Virtual Site Planning
Andrew Roberts

This paper looks at the potential for the Virtual Reality to be used as a medium for the development of teaching tools in Architectural and Urban Design Education. It identifies examples and lessons learned from the development of teaching tools in other disciplines.

The paper outlines a prototype system developed at Cardiff University to help Town Planning students understand the three dimensional nature of site planning and design. This was developed following difficulties encountered by students in using CAD which was seen as insufficiently intuitive to allow effective use within the short timespan available.

The prototype system allows students to access their site through the familiar environment of a Web Browser. A number of ‘Standard’ house types are available which can be selected and inserted into the design space. Once in the space the houses can be viewed in three dimensions, moved and rotated in order to form any configuration that the students may wish.

The system is easily customisable; it need not be limited to uses in urban design, but could be used in many situations where component parts are arranged in space.

Keywords. Virtual Reality, Teaching, Learning, Site Planning,

Virtual Reality as an Educational Tool

The potential for the use of Virtual Reality techniques within design education is well recognised, with the technique increasingly being used as a way of visualising students design work in order to obtain immediate feedback on design decisions. This may be done using an immersive environment, with a head mounted display or projected CAVE environment; or more commonly using a desktop set up running Virtual Reality Modelling Language, or a proprietary system such as Superscape. Networked computers lend themselves to the possibilities of Collaborative working, with examples such as the Collaborative

Virtual Design Studio developed at University College London (Smith 1998). In this desktop based system, one enters a simulated city scene and can meet and converse with other inhabitants. It is possible for an inhabitant to build within that city, though this may involve collaboration with others, thus replicating processes that occur in urban planning. The Conceptual Design Space (CDS) at Georgia Institute of Technology (Youngblut 1998) allowed students to work collaboratively within an immersive environment in order to modify elements within a pre-developed virtual world, although major changes to geometry proved less easy. More commonly VR is being used to create a record of individual buildings (past or present), or of whole cities.
Virtual Reality also has potential as a medium for the development of teaching tools which can be actively used as part of a student’s learning process. These are more likely to have a focussed purpose, in that they are designed to illustrate a particular point, perhaps simulating a concept that would be difficult to explain by traditional means. Despite its great educational potential, there is little evidence of the use of this type of tool within built environment education, with the more open ended design related options taking priority.

Bricken (1990) and Kalawsky (1996) describe the many benefits that Virtual Reality can have upon a student’s learning experience. These can be summarised as follows:-

- Virtual Reality is experiential in that it enables one to build upon real life experiences within a familiar (albeit virtual) environment. This constructivist approach to learning has been advocated by a number of educational theorists for many years.
- It assists students in the conceptualisation of abstract concepts, through visualisation.
- It facilitates 3D interaction which is seen to aid understanding.
- It enables manipulation of 3D objects within space.
- It enables collaborative learning between users in remote locations.
- It allows new experiences to be simulated that may not be possible within the real world, including those that would be too dangerous or costly for real life experience, or would happen over an excessive time span.
- VR learning environments can be tailored to fit the particular learning style of individuals.
- They are intuitive to use, as in theory no additional skills are required to operate within a virtual environment than are learned through real life.
- They can provide a real life sense of scale, particularly useful to Architecture and Urban Design

The latter two points specifically refer to fully immersive Virtual Reality which Psotka (1995) argues to be a more effective educational delivery mechanism than the lower cost, desktop computer based system, where the interaction is through the unnatural interface of mouse and keyboard. This is especially true of some of the most popular web based browsers which are particularly difficult to use.

At the present time, it is unlikely that most teaching institutions would have access to the facilities required to use fully immersive VR as a teaching tool, and a desktop system is a more likely option. Newer versions of the Virtual Reality Modelling Language (VRML) are becoming increasingly comprehensive and provide a number of features which allow it to be used as the basis for the development of learning materials. Such features include those that allow objects to be dynamically added to a scene, manipulated and even animated. These interactive elements of a Virtual Reality learning tool are seen as being of particular importance in the educational process. Experiments by Byrne (1996) suggest that interactivity may be more important than immersion.

Work in other disciplines has shown that Virtual Reality can be a particularly useful media for developing teaching tools. An extensive evaluation of a number of these has been compiled by Youngblut (1998). A further example of the potential for VRML as a teaching tool is the ‘Visible Human’ project produced by the Northeast Parallel Architectures Center (NPAC) at Syracuse University. Here the user drags a section plane through a 3D human body, and then is able to see an image of what that cross section would look like in reality. Although this is a relatively simple tool, it shows the potential for describing something that would be difficult to achieve using traditional teaching techniques. The ‘Visible Human’ will not replace traditional teaching, but provides a mere point of reference, from which students can learn. With this and most VR teaching
tools there still remains a key role for the teacher in providing a guiding framework within which the software is integrated.

**Site Planning at the Department of City and Regional Planning**

The teaching of site planning and design within the Department of City and Regional Planning at Cardiff University is conducted through a series of practical modules. These aim to explore the application of design theories to site analysis and planning, building on general knowledge of design control and area-based studies of urban character and design quality. Students receive an introduction to the site planning process and are asked to prepare a site plan for a new residential and/or mixed use development. The modules are seen as an important source for the development of skills and therefore are generally taken by students who have little experience at both drawing and design.

Since 1997, Computer Aided Design has become an integral part of the site planning teaching within the Department. This was initially seen as a means of developing drawing skills that would be used later in professional practice. However it was soon realised that CAD had the potential for strengthening students' generally weak 3D visualisation skills. CAD was initially introduced into the course at first year level, but has now been expanded to an option at diploma and M.Sc level. MiniCAD was chosen as the most appropriate software to use, as it contained all the drafting tools necessary for the professional skills element, as well as allowing simple block models to be created, and viewed in perspective and moved around the site.

Students were given a brown field site near to the City Centre of Cardiff, within which to develop a layout for 60 housing units together with associated areas for public and private space, vehicular access and parking. Students worked in groups of 8-10, each working in pairs to develop a quadrant of the site. Groups had to work together to ensure continuity and consistency of design between each quadrant. It should be noted that the time allocated to preparing these layouts was approximately five days, including initial training and necessary research. Therefore there was little time for students to develop design skills. The solution was to adopt a Planning For Real™ approach (Gibson 1991) where people with relatively few design skills can experiment with (and comment on) different layouts created from a kit of parts. Students were given a library of pre-designed standard houses and other symbols which could be inserted into their drawings. The house types were selected from those typically being used by housing developers and were primarily 3D block representations, with few details such as windows and doors. This allowed emphasis to be placed on massing and the spaces created between buildings. Students were also encouraged where necessary to produce their own house types, but in most cases this was not accomplished.

As the course progressed it became clear that students were struggling to master the technology in the short timespan available to them. They appeared to have few problems in developing 2D drafting skills, but had difficulty in using the three dimensional side of the technology in an effective manner. It had been hoped that the students would use the CAD system to move and rotate objects in 3D, experimenting with different arrangements, thus allowing them to gain instant feedback on their decisions on which they
could reflect and make amendments. In reality moving objects within a 3D space proved to be more complex, as it is difficult to judge in which plane objects are being moved, whilst looking at a 2D computer screen. When trying to move objects whilst in plan view students became more concerned with aspects of neat drawing than with experimentation. Generally, designs were produced by hand, on paper in two dimensions, and the three dimensional CAD work tended to be used as a presentation tool only. The difficulties encountered by the students also led to a significant strain on technician resources.

Because of these problems it was suggested that in future the CAD work would be concentrated upon the development of the necessary drafting skills. This left a gap as to how students would learn about the crucial three dimensional aspects of their work. Therefore there was a need to investigate the development of a simple tool that could assist students in their understanding of the three dimensional built environment. The criteria for the development of this system were that:

- It should be simple to use and require a minimal degree of training in order to use the product.
- It should allow students to rearrange buildings whilst looking at them in three dimensions and thus immediately see the spatial implications of their changes.
- Its use need be no more than an outline ‘sketching’ tool, as detailed work would still be carried out using CAD.
- It could allow groups of students to collaborate on design decisions, in reality this would be achieved by sharing a single computer, but it should be possible to collaborate over a network or internet.
- The software should be easily customisable, so that different sites or housing designs could be inserted.

Clearly a kit of parts approach is not appropriate for the development of comprehensive design proposals, however it has a role as an elementary teaching tool, to assist students, who are unlikely to become designers in their understanding of the built environment. The approach is similar to that developed by LEGO for their latest LEGO Creator product [ii], where a complete model can be built from a series of individual elements.

Virtual reality seemed a particularly suitable medium for the development of this teaching tool, as it requires relatively little training to be used effectively by students. CAD packages are designed to allow one to draw accurately, and therefore for every operation that a student performs, the computer will ask for a certain number of parameters. For instance in order to rotate a building, the user would need to choose the building to rotate, indicate a centre of rotation and then an angle of rotation. For students with limited knowledge of drawing or design, this mode of operation does not lend itself well to intuitive sketching. In a Virtual Reality environment, one could simply pick up an object and rotate it around as would happen with a real life model. To gain the full benefits of working in this way would require a fully immersive VR system, in reality however this is difficult to achieve with a large group of students, therefore a desktop system was chosen, using VRML. This has the advantage of being run through a web interface, with which students are familiar and also being free of charge. VRML contains sufficient scripting capabilities to enable full interaction with the model and also lends itself to the possibilities of collaborative working.

The Prototype

A prototype [iii] has been developed using a combination of VRML and Java, to run within a web browser containing a VRML97 plug in. Initially the user is presented with a blank VRML world possibly containing site information, surrounding buildings etc. It is useful to have a series of pre-set views within this world, as this allows students to quickly reorient themselves if they become lost. A Java applet,
contained within the same web page, is responsible for adding components into the scene. This is done through VRML’s External Authoring Interface [iv] which allows a Java Applet to interact directly with a VRML world. Each of the standard components which can be added to the scene is saved as an individual VRML file. The Java applet takes a selected component and dynamically writes a short piece of VRML code that allows it to be inserted into the scene.

As the object is inserted into the scene, it is assigned plane sensor. Plane sensors are one of a number of VRML sensors that track user activity when the mouse or viewer is positioned near to an object. When the mouse button is pressed over an object with a plane sensor assigned to it, the object is able to track the X and Y co-ordinates of the mouse, and a simple piece of scripting allows the object to be moved with the mouse. This has the effect that regardless of which angle the scene is viewed from, objects will always move parallel to the ground plane, thus avoiding any of the confusion related to working on a three dimensional model, whilst viewing on a 2D screen, where students may inadvertently move objects into the air. The Java applet also contains routines to rotate the currently selected object, by means of a small slider which forms part of the applet. It would also be possible to add a similar slider to change the scale or vertical elevation of individual components, if for instance a sloping site was adopted.

As the Java applet contains all the working data about the positions of each building within the scene, it should be possible to use the system to give students instant feedback on abstract matters such likely population densities, which are seen as a key design criteria for the site planning project.

