Architectural Design (CAAD) tools is now part of the daily practice in most architectural firms. But in the last few years the CAAD community has been experiencing a new revolution that is leading the move from static representation, based on 2D renderings or pre-recorded animations (effectively as a sequence of 2D images), to dynamically generated 3D representations. Real-time navigation and interaction, typical of VR environments, potentially, provide fluency of interface that can enable an exploration of the design proposals that architects have not been able to get with any other media.

The increasing growth of computational resources and hardware power is promoting the anticipated transition to desktop VR applications, making them truly feasible tools for everyday practice. Furthermore, the recent growth of network-based virtual communities has brought a new level of capability to the notion of virtual spaces, and offers the profession of architecture the opportunity of designing virtual worlds.

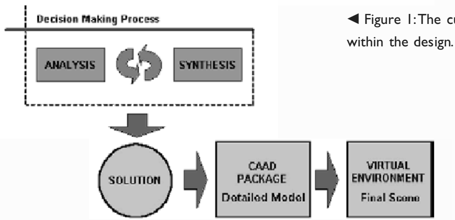
Although VR is nowadays a quite mature technology, it is seldom used in architecture throughout the design process. More often it is merely used as a powerful presentation technique. Design methodologists in the past agreed on the need for iterative cycles between several phases of the design process. From studies concerning designers' behavior many authors observed an indefinite number of return loops from the moment when gathering information and structuring the design problem takes place (known as analysis) to the one when design solutions are generated (known as synthesis) [1].

The use of Virtual Reality within the design process potentially provides the designer with appropriate, quick and practical feedback, which facilitates search for design solutions. Moreover, it enables the capture of more information than would be possible with the use of the traditional media and can make the checking of design solutions more efficient by enhancing simulation capabilities. The use of VR in design broadens the boundaries of traditional perception by providing experiences of worlds not necessarily real or material. In short VR has the potential to be a particularly effective simulation medium for architects investigating design solutions.

It is then highly predictable that in the near future VR will become the interface for the next generation of computer aided design (CAD) applications and we can anticipate the change of its use from a mere presentation medium to a powerful and effective design tool [2, 3].

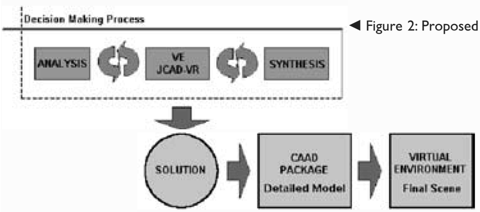
At present Virtual Environments (VE) are often created using CAAD packages for refinements, adjustments and exportation based on traditional 3D scenes. Documenting the evolution and development of design by constant updating of 3D models is an expensive business, and obviously even more expensive is the upgrading of the VEs generated from these models. In most existing design scenarios the decision-making process does not take advantage of the technology, but relegates the use of VR to the end of the process as a more convincing tool to impress other protagonists such as contractors and clients. In such a scenario, only once the final solution has been achieved is it worth investing time into more powerful visualization media.

With this background knowledge the research task addressed by the authors was to develop a VR system, which would help designers in the initial stages of the design process to take advantage of VR as a new design tool [4, 5].



◀ Figure 1: The current position of VR within the design.

The system, named JCAD-VR, provides a flexible user-friendly immersive (and non-immersive) environment to support collaborative design on a synchronous basis. It can be thought of as an investigation tool that allows the designer to freely sketch 3D objects within the virtual context. Moreover design solutions are shared in a synchronous fashion with other participants through the system's network-based architecture. Figure 2 shows the proposed scenario for using JCAD-VR within the decision making process.



◀ Figure 2: Proposed scenario.

Here JCAD-VR provides the means for a more effective use of VR, bridging between the phases of *analysis* and *synthesis*. VR is thus employed at the very beginning of the decision-making process when it is most likely to help in finding better design solutions. Once a desired solution is achieved the task of the creation of a very detailed 3D model and the final VR scene is given to appropriate CAAD packages. Moreover the participants are able to investigate design solution through concurrent design and synchronous collaboration.

2. JCAD-VR: The system architecture

The two ideas upon which JCAD-VR is being built are:

- That all the users present in the virtual world have to be able to share the same virtual environment in a "transparent" fashion.
- The user interface, instead of the traditional menu/windows based layout, is part of the virtual world itself. Any element of the interface becomes an object belonging to the 3D world and therefore it is treated as any other object. Each element of the interface can then be moved or scaled according to the user's needs.

The entire project is based on a client-server architecture where every user logs into a virtual world and starts sharing design tasks with other users.

JCAD-VR is organized in an object-oriented fashion, where each module is able to fulfill a certain task and is independently coded. This approach allows the delivery of an initial functioning core of the JCAD-VR system, which will be expanded in the near future by adding several modules currently under development.

