Designing within Virtual Worlds

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Abstract: This paper celebrates the successful outcome of a trial of an innovative multi-platform distributed design decision support system in which the shared design environment exists within the virtual world. The outcome is the result of a sustained three-year research and development effort, within an internationally recognised research group. The project set itself a number of ambitious targets within the broad spectrum of distributed design decision support, viz:

- A multi-platform environment: the trial demonstrates inter-operability of different machine platforms - from a home PC to an international standard Virtual Reality Centre.
- A distributed environment: the trial demonstrates the high level of understanding amongst the design team separated by time and space.
- An ability to propose, discuss and agree upon, design decision from **within** the virtual world. Hitherto, virtual environments were viewing galleries; designers had to leave them to effect design changes in a conventional CAD package. The trial described in the paper amply demonstrates the potential to design, collaboratively and, in distributed mode, from **within** the virtual world.

The two ideas upon which the system (known as JCAD-VR) is 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 client-server architecture where every user logs into a virtual world and starts sharing design tasks with other users.

The authors propose to present a video which demonstrates the positive outcome of the trials to date. More importantly, perhaps, the authors will put the achievements of the R+D into the context of past aspirations and developments in the subject area and, most importantly of all, suggest how these modest achievements will impact on the next decade of increasingly rapid R+D.

1 CONCEPT

Historically, architects have experienced the need to prove their design proposals using physical models. Due to the intrinsic spatial nature of the act of designing, even the most accurate 2D paper representation is usually not suitable to deliver the complexity of some architectonic ideas.

In the last decades the profession of the architect 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 architecture 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 pre-recorded 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, 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 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 could give to the designer an appropriate quick and practical response to his/her need of iteration and 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. Furthermore VR broadens the boundaries of traditional perception by providing experiences of worlds not necessarily real or material. In short it 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 drawing (CAD) applications and we can anticipate the change of its use from a mere presentation medium to a more powerful and effective design tool.

CAD/CAAD packages are very powerful but often complex rendering tools, which were not meant to be investigation tools, and therefore generating 3D models is often impractical and time-consuming. Therefore such models are usually employed when every design decision has been already taken.

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 these circumstances the use of VR would just increase costs. As result VR is relegated to the end of the design process rather then being used to engage design creativity through immersive design.

In the traditional scenario 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. Only once the final solution has been achieved it is worth investing time into more powerful visualisation media.

Being aware of this background the research group engaged itself in the development of a VR system, named JCAD-VR, to help designers in the initial stages of the design process to take advantage of the VR as a new design tool.

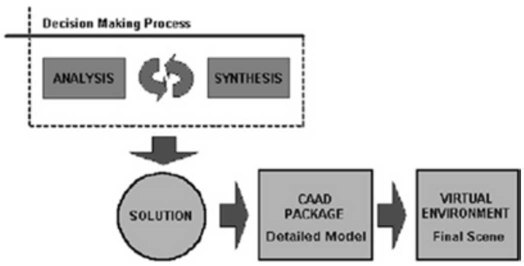

Figure 1 The Current Position of VR within the Design Process

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 shapes 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 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 solutions through concurrent design and synchronous collaboration.

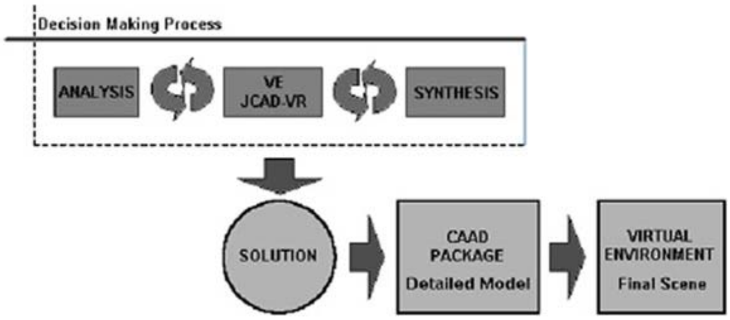

Figure 2 Proposed Scenario

This paper reports the present state of the JCAD-VR system (Java™ based Collaborative Architectural Design tool in VR) and will highlight its future development and testing.

2 IMPLEMENTATION

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.

To better communicate the capabilities of JCAD-VR, the explanation of the client side is presented separately from the explanation of the server. As if in a software demo, all the possible actions/options allowed by the system will be identified.

2.1 Client Package

1) On initiating JCAD-VR, 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 (in case the software is running on a local server).
- Decide if running in single or multiple screen mode. Single mode is set in case the display device is a normal 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.
- Load a VRML 97 file as a VR scene, if any.
- Activate or de-activate video conferencing facilities for the session (in case video conferencing facilities have been activated, support for video capturing device recognition and checking are provided).