The system is designed to be flexible in its use, and could be easily adapted to suit particular site situations or to add in new components. In order to achieve this, very little is ‘hard wired’ into the Java Applet, as making changes here would be a complex process. The buttons required to insert and delete buildings are simply HTML links within a web page. A simple JavaScript function contained within the page header takes the name of the selected component and passes it to the Java applet. Thus the system can be customised by anyone who has a basic knowledge of HTML. Creating additional components can be done using any proprietary software for generating VRML worlds.

It is possible to foster collaborative working over a network using the prototype, although at the time of writing this is only possible by using the application sharing features of Microsoft Net Meeting or Netscape Conference. Attempts were made to use Blaxxun CCPro as a means for collaboration, but problems arose when participants joined a scene, midway through a session, as the new participants were unable to see the modifications previously made. This could be solved by regularly saving new versions of the scene to the server, using CGI or similar technology, but it was not felt necessary for initial evaluations.

At the time of writing it has not been possible to run a comprehensive evaluation on the software in use in a teaching situation, and it is hoped that this can be carried out during the forthcoming academic year. However initial informal comments have been positive, although difficulties in navigating within the current generation of VRML browsers (such as Cosmo Player 2) are likely to be prevalent until an easier interface is developed. An evaluation strategy with
some of the group using the tool and others continuing to use CAD is the most likely scenario.

Conclusions

This paper has examined the ways in which Virtual Reality can be used as a medium to develop tools that will be of assistance within the teaching and learning process and why this media may be particularly appropriate. It has looked at a specific teaching project and has identified a concept with which students have difficulties, that being the ability to understand and visualise 3D space. While CAD has not proved particularly successful in this light, Virtual Reality presents a potential means to assisting the students achieve understanding of this concept.

It has also become apparent that a tool where a kit of parts can be rearranged within space may have a potential benefit elsewhere within Architectural Education. Possible other uses might include

- The fitting out of office space
- Simulated assembly of parts of construction details
- Exercises in the manipulation of building geometries, as part of an architectural analysis project.
- Collaborative development of plans for urban areas using the internet as a means of communication (a kind of Planning for Real™ over the internet).
- Rearrangement of furniture within houses (as a sales tool for housing developers)

It is important to note that educational tools of the type described are not intended to be self teaching packages which would provide an alternative to the teacher. It is envisaged that VRML simulations would primarily be used to supplement existing teaching and learning activities, by assisting in those areas of the teaching and learning process where concepts were difficult to explain or understand. The teacher retains an important role in promoting a guided integration of the software into teaching. When considering the development of any tool of this type it is important to ask what is the added value of its use, as unless there is no added value the tool is unlikely to be used.

References


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Rick Hall

Virtual Site Planning

Andrew Roberts
Computer Architectural Representation - Applying the VOIDS Framework to a Bridge Design Scheme

Peter Szalapaj, David C. Chang

A virtual environment presents sensory information and visual feedback to the user in order to give convincing illusion of an artificial world. In the architectural profession, the spatio-temporal metaphor in itself constitutes significant information retrieval, because we understand architecture by seeing it. This paper attempts to understand, and then to analyse the characteristics of representation of architectural models in virtual environments.

We will examine the use and creativity of current computer generated architectural presentation in virtual environments. Our observations will be applied to the modelling of a bridge in Castlefield, Manchester, and evaluated by a group of students within the School of Architecture at Sheffield University. The conclusion of this paper will be the presentation of a conceptual structure for representing architectural models in virtual environments.

This paper also explores the tension between the correspondence and constructivist views of representation. The correspondence view of representation relies on the idea that a representation corresponds to what is out there in the world. The constructivist view of representation advocates that any actual interpretation would depend on the context of their social and cultural backgrounds. However, the authors believe there should be a combination of these two views for architectural representation in virtual environments, and a framework developed by the authors - VOIDS will be presented.

Keywords: Virtual Environment, Architectural Representation, VOIDS, Correspondence, Constructivist

Introduction

Most practitioners in the architectural design profession are familiar with, or have some basic understanding of computer technologies, especially CAD systems. According to a recent survey published in February 1999, in which over 500 architectural design firms and construction companies in the UK were investigated, 95% of companies are now using computers for doing 2-D drafting, and 5% for producing 3-D models. Other popular applications include rendering, animation, energy evaluation, structural calculations, image manipulation, video editing and construction management software. Surprisingly, although we have numerous types of applications for producing computer 2-D drawings and 3-D models, we have few applications for presenting computer generated models in virtual environments.
Moreover, less research has been done in investigating the properties of virtual environments, in both theoretical and pragmatic aspects, which could enhance the visualisation and presentation of architectural virtual models in cyberspace.

Virtual reality (VR) has been widely used for flight simulations, remote control or training for operations in dangerous locations, delicate surgery. With virtual reality technologies, some unfinished architectural designs may be suited to walk-throughs of their environments. It is predicted that virtual reality will extend to the fine arts, entertainment, education and communications. The discourse of virtual reality has now split into two constituent components: immersive VR and non-immersive VR. In immersive VR, viewers have a higher level of sensational interactions with the virtual environment, because movement corresponds to the physical movement of viewers in real life. However in non-immersive VR, viewers are playing similar game, but keep their bodies outside the virtual environment.

How can current VR technology be used in the architectural design profession? (It is now worthwhile to set aside immersive VR, because most VR technologies being used in this profession e.g. CAD, rendering and animation software, applications of real-time navigation, ...etc. are mainly non-immersive.) Instead of simply admiring the ability of computer technology to create a fantasy for exploring a proposed architectural design scheme in a virtual environment, what is the ability of this technology in actually bringing to us an insightful understanding of the design? For current computer animated architectural presentations, most viewers have a general problem of understanding the overall design scheme, and often lose their orientation during the presentation. This could cause misunderstanding or, even worse, the viewer eventually may not perceive an overall picture and perhaps confuse their original perception gained from other media. This is certainly not the purpose of having a presentation. Why does this happen so easily?

First, the script (scenario) of an animation should obey the general rules of human perception e.g. rhythm and speed of movement, viewing paths and flow, correlation and transformation between different scenes. If the script does not obey the general rules of human perception, then the whole presentation becomes incoherent. This is not only because the arbitrary circulation created by the producer demarcates the route of movement, but also because the unconventional and unacceptable way of passing through virtual models gives an unpleasant experience of exploring it. An example of architectural animation created by a student in the school shows a frequent change of clips and irrational speed of movement e.g. moving quickly may result in an unpleasant perceptual experience, leading to an ambiguous cognition of the design scheme. A well-structured architectural animation which obeys general rules of human perception is capable of generating an awareness in the viewers. Secondly, losing the context of a design scheme is often a problem. Presentations such as fly-throughs from point A to point B without any meaning, jumping from one scene to another without any relation or correlation between these scenes is often a cause. No information is given during the fly-through which makes the whole sequence meaningful to the overall presentation. Thirdly, a lack of build-up or sequential (processing) description. Computer generated architectural animation generally tries to distribute the design concept by exploring the spatial metaphor using motion. Actually, the constitution of a design scheme e.g. formalisation (depiction) of the design idea, establishment of structural elements, aggregation of spatial arrangements plays a more significant role in understanding the original intention of the scheme.

The best way to present an architectural design scheme is to create a ‘living-space’ in virtual environments which allows viewers to participate in the life-cycle of a project. They should have freedom of movement to navigate, to interact and inhabit this virtual environment.

The aim of this paper is to propose a conceptual model for virtual environments that can be used for
presenting architectural design models. We will focus on both the theoretical and pragmatic implications of the use of non-immersive VR technology in order to understand architectural virtual models.

Theory

In order to develop a conceptual model which has the property of representing architectural design models in virtual environments, the authors have investigated the question: what are the properties of virtual environments?

We are aware that there have been many developments in the philosophy of knowledge in recent years since the introduction of computing e.g. Rorty (Rorty, 1980), Lakatos (Lakatos, 1970), Dennett (Dennett, 1981), etc.. We believe, however, that Popper (even though his own theoretical ideas were developed without any obvious reference to computing) and Bijl, still have much to offer in the development of a framework for understanding systems in which people interact with environments that have particular information contexts, which can be viewed in some sense as externalisations or objective expressions. Computer cyberspace environments are of this type.

First, we have looked at Popper’s Three-World Theory (Popper, 1972). He suggested that the ‘world’ we commonly know of consists of three distinguishable worlds: World 1, World 2 and World 3. World 1 is the physical world or the world of physical states. It is the objective world of natural materials and their physical properties, energies, processes and motions. World 2 is the mental world or the world of mental states, such as the world of feelings, memories, thoughts and dreams. World 3 is the world of intelligibles, or of ideas in the objective sense. It is the world of objective contents of thought such as ideas, theories, arguments, explanations and all artefacts of the mind. A controversial argument here relates to the differences between world 2 and world 3. Popper furthered his argument:

“One man’s thought processes can neither contradict those of another man, nor his own thought processes at some other time; but the contents of his thought - that is, the statements in themselves - can of course contradict the contents of another man’s thought.” (Popper, 1972)

Therefore, world 2 contains subjective thoughts in the sense of thought process - arbitrary and intuitive psychological relations, and world 3 contains objective thoughts in the sense of thought contents - essentially the product of the human mind and is purely informational. Cyberspace environments are clearly the products of human minds and full of thought contents. Extensive summaries of these arguments are provided by Benedikt (Benedik, 1991) and Szalapaj (Szalapaj et al, 1998).

Second, we have investigated Bijl’s definition of knowledge. Virtual models in cyberspace involve both architectural design and computing disciplines. Bijl (Bijl, 1989) showed that the knowledge included in both design and computing disciplines consists of overt knowledge, but that design also involves people’s own intuitive knowledge. Overt knowledge can be rationalised and represented by means of abstract symbolic expressions independently of people. Design (design here means design objects, any objects such as architecture of buildings or furniture) is a kind of activity that not only contains calculated reason but also involves inspiration of thoughts. This inspiration of thoughts takes place in the mind of people and should not be confused with externalised thought or processes which are represented or completed outside people. Bijl calls this intuitive knowledge. The emphasis of Bijl’s argument here indicates that both overt and intuitive knowledge must be valid information for architectural design or computing disciplines.

Lastly, we have investigated media for presenting architecture, from conventional media to computer based technologies, to see how designers using different media present their design ideas. An
interesting point here is the reliance on physical objects among these media, and what they convey from designers to receivers. Media with lower dimensions rely heavily on physical objects, that is to say, higher dimensional media rely less on physical objects, and may even be independent from physical objects altogether. For example, when we listen to someone’s talk about one design description of a building, the information we receive relies heavily on the vibration of sound waves distributed from his vocal chords. Similarly, when we read a design description, it relies on the understanding of text symbols. We have to listen and read each piece of information in order to understand. If we have difficulty of language, then these sounds and texts become meaningless physical objects to us. Graphical representations are two-dimensional media, so they rely on physical objects less than on linguistic ones. The information which 2-D media has conveyed has more clue on the imagination, and this leads 2-D media less dependency on the physical material than 1D media. For example, when we read a 2-D drawing, we are receiving information through pictorial impression rather than observing each fine line. In a 3-D model, we observe its spatial arrangement, scale, proportion rather than the materials which compose the model itself. Therefore, we can predict that virtual models in cyberspace will rely much less on physical objects.

