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 body 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. The 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 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 a Reality Centre.

The research and teaching/learning experience in the collaborative design environment reported in this paper describe the development and application of software that aims to increase the opportunity for architects to collaborate within virtual worlds which enable effective and transparent information exchange.

***Keywords**: VR, Collaborative Design, Virtual Environment, Interface, Architecture, Experiment, Design Process.*

Introduction

In the recent decades the design profession has been deeply affected by the digital revolution and the use of Computer Aided Architectural Design (CAAD) tools is nowadays part of the daily practice in most architectural firms. But in the last few years the 'CAAD community' is experiencing a new revolution that is leading the move from static representation, based on 2D renderings or prerecorded animations (considered as a sequence of 2D images), to dynamically generated 3D representations. Real-time navigation and interaction, typical of VR environments, provide just that fluent interface enabling the 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 probably preparing 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 complexity to the notion of virtual spaces, turning the profession of architect into something that might now resembles the one of the virtual architect.

Although VR is nowadays a quite mature technology, it is seldom used in architecture throughout the design process, but 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' behaviour [6] many authors observed an indefinite number of return loops from the moment when gathering of information and structuring of the design problem take place (known as analysis) to the one when design solutions are generated (known as synthesis).

The use of Virtual Reality within the design process provides the designer with an appropriate, quick and practical feedback which facilitates search for design solutions. Moreover, it enables the capture of more information than would be possible to capture with the use of the traditional media and makes the checking of the 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 is the perfect 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 more powerful and effective design tool.

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 contractors and clients. In such a scenario, only once the final solution has been achieved is it worth investing time into more powerful visualisation media.

With this background knowledge the research task we set ourselves was to develop the VR system which would help designers in the initial stages of the design process to take advantage of the VR as a new design tool.

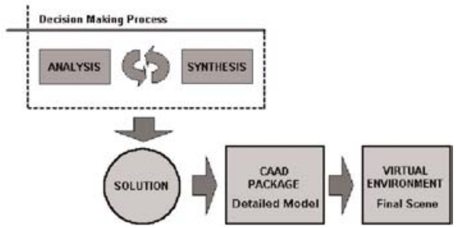

Figure 1. The current position of VR within the design

The system named JCAD-VR provides a flexible user-friendly immersive environment to support collaborative design on a synchronous base. It can be thought of as an investigation tool that allows the designer to sketch freely 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

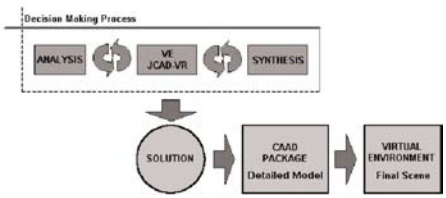

Figure 2. Proposed scenario

scenario using JCAD-VR within the decision making process:

Here JCAD-VR provides the means for a more effective use of VR bridging between the phases of analysis and synthesis. VR is now 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.

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”
- user interface (UI), 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 client-server architecture where every user logs into a virtual world and starts sharing design tasks with other users.

JCAD-VR is organised in an object-oriented fashion, where each module is able to fulfil certain task and it is independently coded. This approach has allowed 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.

The Collaborative Approach

When JCAD-VR is initiated, the user is asked for a login name for the session and through an options panel he/she can decide which server to connect to and through which server port. This name will be 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 devices such as the multi-projector display system processing the visual output of a Reality Centre which was used for 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 provides also a stand-alone option in case collaboration is not required.

Once the system is initialised 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 be following: geometric primitives (cones, boxes, spheres etc.) and architectural entities (walls, doors, windows etc.). The system routinely checks for constrains and allows only the possible 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 which 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 with a unique id-number. The ID is a combination of 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 any object is selected by the user, this object is locked and such 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 controls 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 internal database of any creation or modification of geometric objects within the virtual scene and broadcasts their numerical information.

To ensure 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. This architecture allows a real synchronous collaborative design making designing a true multi-user collaborative experience.