The system has been entirely developed around a client-server architecture to allow constant synchronous collaboration between several users. Every user accesses the virtual world, interacts with the VE and shares design tasks.

3. The collaborative approach

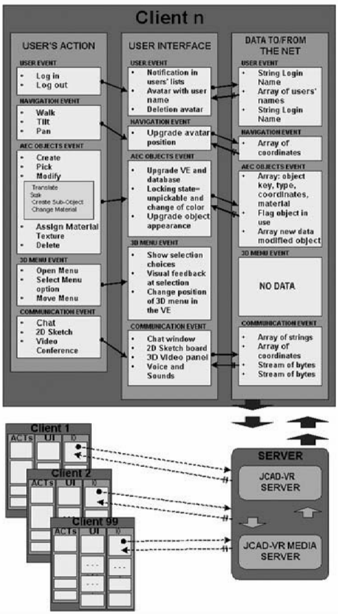
When JCAD-VR is initiated, the user is asked for a login name for the session. Through an options panel the user can decide which server to connect to and through which server port. This login name is used to identify participants and to communicate within the virtual world.

The system can be initiated in single mode or multiple screen mode. Single mode is set for the display device, which consists of a standard computer screen; the multiple screen option has been included to allow display via devices such as the multi-projector display system processing the visual output of a Reality Centre, which was used in the experiments.

In this phase it is also possible to activate or de-activate video conferencing facilities for the session. In instances when video conferencing is activated, support for video capturing device recognition and checking is provided. JCAD-VR also provides a stand-alone option in case collaboration is not required.

Once the system is initialized, every window disappears freeing the space for the 3D graphic user interface (GUI) of the system. A set of 3D menus and icons appear on the screen and through them each user can interact with the system and with the other participants. A number of functions can be accessed through these menus, such as navigation and creation of objects. A number of 3D shapes and 3D AEC objects can be created and shared with other participants. The objects created can include the following: geometric primitives (such as cones, boxes and spheres) and architectural entities (such as walls, doors and windows). The system routinely checks for constraints and allows only appropriate modifications; for example a door cannot be moved onto or too close to another door. A "3D ruler" and a 3D panel close to the object are constantly providing the user with feedback related to the parameters that can be edited such as size, materials and cost.

The architecture of the system has been developed to allow every object created in the system to be assigned a unique identity (ID)-number. The ID is a combination of a local ID and a user ID assigned by the server. In this way each object is attributed a unique number consistent for all the users in the system. When the user selects any object, this object is *locked* and such an event is sent through the network to other users. Every time the user is about to modify an object this is checked against a network lock mechanism. This mechanism ensures that several participants are not editing the same object at the same time and is designed in order to ensure consistency throughout the system. The system notifies every user's internal database of any creation or modification of geometric objects within the virtual scene and broadcasts the appropriate numerical information.



◀ Figure 3: Client/Server Architecture of JCAD-VR.

To ensure good communication between users, represented in the 3D world by avatars, different means are provided, from basic chat to voice and video conferencing. Freehand sketching in 2D is also possible through a shared electronic whiteboard.

4. The interface

Besides the functions provided by the system a great deal of attention has been paid to the visual interface. The GUI is part of the virtual world itself.

This choice was made for two main reasons. From the technical point of view once the interface has been designed, it becomes independent from the visualization device used. The system can therefore be adapted easily to different devices by a simple rewriting of the code that is handling the device; no matter whether the system is running on a simple screen, on a Reality Center or linked to an head mounted display – the interface will always be in place.

Furthermore, from a more theoretical point of view, the interface becomes one of the elements of the virtual world and therefore it can be treated as any other object. Elements of the GUI such as panels, icons, rulers, are treated just like any other 3D entity within the VE. For instance, in the case of the video conferencing panel, the video coming from the other users is continuously rendered as a texture on a 3D panel.

All these elements can be replaced, dragged, re-scaled for the convenience of the user and this can promote the impression of a higher degree of immersion. The user interacts with the objects through elements of this interface, such as arrows placed to help edit the object. Feedback is provided through the visual modification of the object itself in the scene. The 3D engine renders all the possible changes within the VE: movements of avatars, video conferencing streams rendered on 3D panels and, most importantly, creation and modification of objects created within JCAD-VR.

5. Server package

The server consists of two parts: a module which looks after the VE information to be broadcast, and another module which takes care of media streams and video conferencing tools. Both parts constitute a server system and they are closely linked to each other.

As an independent part of the framework the server has an autonomous and simpler interface that provides information about the network status and transfer rate. A number of components of this interface are envisaged such as the communication status, the users on line, VR shared environments and the quality of the broadcast video for conferencing. Since the clients are communicating through independent processes, a future enhancement will allow the server to deal with several VR environments simultaneously.