**VOIDs**

After integrating the frameworks from Popper’s three-world theory, Bijl’s definition of knowledge and present media for presenting architecture, we have developed our own conceptual model of the properties of virtual models in cyberspace which we call VOIDs – **Valid, Objective, Informational, Design Theories**.

**Valid**
The information which is provided in world 3, according Popper, is purely informational, and is only informational without any judgement. This indicates that a validation process of virtual models in cyberspace has to be taken into consideration. Virtual models have to present valid information.

**Objective**
Virtual models in cyberspace, according to the properties of objects in *World 3*, need to be objective. This also means virtual models need to have abilities to manipulate themselves in order to update current information settings. This is the autonomous capability of virtual models. Users can then explore virtual models freely without constraints.

**Informational**
The most important characteristic of objects in *World 3* is the information that they carry. Virtual models must provide sufficient information to allow users to retrieve and add information as they require.

**Design Theory**
Architectural models should present designers’ thoughts and ideas to others. It is this kind of design theory which needs to be implicit in architectural models. Traditionally, architectural design theories were presented in linguistic and drawing forms. It is unlikely that design theories can be described just in models. Virtual models have the abilities to make dynamic presentations in which moving pictures can give receivers more vigorous information.

We can say that if the VOID of a virtual model is full, then it has a richer cyberspace quality. If the VOID of a virtual model is empty, then it shows little, and perhaps the model is very constrained. We believe that if we understand the process of how knowledge is being transformed in cyberspace, and the properties and qualities of cyberspace, then it will be possible to create architectural virtual models in cyberspace with fuller VOIDs for viewers to perceive the essential design scheme because the frequency of transforming information has been reduced. As Coyne (Coyne, 1995) mentioned “… according to some, the best kind of representation is one that does not need to package and unpackage the information inherent in a scene through the medium of a picture but confront a
duplicate of the real scene…” We will use this VOIDs frameworks to examine a bridge design representation scheme in a later section.

**Correspondence and Constructivist Views of Representation**

The correspondence view of representation relies on the idea that a representation correspond with what is out there in the real world. According to this view, we need increasing more input to effect the sense of feeling real. An architectural virtual model in the correspondence view of representation tends towards becoming a realistic one, which is evidenced in the quest for visual realism in computer-graphics research generally. The correspondence view also assumes the world contains structures, which we can discern and represent. However, the architectural design process is also a kind of activity which contains ‘intuitive thinking’. Intuitive perception of a thought cannot be reasoned or structurally organised. The correspondence view may be suitable for representing formal aspects or physical properties of a design project, but may not be appropriate for representing an intuitive thinking process or the mental activities of a design.

Architectural presentation is certainly not just to present the physical form of a design, but also to present the idea behind it. An alternative common view of representation which contrasts with the correspondence view is the constructivist view of representation. The constructivist view suggests that virtual reality does not have to strive for realism through better and more complete sensory input. As Coyne has stated: “Representation is a cultural phenomenon.” It would be very difficult to ‘feel’ the increasing population of a city, because feeling is an intuitive projection of the human mind. However, it would be much easier to read an explicit diagram showing an increasing curve instead. Applying this to the design of architecture, the design process is a series of arbitrary thoughts in the intuitive mind of the designer. The best way of representing this thinking process is to show an abstract projection of the construction. Applying the constructivist view to architectural models in virtual environments, there are no essentially, closely corresponding, canonic descriptions from which views can be derived - they can only be stimulated and inspired from the models. We may now argue that virtual models can apply the correspondence view to represent overt knowledge and the constructivist view to represent intuitive the knowledge in a design.

Having discussed the VOIDs theory and the correspondence/constructivist views of representation, the next section will look at how to apply VOIDs theory as the principle for and correspondence/constructivist views as methods for creating architectural presentations through the use of virtual models in cyberspace.

**Case Study: Merchants Bridge Design**

Merchants Bridge, designed by Mark Whitby and Des Mairs partner and associate respectively, with consulting engineer Whitby and Bird, is situated at the junction of the Bridgewater Canal and the Rochdale Canal in Castlefield and is a heritage site for the industrial revolution. This bridge is a curvaceous sickle-shaped arch which arcs both horizontally and vertically. The deck of the bridge is held by 13 tapering hangers that incline upwards to the bowing arch overhead. These two mutually compatible parts counterbalance the overall structural system of the bridge.

Before starting to build a model of this bridge, we first have to ask what is the intention we want to present? A theme for this presentation is first constructed: to demonstrate the sophisticated geometry and structural system of the bridge. Viewers will be able to visualise the virtual model, experiencing the geometry of the bridge and retrieving information regarding structural analysis. Secondly, we have to set up the virtual environment in order to present this theme. The techniques we use to present the theme
of this bridge design scheme uses a 3D motion model (walk-through & animation) together with real-time navigation. It is possible, therefore, for users to interactively control, in real-time, their viewpoint and position within any animation.

The design idea of this bridge was inspired by several influences. From the interview with the structural engineer Mark Whitby he mentioned (Ridout, 1994)

"we have bending, shear and tension worked out but we have yet to make use of torsion. In the aerospace industry, they know about torsion and its effects on the fuselage and wings of a plane."

The result of adding torsion to the design is to weld the deck with tapering hangers which incline upwards to the bowing arch. Therefore, in order to represent bending, shear, tension and torsion of the structure of the bridge, some animation explaining the structural analysis is needed. Other design ideas of this bridge are to create a horizontally curved path closely following the desired line of movement; and that the visual as well as physical weight of the deck should be as light as possible to delight pedestrians crossing over it.

A group of students in the School of Architecture at Sheffield University participated in an evaluation of our VR presentations. An animation of the bridge which contains sources of inspiration in the design of the bridge, and pre-recorded walk-throughs were shown to the students. Also, students were invited to carry out real-time navigation of the virtual bridge model. Our preliminary observations show that when we were trying to express a thought process - analysing the distribution of shear, bending, tension and torsion forces; creation of the geometry; light deck - students preferred to observe abstract representations and models. When we tried to express
the content of thought (or the artefact of human mind) - the final geometry of the bridge, atmosphere around the bridge, construction of the bridge structure; actually walking on the bridge (the artefact), viewers expected to see more realistic models. Also, 3-D motion models are appropriate for presenting the process of thought and real-time navigation is more applicable for experiencing the content of thought.

**Conclusion**

The VOIDs theory that we have described attempts to capture the quality of cyberspace which virtual architectural models should be situated in. In this paper, we have investigated VOIDs theory from Popper's three-world theory, Bijl's definition of knowledge and present media for presenting architecture, and then we looked into the correspondence and constructivist views of representation. The case study of the Merchants Bridge scheme was an attempt to produce an architectural presentation according to the theory and methods which were developed. We have found that different types of presentation techniques and different qualities of virtual models are suitable for different kinds of thought processes. A cyberspace with full VOIDs is actually an integrated one with a full and comprehensive ability to present architectural virtual models.

Examples from computer games may give us some idea of how virtual models work. In a car racing game, you can re-play your driving scene from several different cameras. You can see how you crashed into another car from different angles, or see how you slid your rear tyres when you were driving through a sharp angle. It seems like what you have just played is actually what you did in a real scene within the virtual world. The game is no longer situated in a 2-D simulated 3-D environment, but has its residency in the virtual world. A full VOIDs cyberspace environment for architectural presentation should have similar abilities to make sense of dwellings. According to the theme of a design scheme, situations and circumstances can be generated or created by user-manipulated rules in computer environments, or participants in virtual environments.

This research has investigated the kinds of abilities and properties which virtual environments should contain, especially for the architectural profession. We believe the VOIDs theory is appropriate for architectural representations. Further research will focus on experiential aspects of how we perceive spatio-temporal elements e.g. space and time in the design of buildings.

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The Fake.Space Experience - Exploring New Spaces

Maria Papanikolaou and Bige Tunçer

Fake.space is an elective CAAD course in which teachers and students form an online community. It is a Web-based communication environment for the exchange of ideas on the concept of space. Fake.space is also a narrative structure consisting of threads of nodes created by students. These nodes present different aspects of space. Fake.space represents our current generation of teaching environments. In this paper we describe and analyse its latest incarnation and discuss our aims and thoughts for further development. We believe that fake.space reflects on a future where online environments entice the students in a playful way to work with computers and CAD and consider the role of networked environments in architectural space.

Keywords: online community, learning environment, identity, transparency, visualisation

Introduction

In the development of information technology Henri van Praag distinguishes five stages: a formal, a scientific, a technical, a social and a cultural stage. At the moment, we are in the cultural phase: information technology is increasingly becoming a culture-determining phenomenon, and computers are no longer used only for calculations and data storage, but also for cultural expression and reflection (Rijken, 1998:19). Only in the last two decades, the computer has slowly started gaining recognition as a communicative, artistic and literary medium.

The World Wide Web plays an important role in education, because it represents a convergence of information access methodologies that facilitate the use of technology for educational purposes. At the chair for Architecture and CAAD at the Swiss Federal Institute of Technology Zurich, we have adopted the World Wide Web early on as a teaching environment for our courses.

The Web offers many degrees of freedom for publishing and sharing multimedia data. In the past we have made use of these advantages by establishing students’ homepages as a place to present their work. We also developed means - webpages generated by scripts - to create an overview of the students’ work. The fake.space experiment results from these experiences. We wanted to further explore the Web’s potentials as a medium for the communication, representation, and expression of architectural ideas and to experiment with new, more sophisticated teaching environments by developing mechanisms for a more effective use of this powerful medium.
Fake Space: an educational experience

Fake.space is an elective CAAD course taken by 120 architecture students from the upper semesters. Previous computer experience is not required. The students, teachers, and to some extent guests form the fake.space online community for the duration of the course. Fake.space is a narrative structure consisting of threads of nodes. These nodes are created by the community and present different aspects of space - virtual, simulated, imaginary, faked space.

Space

Space has been an issue in general philosophy and natural sciences long before it entered the architectural discourse at the end of the nineteenth century. Different social and moral, but also scientific changes, necessitated at that time an increasing interest from the architect in theoretical issues (van de Ven, 1978).

The technical concept of space has its origin in mathematics and computer science. Scientists use space as a metaphor to describe complex systems and networks, e.g., information spaces.

There is a bi-directional influence between the design approaches of architectural and information space.

An information space’s structure may be experienced as an environment where “here” and “there” are distinguished and the “spaces” in the structure have different connections (Rijken, 1998:55). The conceptualisation and visualisation of an information space will be influenced by the organisational principles known to architecture. Concerns that were previously limited to our built environment will become more and more familiar inside cyberspace: How are flows of usage organised? What defines a sense of familiarity and place? What are useful systems of navigation? (West, 1998:44)

On the other hand, within the architectural discipline, the impact of the computer on our very conception of what constitutes architecture and architectural space also needs to be investigated.

At the Vienna Architecture Conference in 1992, Coop Himmelblau remarked that “General interest in tangible, three dimensional architectural creations is steadily decreasing... Virtual space is becoming the sphere of activity for the life of the mind” (Lunenfeld, 1999:10). Fake.space is the sphere of activity for the life of mind of the community, it is the shared space, the common ground and the symbolic basis for the expression and communication of ideas among the members of the community.