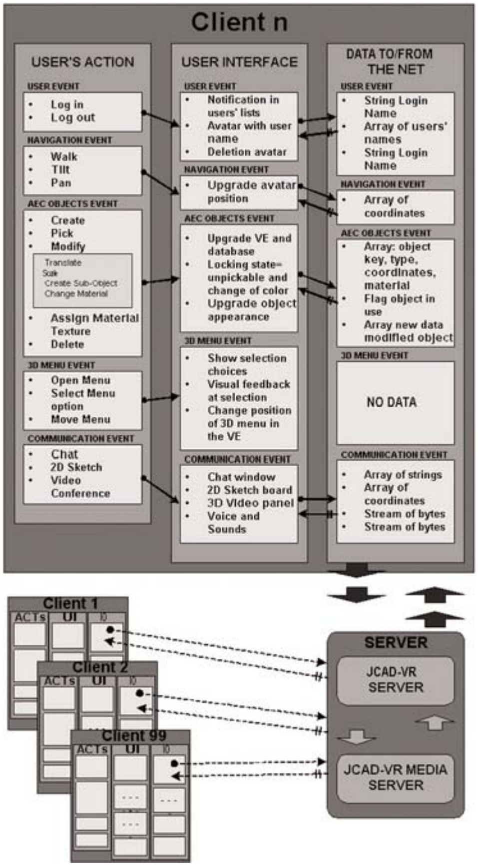

Figure 3. Client/Server Architecture of JCAD-VR

The Interface

Besides the functions provided by the system a great deal of attention has been put into the visual interface. The GUI or perhaps 3DGUI is in fact thought of as 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 visualisation device used. The system can therefore easily be adapted to different devices by just rewriting 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 HMD - 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 entities 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 perhaps they even provide a higher degree of feeling of immersion. The user interacts with the objects through elements of this interface, such as arrows placed to help the user editing the object. Feedback is provided through the visual modification of the object itself in the scene. The 3D engine just renders all the possible changes of the VE: movements of avatars, video conferencing streams rendered on 3D panels and, most importantly, creation and modification of objects created within JCAD-VR.

Server Package

The server is made 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 the 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 primarily information about the network status and transfer rate. A number of components 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 normal PCs to the supercomputer running a Reality Centre, and leaves the research team the freedom to test the software with several operating systems. The communica-

Figure 4. A screenshot from JCAD-VR

tion channel ensures the link between server and clients through a TCP/IP network.

System Implementation and Hardware used

The whole framework of JCAD-VR was organised to allow concurrent software development, in a modular fashion, by individual members of the R+D team [3]. To facilitate this, an object oriented approach was identified as the most suitable one and the entire system was coded in Java‘.

The choice, even if less efficient in term of performances if compared with other choices, indeed 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 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 customised to run on PCs as well as on a Sgi supercomputers. The former are normal PCs whose video-card displays the virtual world only on 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 tassellated 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. A great deal of effort has been expended by the research group to integrate the 3D module with the multimedia one.

Figure 5. An image of JCAD-VR during an experiment of collaborative design

Collaborative Experiment

The obvious first line of inquiry regarding the usability and usefulness of the emerging system was in the academic environment within which it had been created. For the past three years, the academic with overall responsibility for CAAD teaching had offered an optional class, to fourth year students (and to students from less senior years with exceptional commitment and skills in CAAD) in the design application of innovative VR technologies. In Session 2001/2 three of thebstudents taking the class were introduced to JCAD-VR and invited to put the system to its first serious test.

Students Christoph Ackermann, Ross Marshall and Edward Wright were located, each with an appropriate workstation, in three different areas within the Department of Architecture, with fixed and hand-held video cameras covering the actions and observations of the students. Over the two-hour design session, the three students were invited to design an information centre in a public square and in a given urban context of Glasgow. The introduction to the project and to the specifics of the interface to JCAD-VR lasted a mere 30 minutes. This meagre introduction was purposeful and intended to test how intuitive (or not) the system was.

The in-house experiment was a revelation to the authors of this paper. Over the two-hour design period there was:

- Fast and furious interaction amongst the three design participants within the common design environment; some 60/70 design scenarios were commonly generated, modified and agreed.
- Both satisfaction and frustration amongst the participants was noted regarding the high degree of mutuality in the interactive process.
- A real sense of having experienced a wholly immersive and shared design experience which heralds a future way of exploring and determining the configuration of the built environment.

The entire outcome of this limited experiment - with all its local and 'non-scientific' constraints - in common with the experiments in the late 1960' - is, thankfully, to stimulate further trials, tests and transformations.

The notion of a distributed design environment within which *all* can contribute, has, the authors claim, been significantly advanced.

Conclusions and Further Developments

The prototype JCAD-VR system makes some steps toward the change of VR usage from 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 (CAAD) applications for architecture. Several enhancements are being considered for further development if the system including:

Figure 6. Screenshots from the Experiment

Figure 7. Pictures from the Experiment

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

References

Barrilleaux, J.: 2000, 3D User Interfaces with Java 3D, a guide to computer-human interaction in three dimensions, Manning, Greenwich.

Bertol, D.: 1997, Designing Digital Spaces, An architect's guide to Virtual Reality, John Wiley & Sons, Inc.

Conti, G., Ucelli, G. and Maver, T.: 2001, JCAD-VR - A Collaborative Design Tool in Virtual Reality, Proceedings of ECAADE 2001, Helsinki, pp. 454 – 459.

Dorta, T. and LaLande, P.: 1998, The impact of Virtual Reality on the design process, Proceedings from ACADIA '98 Conference, Quebec City, pp. 139 – 161

Hughes, M., Hughes, C., Shoffner, M. and Winslow, M.: 1997, Java Network Programming, Manning, Greenwich.

Lawson, B.: 1990, How designers think: the design process demystified, University Press, Cambridge.

Sowizral, H. A. and Deering, M. F.: 1999, The Java 3D API and Virtual Reality, IEEE Computer Graphics and Applications, May/June 1999.

Petric, J., Ucelli, G. and Conti, G.: 2001, Educating the Virtual Architect, Proceedings of ECAADE 2001, Helsinki pp. 388 – 393.