Providing the information required for this initial window is quite straight forward.

Ease of use has been taken seriously in consideration of those not accustomed to the system. JCAD-VR provides also a single user option in case collaboration is not required.

2) Every window disappears freeing the space to the 3D graphic user interface (GUI) of the system. 3D icons appear on the screen showing, as intuitively as possible, the functions that they allow; the chosen VRML 97 file is rendered and is shown on the screen as in a traditional VRML browser. Each user can now:

- Navigate through the VE: walking, tilting and panning movements are allowed.
- Observe other participants' movements through their 3D avatars in the VE. Avatars are made distinguishable from each other by having, nearby, a 3D text of the users' login name.
- Listen to the other participants' voices through the loudspeakers.
- Watch, in the virtual scene, the 3D panels showing the video captured and sent by other participants. Every 3D panel shows the participants' login name to make them clearly distinguishable. These 3D panels are intrinsic parts of the GUI of JCAD-VR. Instead of being conventional windows they are 3D entities within the VE. These panels, as well as all the elements of the 3D GUI, are moveable for the convenience of the user.
- Check in a monitor the local user's captured video that is streamed out to the server.
- Check the list of users.
- Chat with other participants. This option is provided to assure a certain degree of communication between the participants in case the video conferencing facility is de-activated; this is available even when the video conferencing has been set as active.
- Freehand sketch in 2D on a shared electronic whiteboard, the possibility to set colours is provided in order to ease distinction between participants' contributions.
- Create 3D shapes and 3D AEC objects: both geometric primitives (cones, boxes, spheres etc.) and architectural entities (walls, doors, windows etc.) are available. A "3D ruler" is provided to help the user in constructing objects.

The choice of a 3D GUI was made in response to the possibility that modules supporting several display devices such as CAVEs and head-mounted displays would be included. Not having a traditional windows/menus user interface JCAD-VR can be used freely in every display situation minimising the effort to customise it for each device.

3) The 3D engine of the system renders all the possible changes of the VE: movements of avatars, video conferencing streams on the 3D panels and,

most importantly, creation and modification of objects created within JCAD-VR. Each user, concerning 3D objects, can:

- Observe every object created in the VE both those created locally and by other participants. The system upgrades the VE with the objects created by all the participants in a synchronous fashion. An identification routine is provided in order to give each object a unique ID number to avoid interference in each user's local database of objects.
- Pick every active object in the virtual scene. Active objects here are all the objects created within JCAD-VR and not geometry imported with the VRML 97 file. Objects originally part of the VRML 97 file are considered to be passive and are not pickable. Once an object is selected:

a) User priority on selected objects is set by a distributed locking mechanism. Locked objects will be no longer pickable for other participants until unlocked and their locked status becomes apparent through change into a red colour.

b) 3D icons, 3D panels with general dimensions and x, y, z arrows are set visible to help the user operate on the object.

c) Translation, rotation and scaling in every direction are allowed. These modifications are operated on the object by simple dragging of the arrow representing the x, y or z-axis. A 3D ruler and a 3D panel provide simple visual feedback to check the modified dimensions. Some routines to constrain modifications allowed on AEC objects are included, for example a door cannot be moved onto or too close to a second door and vice versa.

d) Change of material is supported. In the first instance objects are created with a default grey colour but a library of textures is provided.

e) Deletion of the object is allowed.

- Observe the visual feedback of the locking engine mechanism in case one of the participants has selected an object.
- Observe upgrading of the VE in case any modification on one or more objects has been carried out by any participant.
- Check for information on all active objects in the VE through a local database of objects. Objects are divided by type and general geometrical information is provided such as length, width, height, volume, radius, material etc. The system notifies to every user's internal database any creation or modification of geometric objects within the virtual scene and broadcasts their numerical information.

Figure 3 shows that for every action performed by the user, the consequential visual feedback and data as sent/received to/from the server through the network.