Environment

Technically, fake.space is a custom web-interface to a relational database. There are no static pages in fake.space, all views of the database are assembled by scripts, on the fly.

Node System

A node in fake.space is an entry into the system and it contains one entity. A node can be of one of two types: a pipe or a tank. A pipe contains text, and a tank contains graphical information. This graphical information can be an image, an animation, a 3D model, a sound, a rendering, or a combination of these. The exercises that the students do in this course are also considered as node types, and are mainly used for classification purposes.

The project for the exercises is the student’s own room.

- node1 - plan: The students create a plan of their room.
- node2 - view: They make a 3D model of this room and create inside and outside views.
- node3 - circulation: They form groups of at most four people and connect their rooms creating a public circulation space.
- node4 - animation: They experience space through motion by making an animation through it. In this animation, not only the viewer moves in space, but the objects that
make up the space may also move and transform in order to continuously redefine the space.

- node5 - light: They define specific viewpoints and render the views to experiment with light simulation.
- node6 - movie: They make a frame-by-frame animation through their model, which helps them to grasp the difference between a real-time animation and a frame-by-frame animation.
- node7 - tour: With a special tour tool developed as part of the fake.space interface, the students put together a fake.space tour, connecting interesting nodes, thus creating a second layer of connections on top of the existing node structure. This way, a second spatial structure, resulting from the subjective interpretation of the original one is established.

The fake.space node system initially consists of eight nodes. These eight nodes form an inner circle in the tree structure we call the node system. In the center of this system is the fake.space connector. The eight nodes attached directly to the connector form the starting points for further growth. These eight initial nodes represent eight literary texts that discuss space in different contexts. We provide these texts to the students in the form of a reader.

The system grows as nodes are added to it. The mechanism of adding a node is similar to writing an e-mail message. A form is filled out and the content of the node is uploaded to the server. In this way, it is possible to post nodes from any Internet client.

A new node is always attached to an existing one. This neighborhood relationship specifies the context within which a node is created. Different motivations may exist for adding a new node: continuing an idea, objecting to it, or creating alternatives are all possibilities.

Adding a node is reacting in some way to the existing one, resulting in the formation of threads of nodes. The narrative interactions within the threads define stories providing a spatial continuity in the system. The users build their own relationships to the story; their own unique memory spaces.

**Visualisation - Navigation**

The resulting information space, basically a network of information entities and relationships between them, needs to be visualized in some way in order to provide a spatial quality, as the information “space” itself has no inherent spatial qualities. An expressive visualisation must make strong use of the relationships between the information entities and the attributes attached to these entities (e.g., authorship information, submission time). In a well-designed visualisation, a wider set of actions beyond searching are possible: browsing, touring, and interaction. An effective visualisation can help the user to deal with the complexity of the information network and to provide structural awareness.

Transparency is reflected in the course interface through an overview of all students’ works which are accessible as soon as these are submitted. This promotes immediate reaction and enables a flow of ideas and inspiration between the members of the community. Transparency is also supported by the visualisation and navigation mechanisms of the system, which allow for diverse views of the information stored in the system’s database and show the complex relationships between the nodes.

In a system that constantly grows, effective mechanisms for navigation are needed.

Users acquire experiences every time they proceed through the information environment. There is no single route, instead there is the potential for many possible paths or actions. It is possible, and intended, for the users to switch to different navigation modes at any point, according to their interest, without interrupting the spatial experience.

The mental representation that the navigation constructs of the information space corresponds to a conceptual map that reflects the principles used to design the visualisation, and thus the underlying
Figure 1 (left). Different views of the fake.space system: the browser, thread, profile, comments and sky modes provide a space to move around in and create the memory space.
relationships in the information [i]. The users, while browsing through the nodes, obtain a conceptual path of the spaces that they pass through.

The fake.space interface provides different views of the information space. These views vary from the visualisation of a single node and its immediate neighbour nodes - the inworld view - to an overview of the whole structure in relation to the node attributes and relationships - the outworld view. It also provides an overview of the individual contributions of a student or a group to the system - the profile view.

The “inworld view” of the node system shows a selected node with its immediate neighbours.

- **browsing**: The default view of the node system is presented in a standard frame. The current node appears in the center, and the predecessor and the possible successors are placed on opposite sides. One can move to a neighbour node by clicking on it.
- **auto-motion**: This is an automatic motion mode that follows threads through the node system, starting from a random location. Whenever it reaches a dead end, it jumps to another random location and continues the journey.

“Outworld views” give an overview of the node system, in different ways. The user may look at the whole structure, or retrieve groups of nodes according to certain attributes.

- **map**: This is a list of all the nodes, organized by node types (exercises, pipes, tanks). The newest nodes are listed at the top for easy referral. One can also sort the nodes according to other criteria, such as the best rated nodes, the oldest nodes, etc. A search mode is also included, where a full-text search is performed on keywords.
- **sky**: The sky view is a graphical representation of the tree structure underlying the node system. This is a clickable map that lets one access the nodes based on the position within the system, and provides a graphically attractive overview of the growth of the node system. It is also possible to highlight the nodes submitted by any student or group, enabling one to see which strategies the students have used to place their nodes.
- **threads**: This view visualises all the threads that evolve from the eight initial nodes, making it very straightforward to follow all the branches and stories that have evolved in the system.
- **profile**: The profile view gives an overview of all the nodes that a member of the course has submitted. As the students form groups after the second exercise, the profile view also provides an overview of groups’ work.

**Community Members**

Identity plays a key role in online communities. When collaborating, an awareness of the identity of those who share responsibility for building up the system is essential. In our community we support this requirement in various ways, two of which are the establishment of the “online identity” and the “profile”.

In the online identity, the members define an alias under which they are known in the community, make a statement on the subject of space, and provide personal information. The profile presents an overview of the members’ contributions to the system. These contributions are the submitted nodes and comments. In the inworld view each node is a link to its authors profile.

Over time the students developed a personal style in the representation of space and in the expression of conceptual ideas. This personal style is noticeable in the profile and recognisable when reading the commonly built story threads.

**Self-Qualifying System**

Our aim is to motivate the community members to contribute towards a common goal, while they pursue their personal interests. Apart from keeping track of
authorship and visualising individual contributions, we encourage participation by ensuring an objective evaluation of individual contributions.

In the latest version of fake.space we introduced interactive critics facilities. Every member and guest can rate nodes in a range of three stages, “-”, “=“ and “+”. At the same time the average of all the ratings of a particular node is visible to everyone.

Besides the collaborative rating, another motivation source is the personal evaluation. The interface provides the participants with the possibility of submitting comments on the nodes and thus expressing their opinion publicly.

It is likely that our rating system motivated the students to match the quality of previously submitted nodes with high rating. After all, the ability to criticise, as well as to accept criticism are pre-requisites for a responsible involvement in the community.

**Evaluation**

Fake.space was a successful experiment in many ways. We have taught the fake.space course three times and always used state of the art possibilities of database supported collaborative work.

The way the students made use of CAAD tools as a means of expression and the story-telling environment as a place to communicate their ideas sometimes surpassed our expectations. In order to place their nodes in the node system they used different strategies. Some of them preferred to spread their nodes over the system, others wrote a part of a story-thread by adding nodes in a sequential way. At many places in the node system, intensive “dialogues” took place between authors that led to unexpected and very interesting developments of the story threads. However, there were also cases where the students did not consider the context of the nodes onto which they linked their own, such that the story-telling did not always work.

Comparing the results of the last fake.space version to the previous one, the quality of the nodes has increased tremendously. We attribute this improvement in part to the enhancements we provided in the environment, in particular, to the enhancements in the visualisation of the information stored in the database. These enhancements include the design of new visualisation options such as the students online identity, the profile, and the threads. We also attribute this improvement to the interactive critics facilities.

For more information on the earlier version of fake.space, see Hirschberg (1998).

**Discussion**

In the future, communities formed by ideas will be as strong as those formed by the forces of physical proximity (Negroponte 1998). The formation of an online community requires that the participants have common interests and that a need exists to share ideas. Fake.space was a success because its main topic “space” worked in this respect. The students had the opportunity to experience “life” in an online community and think about space in its different aspects.

In order to create a viable online society, not only is the latest technology needed, but foremost is a deeper understanding of interface design and of the sociology of online communities required. The experience we gathered over the past three years have enabled us to substantiate the direction that this course should take in the future. These include the content of the lectures and the enhancements we should make in the design of the teaching environment.

A next stage in the development of our teaching environment is the design of mechanisms of “sophisticated survey” that will increase the students’ motivation.

Identity plays a key role in online communities. Establishing one’s online identity provides a great deal of motivation. For most participants both the establishment of their own reputation and the recognition of others plays a vital role. In an anonymous environment any kind of reputation is
impossible. The very purpose of anonymity is to facilitate wrong by eliminating accountability (Donath 1998). Transparency mechanisms ensure the elimination of anonymity, increase a member’s responsibility to the community, and motivate participants to contribute to the group. Responsibility in this case concerns the fact that every individual’s work becomes part of the system where good contributions augment the overall quality and bad ones have a diminishing effect.

Fake.space should allow members to develop a reputation based on the quality of their work and ideas. The motivation for quality that we associate with communities depends on the existence of distinct and persistent personalities. The design of the environment must provide for a vibrant and detailed impression of the personalities of the community (Donath 1998).

The existence of a quality control system that provides interactive critics facilities is of great importance for reputation mechanisms. In our environment we have used such mechanisms with success. In the future, we envision the development of a more sophisticated qualifying system.

Recognition by the system also increases motivation and involvement. Mechanisms can dynamically visualise the oscillation between the most successful works in terms of rating, “reveal” the most enthusiastic raters, show the most engaged commentors, and the most provocative works that have been the subject of discussion.

More work remains to be done in scaling up our user community by accommodating groups of architectural students from other institutes. We have tried this in the past with the Technical University of Kaiserslautern and our experience was very positive. This will form a richer environment as different architectural ideas and aesthetics, that can also derive from the use of different software, flow in. It would be very interesting to investigate the reactions and influences between the different groups.

Conclusion

In our course, we teach students how to use CAD software with respect to a spatial theme and stress the meaning of computers as a medium by providing the students with a working environment that allows the contextualisation of information. The experience we gathered in the previous years should feed back into our lectures. The topics of “online communities” and “information spaces” should become an essential part of the lectures in the future.

Fake.space created the genre of spatial storytelling that suggests new concepts for architectural work in cyberspace. It reflects on a future where online communities entice students in a playful way to work with computers and CAD and gives them the opportunity to think about the role of networked environments in architectural space.

By enhancing our lectures we aim to motivate students to think more deeply about the abstract idea of space and the role that information spaces play in the conceptualisation of architectural space.

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Virtual Environment Design – Defining a new direction for architectural education

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This paper considers the design and development of virtual environments (VEs) and the way that it relates to traditional architectural education and practice. The need for practitioners who will contribute to the design of 3D content for multimedia and virtual reality applications is identified. The design of space in a VE is seen as being partly an architectural problem. Therefore, architectural design should play an important role in educating VE designers. Other disciplines, intrinsically related to the issue of VE design, are also identified. Finally, this paper aims at pointing out the need for a new direction within architectural education, which will lead towards a generation of VE architects.