The intrinsic multi-platform nature of JCAD-VR, inherited from the language used for coding, allows the server to transmit data to a broad range of platforms, from conventional PCs to a supercomputer running a

Reality Centre, and leaves the research team the freedom to test the software with several operating systems. The communication channel ensures the link between server and clients through a TCP/IP network.

◀ Figure 4: A screenshot from JCAD-VR.

6. System implementation and hardware used

The whole framework of JCAD-VR has been organized to allow concurrent software development, in a modular fashion, by individual members of the R+D team. To facilitate this, an object-oriented approach was identified as the most suitable one and the entire system was coded in Java™ [6, 7].

The choice, even if less efficient in term of performance compared with other possibilities, offered great flexibility, true scalability and, last but not least, fully multi-platform support. Its network-centric nature, its multimedia integration together with the use of native graphic hardware and multi-processor support made it the obvious choice for the development of such a real-time multimedia collaborative system.

The client application, in response to the obvious hardware limits imposed by the use of different hardware, has been written so that it can be easily customized to run on PCs as well as on Sgi supercomputers. The former are conventional PCs whose video-card displays the virtual world only in a traditional window or at full screen. The latter is a 12-processors Sgi Onyx2 system running the Reality Centre at ABACUS, University of Strathclyde, Glasgow. When JCAD-VR is launched on the Sgi it can take advantage of its computational power to stretch itself on a 5 metre wide 2 metre tall tessellated screen where 3 Barco projectors create a 160 degree panoramic image.

The internal architecture of JCAD-VR is such that modules might be easily adapted to allow use of different VR devices such as CAVEs or Head-Mounted Displays, as well as several pointing devices such as a joystick, 3D mouse and VR Gloves. Further developments will include support for some of these devices.

From the collaborative point of view JCAD-VR is highly scalable and several communication media options are provided depending on the hardware limitations of the computer on which it is running.

The video conferencing facility has been coded using the JavaTM Media Framework (JMF), which enables cross-platform capture, playback and streaming of audio and video at different transfer rates and resolutions. The research group has expended a great deal of effort to integrate the 3D module with the multimedia module.

► Figure 5: JCAD-VR during an experiment of collaborative design.

7. Trials of the system

The prototype JCAD-VR system has been subject to two trials using architectural students.

7.1. Trial 1

For this initial trial a demanding brief was used. Students had five weeks to design a Sailing Club for the Disabled on a canal site in central Glasgow; a real client community set the brief and was involved in the assessment of the design outcomes.

Within the overall JCAD-VR system, students were encouraged to use, initially, a standard CAAD package for creation of the geometry and then to develop the design using VRML. Event management in their virtual worlds was done through the use of sensors and connectivity; these include touch sensors, proximity sensors and time sensors. For the purposes of this trial, students worked independently.

The outcomes were judged by the client group to be exceptionally good in terms of the students' sensitivity to the particular design issues associated with wheelchair users. These encompassed issues including automatic door opening, positioning of light switches, the transparency of balustrades and the angling of window louvers in relation to the line of sight of a wheelchair user and the treatment of level changes.

Quite clearly the experience of designing from within the virtual world contributed substantially to design quality. A further bonus was the ability to accompany the (student) architect on an interactive "visit" to the virtual building.

7.2. Trial 2

For this trial, all of the functionality of JCAD-VR (with the exception of video conferencing) was tested. Three (volunteer) students were physically located separately in the building, each at a workstation of different specification. Their task was to collaboratively design an information pavilion on a site located in a virtual representation of Glasgow's city center. In the absence of video-conferencing they had to communicate with each other through text dialogues (on-line chat), 2D sketching and 3D modeling within the virtual world. *All* the design creation was carried out, collaboratively, from *within* the virtual world with the only constraint being that while Student A was creating, modifying or moving object X, that object was unavailable to Students B and C.

In this trial there was no client group and the evaluation focused on the actual experience of the (student) designers over the two-hour design session, which was recorded on video. The extent of interaction was impressive – some 60 to 70 design scenarios being generated, modified and agreed (or contended). The students reported that they found the experience demanding, exhilarating and wholly unique.

◀ Figure 6: Screenshots from the experiment.

◀ Figure 7: Pictures from the experiment.

8. Conclusions and further developments

The prototype JCAD-VR system makes some steps toward the change of VR usage from a mere presentation medium to a more powerful and effective design tool, and establishes the feasibility of VR becoming the interface for the next generation of computer aided design applications for architecture [8]. Several enhancements are being considered for further development of the system including:

- A voice driven interface enhancing friendliness of the user interface.
- Support for driving devices such as a 6-degrees of freedom virtual glove.
- Implementation of a multi-environments server capable of dealing with several VR environments simultaneously.

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