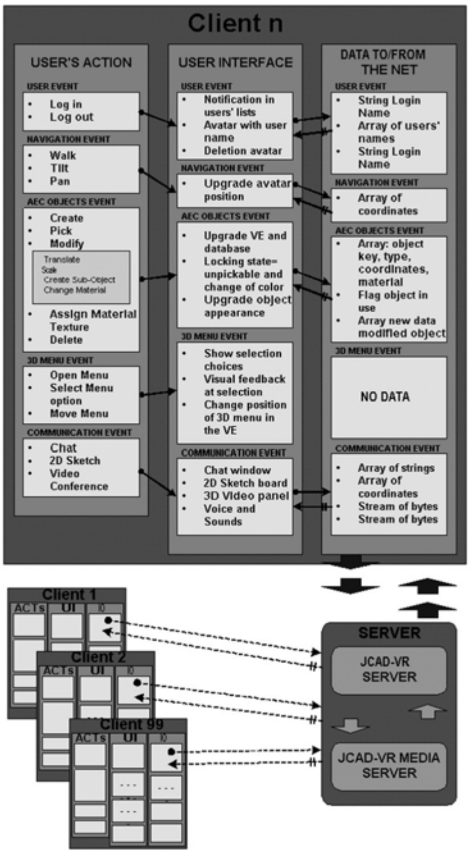

Figure 3 Client/ Server Architecture of JCAD-VR

2.2 Server Package

The server is made of two parts: *JCAD-VR Server* which looks after the VE information to be broadcast, and *JCAD-VR Media server* 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 settings and size of video conferencing windows. 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 to code it, 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 communication channel ensures the link between server and clients through a TCP/IP network.

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 (Conti et al. 2001). 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 some other languages, indeed offered great flexibility, true scalability and, last but not least, fully multi-platform support. Java3D™ was used to code the GUI and everything concerning the VE. Its network-centric nature, its multimedia integration together with the use of native hardware acceleration (OpenGL) and multi-processor support (in the case of Sgi workstation) make it the obvious choice for the development of 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 to be easily customised to run on PCs as well as on an Sgi supercomputer. 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 high 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.

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 Java™ Media Framework (JMF) which enables cross-platform capture, playback and streaming of audio and video at different transfer rate and resolutions. A great deal of effort has been expended by the research group to integrate closely the two sections of JCAD-VR: the 3D module with the multimedia module.

Figure 4 An Image of JCAD-VR

3 TRIALS OF THE SYSTEM

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 the students 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 rewarding 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.

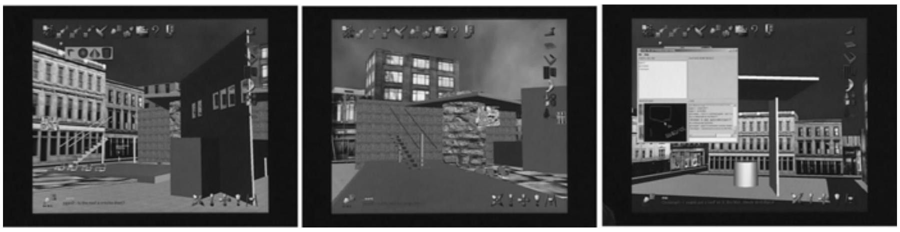

Figure 5 Screenshots from the Experiment

Figure 6 Pictures from the Experiment

4 CONCLUSIONS AND FUTURE DEVELOPMENTS

Assuming the availability of resources, it is intended to conduct further trials and development of the system.

Further trials will be trans-institutional and trans-national and the version of the system will include the recently implemented video-conferencing facility.

Further developments will include:

- 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.

As in the earliest days of the introduction of computers into architectural design, the quantum jump is made by students. The work reported here, and which will be shown during the conference is, we believe, the epitome - in the current state of the art - of excellent practice. It makes a breakthrough, we believe, in the evolution of good design ideas and offers a real prospect for user participation.

There is some way to go, of course, to *design* interactively in a virtual environment. The next step which we envisage is to link to the 3D model the emerging and sophisticated software for the thermal, lighting and acoustics properties of the building. This would allow the user to visualise, dynamically, airflow, temperature gradients, lighting levels and to experience the actual acoustic characteristics of the space as she/he moves through it.

The other exciting development is for representatives of the client/user group to "join" the designer within the virtual environment and to participate directly in the evolution of the design concept.

REFERENCES

Barrilleaux, J. 2000. *3D User Interfaces with Java 3D, a Guide to Computer-human Interaction in Three Dimensions.* Greenwich: Manning.

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

Conti, G., G. Ucelli and T. Maver. 2001. JCAD-VR - A Collaborative Design Tool in Virtual Reality. *Proceedings of eCAADe 2001,* ed. H. Penttila, 454-459. Helsinki: Helsinki University of Technology.

Dorta, T. and P. LaLande. 1998. The Impact of Virtual Reality on the Design Process. *Proceedings of ACADIA 1998: Do Computers Make a Difference*, eds. T. Seebohm and Skip Van Wyk, 139-161. NY: ACADIA

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

Lawson, B. (1990). *How Designers Think: The Design Process Demystified*. Cambridge: University Press.

Petric, J., G. Ucelli and G. Conti. 2001. Educating the Virtual Architect, *Proceedings of eCAADe 2001,* ed. H. Penttila, 388-393. Helsinki: Helsinki University of Technology.