Keywords: Virtual Environments, architectural design, architectural education

Background

This paper considers the design and development of virtual environments (VEs) and the way that it relates to traditional architectural education and practice. The design of space in a VE is seen as being partly an architectural problem. The aim of this paper is to point out the need for a new direction within architectural education, which will lead towards a generation of architects able to design space in VEs.

Following recent advances in software and hardware, supporting the generation of interactive three-dimensional content, this paper suggests that there is a need for professionals who will contribute to the design of space in VEs. Among the disciplines that could provide the knowledge base for such a profession is architecture. The majority of formal higher education courses currently available in Europe do not cater for this need.

A term often used in the context of architecture and virtual reality is the “virtual design studio”, seen as a system supporting remote audio-visual communication between architects, architectural students and educators for learning and collaborative work purposes. It has to be clarified that this concept does not relate to the concept of VE design and as such will not be dealt with in this paper.

Considering the need for educating designers of space in VEs

Recent technological advances have enabled us to use computers for representing real-world phenomena in a symbolic, schematic or realistic, multi-sensory way. We interact with such representations via human-computer interfaces (HCIs). Walker (1990, p.444) has suggested that the latest generation of HCI is a virtual environment (VE), which “provides users a three-dimensional interaction experience that includes the illusion they are inside a world rather than observing an image”. Humans therefore, interact with computers via human-computer interfaces (HCIs), in ways that give the interaction experience a predominantly three-dimensional, spatial character.
More so a VE is, by definition, experienced by the user as a kind of three-dimensional space.

As we approach the end of this decade, VR technology has developed and matured into a stable platform, adopted by a large number of commercial establishments for supporting real-world applications. These include aircraft and vehicle simulations for military or civilian purposes, medical simulations, architectural and urban planning, computer games, etc.

The computer games industry in particular, is one of the fastest developing industries world-wide. Currently, most computer games display action within 3D environments. Additionally, 3D environments can be integrated in:

- multimedia applications,
- virtual sets for film or television production
- interactive TV
- urban design and planning
- Remote collaboration - Virtual office.

The emergence of the standard for 3D content on the WWW (VRML) has enabled the hypertextual integration of 3D worlds with multimedia content. Film directors have already used VR applications to design 3D interactive storyboards, as opposed to traditional two-dimensional, linear, non-interactive storyboards.

Among the most popular applications of such technologies so far, are 3D on-line communities like “Active Worlds”, “WorldsChat” (Damer, 1996), “The Palace”, “VUniversity”, BT’s “The Mirror”, or Canal+ “Virtuel: the Second World”. These interactive, three-dimensional, on-line worlds are used by multiple users for:

- communicating with others,
- educating themselves,
- performing certain tasks, which may benefit from taking place in a three-dimensional, on-line, environment,
- entertaining themselves or for
- virtual shopping (e-commerce).

It is likely that in the near future a large number of people will be spending a considerable amount of time ‘inside’ such worlds. If we are to live, even partially, ‘inside’ these worlds we must consider their architecture. The nature of space in VEs (Charitos & Bridges, 1997) however, is fundamentally different from the nature of real space and consequently the architecture of VEs will require a new theory and practice.

These issues are urging us to consider the growing need for designing space in virtual environments and the consequent need for professionals adequately equipped to perform this task. This paper argues that architects, if trained properly, are potentially able to fulfil this role. Moreover, architects could play an important role in the development of the infrastructure for generating cyberspace [A] as a new spatial aspect of life and communication in the next millennium. It is therefore suggested that an alternative direction of VE design, within architectural education, could prove very significant for the architectural profession.

**The current state of architectural profession and education**

Architectural profession has undergone a series of changes since its conception. Seeking alternative directions and practices is inherent to the nature of architectural education and is not associated to unemployment, as is often the case in other professions. Architects have always been curious to investigate new ways of expressing themselves. In recent years, the scope of traditional architectural design’s contribution to construction is slowly changing due to:

- The finite amount of economically viable space, available within most cities of the developed world; cities are largely saturated, so there is limited potential for designing newbuilt, as opposed to refurbishing old building stock.
Advances in construction via prefabricated systems, as well as limitations imposed on designers by building regulations,

Change of working patterns in the architectural profession, which result from advances in information technology and communications (e.g. tele-working, etc.)

Current trends and economic patterns imposing a more frequent rate of refurbishing commercial space.

Additionally, the theory and practice of architecture, in the traditional sense of the word, are being influenced by electronic media, which are currently used by many architects in the process of design. Taylor (1993, p.15) argues that “As pen and paper give way to computer-aided design and virtual spaces whose reality is thoroughly simulated, the very methods, tools and techniques of architectural design are undergoing a thorough transformation”. Novel and unique architectural forms, which would probably never have been designed by traditional media, are being designed by computer-based systems. A good example is the Guggenheim museum in Bilbao, designed by Frank O. Gehry. The use of computer aided design tools is also instrumental to recent attempts towards pursuing novel directions in designing form and space (Toy, 1995, 1998a & 1998b).

Although architectural education should have taken these facts into account and adjusted its direction accordingly, the main relevant change that has happened in architectural curricula over recent years has been the introduction of computing and CAAD classes. Recently, there have emerged a series of higher education courses, which partially address the issue of designing VEs. It is worth noting that the majority of the undergraduate (BSc and BA) courses are organised within computer science departments, whereas faculties of art, design and architecture organise the postgraduate (mainly one year MSc) courses. Although the existence of these courses confirms the previously identified need for educating people in the design and development of 3D interactive content, the knowledge they offer is still seen as supplementary to traditional architectural or computer science education.

The architecture of VEs

The disciplines of architectural design and virtual reality technology may be related in two ways:

- architectural design may employ virtual reality techniques for aiding the design process and
- virtual reality may employ architectural design knowledge, for informing the design of virtual environments.

Architecture making use of VR technology

One of the most common uses of VR technology today is for approximating the experience of moving within an architectural environment of any scale. This type of simulation is called “architectural walkthrough” and can be employed for evaluating, communicating or documenting a designed environment.

Architectural walkthroughs may be employed at several stages in the design of an environment:

- during the iterative design process, for evaluating the design or
- after the completion of the design process,
for communicating the design:
• before the actual construction, or
• for presenting the process of construction or
• after the construction, for remotely experiencing the designed environment.

Historically important buildings, which have been constructed at an earlier point in time, may also be simulated in order to enhance the decision making process in planning control (Bourdakis, 1997) (Fig. 2). This method could be used:

• when a building is still maintained in a very good condition or
• when it is somehow damaged and in need of reconstruction or
• when it does not exist today.

It is also essential to mention the possibility of manipulating the form of a represented object, while being immersed in a representation of an environment displayed by a VE. Real-time, interactive modification of surface representations, may enable designers to perform modeling of objects and surfaces and consequently real-time design of environments, while being immersed in a VE (Slater & Usoh, 1994). By modeling and designing whilst inside a VE, designers can approximately experience the result of their design, in real-time, while actually manipulating elements of it. This way the designer can carry out the modeling process, while being in a very direct relationship with the model. VE systems, which support this level of interaction with the participant, are still at an experimental stage of development and most of this research is done with non-immersive VR systems (Kameyama & Ohtomi, 1993, Fernando et al. 1994). Finally, Slater and Steed (1994) and Slater & Usoh (1994) have also experimented with systems which support modeling of generic objects by an immersed participant.

Such experiments may lead towards systems, which support the design of form within a VE. Such a system is very significant because it provides the designer with a tool contemporary CAD systems lack; that is, visual feedback of what you design, when you design it, as if you were inside the designed environment (Smets et al., 1995, p.204, Kurmann et al, 1997, pp.809-819).

**Utilising architectural knowledge in VE design**

While the use of VR technology as a tool for aiding architectural design and communication has been established so far, it is still necessary to explain why we may need to apply architectural principles in order to impose a certain spatial structure in the design of VEs.

VEs are, by definition, built on the principle of imitating the spatial experience afforded by real environments. Therefore, the experience of a VE has a predominant spatial character. A VE is experienced by humans as a kind of three-dimensional space, comprising several objects and events, which do not necessarily have real-world counterparts. The synthetic environment defined by these objects and events is a setting, which may accommodate human activities like:

• navigation,
• interaction and
• communication

![Figure 2 (left). View of the Bath model](image)
and which can potentially support the creation of viable communities. Consequently, this paper argues that the design of a VE is an architectural problem as well, and as such it may benefit from the use of architectural design knowledge.

In the real world, architecture is the discipline, dealing with the construction of spaces, accommodating our needs. Such spaces are necessary in order to:

- protect ourselves from the forces of nature,
- delimit the vastness of our world into a more comprehensible network of meaningful spaces, which gives form and structure to our everyday experiences and within which we can move and act for our everyday needs.

Architecture and planning are the disciplines responsible for creating such networks.

Space in a VE is infinitely expandable and physically limited only by the computational power of the system, which supports the VE. There may be no need to protect participants from natural hazards but there is still a need for delimiting space in a VE in order to make it

- more legible and therefore easier to navigate
- easier to remember when experiencing a VE more than once.

In order to delimit space in a VE, as we do in the real world, this paper argues that there is a need to impose a certain form and structure onto the space. For the purpose of doing so, we need to develop an architectural framework, as a system of meaningful spatial elements in this VE, ultimately making our interaction and navigation within the VE a structured and meaningful experience.

It is useful to attempt conceiving the role an architect could play in a project of designing a VE. Frericks (1994) proposes the term “virtual architect” for describing the designer who may contribute architectural knowledge to the process of designing a VE. He then goes on to suggest a possible iterative process, through which the developers of a VE and the “virtual architect” may cooperate in order to design and develop this VE:

- Firstly, the application requirements are defined by the developers.
- Then the architect has to come up with the spatial composition, which defines the
geometry of the environment, including all graphical and non-graphical objects for interaction.

- Consequently the developers use this spatial composition to implement an initial version.
- From that point onwards, the developers and the architect may work together on the basis of mutual feedback, in order to optimise the VE for the requirements of the particular application.

An experienced designer may note that the collaborative process described above is analogous to the role of an architect within a typical large-scale architectural design project. It is understood, however, that the design of a VE is a very complex task, requiring input from various other disciplines as well – e.g. software engineering, cognitive ergonomics, perceptual psychology, graphic design, mechanical and electronic engineering, etc. It would not be possible for “virtual architects” to have the knowledge for providing solutions to issues relating to these disciplines. It is however essential that they know enough to be able to collaborate with software engineers, psychologists, graphic designers and engineers who specialise in VR technology issues (I/O devices, motion platforms, etc.), during a VE design project. This implies that the education of “virtual architects” should include fundamental knowledge from these disciplines, which are intrinsically related to the complex problem of VE design.

**Conclusions**

VR technology has been widely used for supporting the evaluation or communication of architectural design. However, this paper has mainly focused on the way that architectural design knowledge may contribute to the design of VEs.

3D content exists in several multimedia or VR applications, computer games, virtual sets or online communities. There is a need for designing 3D content for all these applications and consequently a need for practitioners who can perform this task. Consequently, a series of courses have emerged, attempting to supplement traditional architectural / computer science education with computer related design issues, among which is the design of VEs.

As is the case in the real world, we need architectural design for imposing a certain structure onto a VE thus making the experience of being in it functional and meaningful. It has been clarified however, that the design of a VE requires contribution from other disciplines as well. “Virtual architects” therefore should be trained so that they have an understanding of fundamental issues from other disciplines, relating to the development of a VE system, thus making them capable of collaborating with a series of specialists from these disciplines. On the other hand, traditional architectural design expertise, on composing form which determines functional space, is equally important for designing space in VEs as it is for the real world.

By way of conclusion, it is believed that all necessary knowledge for designing space in VEs could neither be provided by an architectural course nor by a computer science course. A new direction parallel to architectural education but at the same time focusing on the issue of VE design would have to be
introduced. “Virtual architects” could follow the studios of traditional architectural education. Additionally, since the nature of space in the real world is fundamentally different from space in VEs, they should be provided with background knowledge from disciplines relating to issues of VR technology rather than knowledge of technical issues relating to construction in the real world.

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Notes

[A] This paper takes into account the Gibsonian (1984, p. 67) definition of cyberspace as a three-dimensional, on-line, network of computer generated worlds.

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Bike-R: Virtual Reality for the financially challenged

Jules Moloney

This paper describes a ‘low tech’ approach to producing interactive virtual environments for the evaluation of design proposals. The aim was to produce a low cost alternative to such expensive installations as CAVE virtual reality systems. The system utilises a library of pre-rendered animation, video and audio files and hence is not reliant on powerful hardware to produce real time simulation. The participant sits astride a bicycle exercise machine and animation is triggered by the pedal revolution. Navigation is achieved by steering along and around the streets of the animated design. This project builds on the work of Desmond Hii. (Hii, 1997) The innovations are the bicycle interface and the application to urban scale simulation.

Keywords: virtual, design, interface, urban.

Introduction

The Bike-R project is part of a wider study of the impact of digital technology on the design studio in architectural education which on going at the University of Auckland. The aim is to apply available low cost technology to design studio teaching. The primary strategy developed at Auckland has been the implementation of Computer Aided Studio (CAS) where the emphasis was on the integration of digital and traditional media. In our view the physical and pedagogic integration within the design studios is crucial to the effective use of the computer as a design aid.

Consequently when considering virtual reality systems we rejected the purchase of head mounted displays or screen based systems. The cost and ‘fragility’ of such systems would inevitably mean they would at best become isolated areas of interest with little impact on the general design studio. Furthermore we have found that mainstream CAD packages such as ArchiCAD and 3D Studio MAX have developed interfaces that offer sufficient real time manipulation to meet the needs of students “understanding spaces whilst in the design process” (Bourdakis, 1998). In our view such interfaces offer sufficient simulation for the sort of ‘block modeling’ and evaluation that we encourage at the early stages of design. However while these real time interfaces are adequate for the process stage we found students were frustrated when attempting to present a high level of detail and realism during final crits. The problem was most acute when students attempted to animate complex urban scenes. Bike-R is an attempt to provide a low cost and robust means of simulating such complex models for final presentation and evaluation in the architecture design studio. Our aim is to allow students to investigate and present aspects of movement in relation to architecture and urban design.

Mobile Subject / Deforming Object (architecture)

It is self evident (but under utilised) that architecture
is experienced by bodies in a state of perpetual motion - actual body movement and / or through oscillating observation. However the means by which we conceive, evaluate and critique architectural proposals are still dominated by standard orthographic projections - supplemented by models at a scale that reinforce object qualities, or the now obligatory computer fly through. The development of virtual environments such as CAVE has offered the tantalising prospect of developing architecture from the point of view of a roving inhabitant. (Unfortunately the cost precludes use of such virtual reality systems within most schools of architecture.) Less self evident than the roving eye of the viewer is the potential of architecture itself to deform through movement of body parts / skin or to be transformed visually through the oscillation of the territory occupied. Obvious examples are windows and doors or the transformation of surface under different light conditions.

The Bike-R project is an attempt to address both the mobile subject and the deforming object. The aim was to enable users to pedal down a virtual street and evaluate the student projects within a dynamic context. There were three stages involved in the project.

**Stage 1 Composite site video and animation**

We anticipated two main benefits from using actual site video as opposed to animating a digital site model.

(a) Time efficiencies: Compared to 3d modeling, digitizing analogue video is a very effort and time-efficient procedure to reproduce complex geometry and such urban phenomena as wind through trees, cars and pedestrians.

(b) Realism: Form, colour, sound, movements and other behaviors of the physical environment are recorded in a very close manner to how they are actually perceived.

However the requirements for the site video turned out to be more complex than anticipated. The more ‘real’ the site footage the more likely the problems later when compositing the digital buildings. Changes in atmospheric conditions - sunlight intensity, shadows, etc. - and the appearance of foreground objects and events were to cause significant complications. We are currently pursuing two strategies. The first is a tactical move to record low grade site video and use video editing filters to add similar ‘noise’ to the computer animation. The objective is to deliberately lower the expectations of the user so that discontinuities are overlooked. This would be more suitable for evaluation prior to attempting more detailed simulation or for students who wanted a more ‘conceptual’ presentation. The second strategy is to record relatively high resolution video and attempt to solve problems associated with high realism. The major problems relate to disparities in lighting and embedding foreground objects. These problems can be addressed using techniques of superimposition established in the film industry but they are time consuming and work against our aim to make Bike-R a widely used studio resource. (Vaz and Dunignan, 1996) We are hoping this may be addressed as more composite videos are produced and sections of previous video can be reused. The aim would be for these to be used as ‘library parts’ in subsequent videos.

Most of the video to date has been recorded with a Sony handycam with a steadyshot movement compensator. This was attached to the front of a vehicle travelling in as regular a path as possible and at a constant speed of 25 kph. After recording the video, site measurements were taken to locate key objects which could be used as ‘camera trackers’ when compositing the site and digital models. The video was digitised using a low cost video capture card. This was then imported into 3D Studio Max as the background to the digital model. The camera tracker utility was used to match the motion of the digital camera with the real camera and after experimenting with lighting effects a composite video was produced. This was subsequently exported to
Adobe premiere where filters were used to ‘blur’ the edges between digital building and site video. The initial attempts at producing the composite were time consuming and the results disappointing in terms of a seamless integration of the digital model and the site. However once a working method was established we believe we have achieved the anticipated benefits of time efficiency and ‘quasi realism’.

**Stage 2 Interactivity**

We have used Lingo scripting within Macromedia Director to provide interactivity. The speed of digital video can be altered using the frame rate command. Frame dropping becomes extreme on speed increase hence the decision to record the video at an average bicycle speed and slow down the frame rate. Segments of video can be linked together and the user can choose ‘paths’ to explore a network of composite video streets. All events are triggered by ‘keyDown’ events to enable students to prepare and test their urban scenes on a standard keyboard / screen interface.

For students wishing to achieve a greater sense of interactivity we have developed a method to simulate head movement. For these projects video is recorded with a wide angle lenses which is digitised at high resolution. Within Director a foreground layer is introduced to frame a portion of the video. The video can be manipulated behind the masking frame in response to mouse movement. The effect gives a sense of real time movement of the camera position.

**User Feedback and Further work**

Preliminary feedback from users at this prototype stage is positive. It would appear natural body movement (cycling) unencumbered with head mounted displays or body suits facilitates a high degree of immersion. In addition the audience can share the ‘experience’ which makes the interface ideal for the context of a design studio crit.

Bike-R is at an early stage of development and further refinement of the basic technique outlined above can be anticipated. In addition to refinement we are planning to supplement the composite video with QTVR. The intention is to allow the user to stop at various points along the composite street. At these nodes the system will switch to QTVR and allow 360 degree navigation via the ‘helmet mouse’. A further enhancement is planned to allow the real time evaluation of architecture interiors. We intend to use a sophisticated computer game interface which allow photorealistic textures and volumetric lighting for a limited number of polygons.

**Stage 3 The bicycle interface**

An old bicycle was salvaged and bolted to a robust stand which suspended the back wheel above the base by 50 mm. A light sensor reacts to the rotation of the wheel and as the user increases the wheel speed the number of interrupts can be measured. Frequencies are set to relate to a range of speeds and as these thresholds are reached ‘keyDown’ events are triggered by direct wiring to an old keyboard. In another ‘low low’ tech move a infra red mouse is attached to a bicycle helmet to allow head movement interaction as described above. A high end pentium computer is connected to a data projector which is placed above and behind the user. The shadow of the user’s head appears at the bottom of the screen to further enhance the sense of interaction with the composite street.
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Online Photorealistic VR with Interactive Architectural Objects

Vladimir Geroimenko

This paper describes how Virtual Reality (VR) technologies can be used for modelling photorealistic environments with interactive and changeable architectural content. This application of VR allows us to create photograph-based panoramic models of real places that include a variety of interactive architectural objects and details. The user is able not only to navigate through a virtual environment (look around, up and down, zoom, jump to another viewpoint or location) but also to change buildings or their architectural details by clicking, moving or rotating. The following types of interactive objects are completely integrated with a virtual environment: 2D image-based objects, 3D image-based objects, 3D VRML-based objects and onscreen world controls. The application can be used effectively for teaching, including distance Internet-based education, project presentations and rapid prototyping. A sample VR environment is presented and some of the key creative and technological issues are discussed.

Keywords: Virtual Reality Modelling, Architectural Design, Interactive Contents, Photorealistic Environments

Introduction

Using Virtual Reality technology for visualising architectural spaces and objects is becoming a common task among architects and designers. There is a great deal of software and technologies available to help them with creating the precise models of 3D buildings and environments. At the same time, a huge amount of architectural work is connected with the reconstruction of existing buildings or embedding new buildings into existing urban environments. In this case, there is a need to create a photorealistic virtual environment showing all the proposed variants of its improvement as well as to make this environment accessible for many concerned organisations and people including the general public. The Internet is the only effective means of the delivery of such a virtual environment. The environment is accessible from any computer with an ordinary specification and Internet modern connection. Making files as small as possible is one problem. Another, more important and difficult problem is to make this 3D space highly interactive to enable the user to have a personal immersive experience by choosing different versions of the changes proposed by architects and designers.

This paper shows how VR technologies can be used for modelling photorealistic environments with interactive and changeable architectural contents. This use of VR allows us to create photograph-based panoramic models of real places that include a variety of interactive architectural objects and details.
Hybrid VR Technology: Image-Based Panoramic VR with Embedded VRML97 Objects

Virtual Reality technology exists in two different forms. The first of them is based on Virtual Reality Modeling Language (VRML) and consists mostly of three-dimensional (3D) objects and a variety of multimedia components. The second form is based on photographic panoramic images and was firstly implemented as QuickTime VR. Hybrid VR technology integrates both geometry- and image-based approaches (Debevec et al, 1996). This technology is presently being developed by LivePicture Inc. [1]. Photorealistic Hybrid VR includes a great variety of multimedia components such as 360 degree panoramic navigable images, 3D geometry-based objects, 3D photograph-based objects, 2D on-screen and world image-based objects, 3D spatial sound, 2D and 3D animations, and so on.

Photorealistic Hybrid VR opens new possibilities for architects to create architectural spaces with rich and interactive multimedia content. It combines successfully the main positive features of both PanoVR and VRML VR. Because of its image-based nature, Hybrid VR seems to be more suitable for the online presentations of architectural works than “pure” VRML-based VR. This technology allows virtual environment designs that are not only three-dimensional and image-based but also extremely interactive and changeable.

A Sample VR Environment

To show the possibilities of using Photorealistic VR, a sample virtual environment has been developed. The environment consists of the interconnected photorealistic views of the Hoe area in Plymouth. Users can visit this photorealistic environment online using the Netscape Navigator or Internet Explorer browsers. Its Web pages consist of two frames. The right frame includes a LivePicture viewer that enables users to navigate VRML-based environments with panoramic backgrounds. The left frame may display any additional information about the architectural objects, which the user interacts with or about the new locations, which the user enters.

The screen shots below show some samples of user interactions with a photorealistic virtual environment. Figures 1 and 2 show how the user can experience new proposals for changing an existing architectural environment by interacting with the objects in question. Just by clicking on these objects, the user is able not only to see their new image-based versions (fully integrated with a real-based environment) but also to get information in any form (text, speech, photographs, sketches etc.) about a specific part of the architectural proposal.

The use of image-based objects such as photographs, sketches or drawings create a new
architectural environment very quickly. But the possibilities of the user interaction are limited in this case by clicking on a building or its specific details. The virtual world in Figures 2 and 3 contains not only image-based objects but also true 3D, VRML-based objects. Such objects can be moved or even visited by the user. In the situation shown in these figures, a fairy tale castle as well as a plastic palm tree and cactus can be placed in any location within the panoramic environment. The user can enter the castle and walk around. Notice that the interface of this environment includes three onscreen controls (in its right lower corner) that toggle the appearance of the three VRML objects (i.e. the castle, cactus and palm tree).

Navigating through 3D buildings embedded in photographic real-life environment is a really unique experience. This enables both users and architects to notice some unexpected details of integrating new architectural objects with existing surroundings. Figure 5 shows some views from an embedded 3D building.

The above samples have shown only some of the possibilities provided by the Photorealistic VR technology. Because this technology enables the integration of panoramic and non-panoramic images with VRML-based objects and multimedia components, its possibilities seem to be unlimited.

**Application Areas of the Technology**

The technology based on the integration of panoramic image-based VR with geometry-based VRML VR can be effectively used to achieve a variety of purposes. The rapid prototyping (both photorealistic and sketch-based) of reconstruction of existing environments is one sample.

The most important use of this technology lies in a variety of architectural education areas (online courses for university, life-long or on-demand education). For example, a public discussion about the reconstruction of an urban space may become indeed successful if it is supported by an Internet-based virtual environment which any individual is able to visit, to navigate through and to change in order to get a unique immersive experience of architects’ ideas. This application of the VR technology has a strong educational flavour because it opens new
possibilities for general public to get unique architectural knowledge and experience.

**Conclusions**

The development of our prototype of an online photorealistic VR environment with interactive architectural objects shows a high potential of this technology especially in the areas of Internet-based education, project presentations and rapid prototyping.

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The Bartlett School of Graduate Studies, University College London (UCL), set up the first MSc in Virtual Environments in the UK in 1995. The course aims to synthesise and build on research work undertaken in the arts, architecture, computing and biological sciences in exploring the realms of the creation of digital and virtual immersive spaces. The MSc is concerned primarily with equipping students from design backgrounds with the skills, techniques and theories necessary in the production of virtual environments. The course examines both virtual worlds as prototypes for real urban or built form and, over the last few years, has also developed an increasing interest in the practice of architecture in purely virtual contexts. The MSc course is embedded in the UK government sponsored Virtual Reality Centre for the Built Environment which is hosted by the Bartlett School of Architecture. This centre involves the UCL departments of architecture, computer science and geography and includes industrial partners from a number of areas concerned with the built environment including architectural practice, surveying and estate management as well as some software companies and the telecoms industry. The first cohort of students graduated in 1997 and predominantly found work in companies working in the new market area of digital media. This paper aims to outline the nature of the course as it stands, examines the new and ever increasing market for designers within digital media and proposes possible future directions for the course.

**Keywords**: Virtual reality, Immersive spaces, Digital Media, Education

Working in the development of New Media involves a general knowledge and skill base in a number of areas with preferably an expert knowledge in one or two. Aspects of New media design can involve an understanding of typography, layout, graphics, narrative, information visualisation, 2D and 3D space design, circulation, body and self, representation, iconography, communication, behaviour, immersion, interface, interactivity and function. As a result New Media developers tend to come from a broad range of backgrounds, not least that of architecture.
Indeed, architectural theoreticians such as Michael Benedikt and William Mitchell have long argued that electronic information space, or cyberspace, with functions such as community, economy, commerce, art and design and recreation, is equally as valid as their real-life cityspace equivalents and these are indeed the sort of spaces that architects should be addressing. The New Media area has opened the door for exactly this type of exploration.

The MSc Virtual Environments course aims to equip students from a design background with the necessary range of skills in order that they are able to seek out opportunities within this area. The course aims to examine the theoretical aspects, construction and creation of virtual functional environments and analyses the relationship of the creation of these spaces with that of conventional architectural design.

Virtual Environments can be constructed at a number of levels – from the immersive headset to the linking of ‘real’ space via digital multimedia. During the course students undertake a number of practical projects which both reinforce theoretical learning and also introduce the complexities of the software synthesis of virtual environments. The course is taught using a variety of media including lectures, seminars, individual tutorials, workshops, internet, video and interactive multimedia. Students’ time is structured to facilitate the development of project based research.

**Context**

The Graduate School has five main areas of research and the MSc VE course is perceived as a cornerstone within the computer aided architectural design area. The MSc course, PhD student study and The VR Centre for the Built Environment are interdependent and mutually supportive of each other.

The VE course is one of 21 taught Masters courses offered at the The Bartlett School of Architecture, Building, Environmental Design and Planning, University College London. The MSc Virtual Environments (VE) course is one of 11 Masters based in the Graduate School of Architecture. The school has around 150 students a year with the maximum intake on the VE course currently being 12 students.

The course is a modular course as is required by the Graduate School. The current course consists of 6 modules of either 10 or 20 credits, totalling 80 credits, with the summer project accounting for an additional 40 credits. Theoretically, within the modular system, from these these 80 approved credits, students must take at least 60 credits from the VE course curriculum, with the additional 20 credits from any other Graduate School Masters course. However, in the last three years, all Virtual Environments (VE) students have taken all modules from the VE syllabus and no student has opted in or out of any VE module. This is likely due to the intense nature of the teaching programme, particularly in the somewhat linear development of practical programming skills.

The course is 12 months in length and consists of 2 x 11 week teaching terms, 3 week examination period and 12 week summer project and dissertation.

**VR Centre for the Built Environment**

The course is supported by, and is the teaching arm of, The Virtual Reality Centre for the Built Environment, a DTI and Technology Foresight project. This allows the course to take advantage of research in other disciplines such as computer science, psychology and geography as well as establishing collaboration with associated industries and organisations. The VR Centre industrial partners currently include Advanced Visual Technology, WS Atkins Consultants Ltd, Balfour Beatty, Boots, Bovis Construction Ltd, British Telecom, Building Research Establishment, Division Ltd, ESRI (UK) Ltd, Foster and Partners, Fulcrum Consulting, International Computers Ltd (ICL), Ordnance Survey, Ove Arup & Partners, J Sainsbury plc.

**PhD Study**

All PhD students researching any relevant areas of the course are actively encouraged to give lectures, seminars and workshops on the Masters course.
Teaching Programme

Theoretical Discourse
Most of the introductions to theoretical ideas and related topics are taught in term 1 through two modules:

‘Principles of Virtual Environments’ (20 credits) examines ideas concerning the definition of a virtual environment, computational models, shared environments and related mathematics.

Areas covered include: Issues in Virtual World Design, particularly representational fundamentals, light and sound in virtual environments and aspects of presence and immersion (fig i); Virtual Communities MUDs and MOOs explored through introductory workshops and design project based work (fig ii); and Applied Mathematics covering vectors, matrices, surfaces and so on.

The module ‘Space Form Behaviour and Its production’ (10 credits) covers the issues of automatic generation of virtual environments and emergent behaviours and includes: Generative Modelling; Information Visualisation and Emergent Behaviour in complex systems.

As a deliberate policy, both of the above modules rely fairly heavily on visiting lecturers. The support of the VR Centre is that there are a number of guaranteed guest lecturers on hand, available to discuss ongoing research projects. In addition to this, our facilities and central London location attract interested visitors from local architectural practice and new media businesses. The majority of these modules are taught within the Graduate School, but there are a number of workshops and seminars supported by researchers in the department of Computer Science and Geography.

In the second term students are asked to undertake a theoretical exploration of a chosen topic in the module ‘Theoretical Analysis in Virtual Environments’ (10 credits) This module allows for in-depth study into the theoretical basis of the course through the analysis of theories offered through the disciplines of computer science and architecture. The module is taught through individual tutorials and students are asked to submit a 3,000 word paper.

Acquisition of Technical Skills

Technical skills are also developed first of all in term 1 through the module ‘Methods on Synthetic Construction 1’ (10 credits). This module comprises of workshops in which the students are introduced to the internet and to computer programming through the development of 2 and 3-dimensional internet based functional space. To date the module has emerged from being solely HTML based in 1995/6, to a mix of HTML and VRML teaching and next year will be entirely VRML & Javascript. The students have a total of 10 half day workshops where they undertake a small design project.

The second term sees an increase the students technical programming abilities through the module ‘Methods in Synthetic Construction 2’ (20 credits)This module introduces students to the process of constructing intelligent virtual environments through more advanced programming skills. A series of workshops equip students with the ability create and explore both immersive and realtime intelligent environments. The programming language and software used in the workshops can change from year to year. Last year we used Division software, with somewhat limited scripting abilities, to enable students to explore immersive environments and C++ with
Cosmo 3D in order to explore more advanced scripting in real-time interactive desktop environments.

Finally, in the short 10 credit module ‘Multimedia and its Application’ students explore interface design and general multimedia techniques with particular reference to the 2-dimensional depiction of 3-dimensional form.

The Resultant Combination

Over the third term and summer period students undertake their own personal project. Students are required to submit a 10,000 word Report on an agreed subject lying within the scope of the syllabus, and involving the design, construction and production of a virtual world. Examples of recent reports include: Exploring form creation with evolutionary design; Communication and spatial configurations; An exploration of new metaphors in virtual space; Using generative computer modelling to explore the relationship between road systems and the growth of the traditional English village; The effect of form and colour on navigation performance and level of presence in immersive VR (figs iii & iv), A study of the effects of 3D navigation in web based art representation (fig v).

A number of these projects, and the students involved in them, have been a catalyst for PhD research or as research contracts funded by the VR Centres industrial partners. Examples of such projects are: a comparison of virtual and real navigation patterns undertaken for the Tate Gallery (figs vi and vii), BT sponsored work into the development of a virtual meeting room, avatar representation in 3D space and communication patterns in virtual office design.

The course aims to equip students with a spectrum of skills from the practical to the conceptual. Participants survey a wide range of information technology in order to enhance their ability to participate actively in the use of IT in the built environment and in the New Media arena. Dealing with subjects as diverse as CAD, artificial intelligence,
behavioural systems and immersive experiences, students should complete the course having actively experienced and employed a broad range of the art and application of computing in an architectural context.

The Future

As we all know, most of the actual subjects taught on this course, although hardly prolific, are not new to computer aided architectural design courses. Until now subjects such as generative modelling, behavioural systems and artificial intelligence have been applied to either the architectural design process or the analysis of ‘real’ cities or buildings in some for or another. Although these systems are in themselves dynamic, their application to architecture and built form has until now, by definition, ended in a static product. With the advent of our new and ever developing cybercities, the application of behaviours and AI in the design process need not stop at the production of the building but can exist and continue to inform the functional virtual space throughout its lifetime.

It is with these thoughts in mind that it is planned that near future developments of this course are to include a module in information visualisation to examine how in this information age, we can be aided with the assimilation of information by 3-dimensional space. With a longer view, we hope to start to examine relationships between real and virtual and to explore the development of augmented reality systems. We plan to explore how virtual behaviours and intelligence can be projected into our ‘real’ buildings and the effect that these developments may have on our knowledge base, communication patterns, in all, the way that we inhabit the buildings we use today.

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New Worlds; New Landscapes

Steve Ferrar

Evolution, said Julian Huxley, is in three different sectors. The first is organic - the cosmic process of matter. The second is biological - the evolution of plants and animals. The third is psychological and is the development of man’s cultures. It is this third stage that is now critical, and if we are to survive as a species it can only be by replacing nature’s controls by our own, not only birth control but our use of the whole environment.

(Nan Fairbrother, New Lives, New Landscapes)

Keywords: Virtual Environments, Future, Culture.

Virtual Worlds

Y2K (Allegory)

As Gregor Samsa awoke one morning from uneasy dreams he found himself transformed in his bed into a gigantic insect. He was lying on his hard, as it were armour-plated, back and when he lifted his head a little he could see his dome-like brown belly divided into stiff arched segments on top of which the bed-quilt could hardly keep in position and was about to slide off completely.

Franz Kafka, Metamorphosis

The Millennium Bug is not a bug. It is a design fault - possibly the most expensive in human history. When the twentieth century ends many software applications will either stop working or give erroneous results. Perhaps it is also an allegory - for the chaos and uncertainty surrounding the transition to new uncharted territories. The Binary Utopian Gateway; a government sponsored construct, a tool for control, a symbol to mark the shared experience of transition. We are exhorted to purge our systems. Orwellian advertising warns of the dire consequences of non-compliance [A]. The BUG is an acronym; a euphemism, a metaphor, a malevolent presence that has to be exorcised before the New World On The Other Side can be accessed.

We are crossing the threshold from an imperfect, flawed world into a Utopia; or even Heaven. The new, shiny, untarnished Third Millennium. Safe passage is threatened by the machine. Only those who have worshipped at the alter of digital perfection will be admitted. The Unclean will be denied access as they will contaminate this new untrammelled land.

Like the bulletins recounting victories in 1984 [B] daily dispatches from the front line inform us of the latest triumphs in the war against the unseen enemy. British Airways (the world’s favourite airline) proudly proclaim that they are now Y2K compliant. They are cleansed and ready for the bright new dawn. Their executives will demonstrate their utter confidence by being airborne at midnight on December 31 1999 [C].

From our pre-eminent chronological vantage point we can review the past and contemplate the future.

The future will never be the same again. Such is the power and versatility of the emerging technologies, architecture will change for ever. The architect of the third millennium will be part-social engineer, part-scientist and part-software engineer. Or she will cease
to exist altogether.

**Domain (Heaven)**

*When things approach or actually take place our intellects are wholly at a loss; and so, unless some other brings us word we have no knowledge of your human state. From this you'll understand, that instantly the doors of future time have been shut fast and our awareness will die utterly.*

Dante’s Inferno

There is near-religious obsession concerning the nature of multi-dimensional domains. The world our disembodied minds occupy during digital intercourse might be heaven [D]. But unrestricted access has polluted and denigrated this binary Eden. It is a decadent world whose genesis in an unlikely alliance of military paranoia and academic opportunism gave way to a liberal distributed democracy that is now under siege from corporate muscle and commercial greed. It is a world struggling to exist in the face of rising commercialism and frontier lawmaking. A three way dynamic stand-off between the incumbents, the newly enfranchised, and the legislators.

The full potential of this incredibly unifying and enabling environment is still to be realised. For a while it was the domain of the initiated, who treated it as their personal fiefdom, a digital extension of the hallowed halls of academia. It was an esoteric world, difficult to access and manipulate. For the cloistered and arcane world of the remote academics this was a perfect environment; impenetrable to most outsiders. A shamanistic world presided over by high-priests of knowledge.

Cerne scientists infected their world with viral HTML. They threw open wide the gates to their fiefdom and the great unwashed flocked in. The World Wide Web was the conduit through which the invading digital arrivistes attacked the bastions of academia and challenged the hegemony of the great institutions. And with them came the diseases, viruses, vermin and detritus that always accompany huge movements of populations.

This rich environment has been trivialised, vandalised and shamelessly exploited. As a microcosm of the Real World it is excelling itself, focusing and highlighting our worst excesses and shortcomings. Sedentary shoppers browse virtual hypermarkets. Vicarious sexual tourists are offered binary stimulation and satisfaction [E]. Virtual con-men prowl the back streets of the cybercities separating the unwary from their electronic money. Persecutors of racial and gender minorities peddle their shabby wares. The medium is insensitive to weight or proportion. All organisations, no matter how small or marginalised speak at the same volume, reflecting nothing of their pedigree or communal acceptability. The weak, the gullible and the willing are all easy prey. Hate and fear travels well on the web.

The traditional staple of organised information sit neglected on library shelves whilst eager converts restively shuffle through devalued electronic information. Pursuit of knowledge is homogenised. It’s not on the Web? - Then it doesn’t exist. Boundaries of knowledge are defined by the search engine you use. Everything is so equally available that it is difficult to assign worth or credibility.

**VR (Soft Option)**

*The feudal serf’s ‘reality’ consisted of the seasons, local geography, basic feudal politics, religion, sex and gossip.*

Neil Spiller, Digital Dreams

*Outside and inside form a dialectic of division, the obvious geometry of which blinds us as soon as we bring it into play in metaphorical domains.*

Gaston Bachelard, The Poetics of Space

A young man with attitude and a streak of lawlessness works for an American software corporation. By night he is involved in nefarious network activity. We see scenes of normality, images of the late 20c. This is reality.
But he is a participant in a vast piece of software that simulates The Real World. The Real World is a computer programme controlled by machines that now farm humans for their energy. The human body is confined to a tank of viscous fluid and plugged into the matrix. Whilst the physical entity is born into, and permanently maintained in this state, its mind engages with the software and is never aware of this ultimate schism.

This is ‘The Matrix’ [F] and there follows the ‘enlightenment’ of the hero who, Christ-like, joins the ‘apostles’, who know the ultimate truth, and the subsequent penetration and ultimately, we suppose the destruction of this evil system. There are many religious allegories.

This is a true story. We have perfected Virtual Reality to such an extent that we have forgotten that what we take for the real world is in fact a gigantic software construct.

Architects, collaborating with Sony games engineers, movie directors, engineers and designers set out to design a believable virtual world in which to ‘imagineer’ their environmental constructs. As the technology rapidly improved and the ‘softscapes’ became more complex and convincingly populated it was discovered that the softscape visitors were spending longer periods of time in their alternative world, preferring it to their real versions. Several clients opted for permanent occupation of their virtual buildings instead of constructing the hard version. Having established that long-term Virtual Reality was feasible there was little point inhabiting the old ‘real world’ when we could construct a new, better version. We soon exchanged bulky, unresponsive external prosthetics for hardwired neural connections.

More convincing virtual environments encouraged more people to abandon their weak, decaying worn-out flesh bodies for shiny new models that looked and worked like those of their youth. Virtual copulation together with computer controlled artificial insemination ensures a continuing real and virtual population.

Many architects were unfortunately redundant in this environment as the only thing they could provide for virtual citizens was a two-dimensional AutoCAD floor plan. Most architects stubbornly lived out their lonely and meaningless lives in the material world inhabiting buildings of earlier millennia.

NanoWorld (Real Virtuality)

*One of the most fateful errors of our age is the belief that ‘the problem of production’ has been solved.*

EF Schumacher, Small is Beautiful

In 1959 physicist Richard Fynman [G] introduced the concept of building machines atom by atom, an idea taken up 20 years later by Eric Drexler in his now famous book ‘Engines of Creation’. On its publication the book was met with scepticism and little interest. But his dissertation in 1992 [H], provided the impetus for further research and development.

Nano refers to a billionth part of a meter, the width of five carbon atoms. The basic building block, a nanotube, is extremely strong and durable and anything built from it will be far stronger and lighter than a traditional structure. Computers will also be built of nanotubes, and nanostructures or nanomachines will have their brains distributed throughout their bodies.

The key to nanoconstruction is replication. The difficulty and cost of building at atomic level is enormous so initially a simple machine is constructed that in turn builds a more complex machine and so on. These nanobots are equipped with brains and flexible arms and are programmed to self-replicate.

Self-replicating machines will be used for almost any task from navigating the human bloodstream, repairing damaged or diseased tissue and organs, to assembling food, clothing or buildings. It presages the end of poverty and conflict with limitless food and materials together with longevity or immortality as even human cells can be re-engineered.

The boundary between the Real and Virtual worlds is blurred by the concept of nano swarms. Intelligent ‘foglets’, human cell-sized nanobots,
equipped with twelve arms grip other foglets to form larger structures. They are intelligent and can share their computational abilities creating a distributed intelligence. These ‘Fogs’ can be as opaque or transparent, as permeable or resistant as required. They can constantly be reforming themselves creating different materials, different shapes, different properties. One minute you can be sitting in a Living Room the next walking through a park. Virtual environments, but in a real world. Is that man with his dog real or just a fog person and canine?

Bovis NanoBuilders will be providing bespoke swarm technology fog buildings. Wake up in your fog bedroom as it metamorphoses into a kitchen where a fresh cup of nan-engineered coffee is ready to drink.

**Beings**

I think, therefore I am.
Renee Descartes

**Mind (Consciousness)**

Before 2030 we will have machines proclaiming Descartes’s dictum. And it won’t seem like a programmed response. The machines will be earnest and convincing. Should we believe them when they claim to be conscious entities with their own volition?
Ray Kurtzweil, The Age of Spiritual Machines.

*I do not think that non-biological machines can ever cross the chasm between computation and understanding.*
Sir Roger Penrose, Rouse Ball Professor of Mathematics, University of Oxford.

And what of the sentient beings that populate real and virtual worlds, that give meaning to built environments, that physically reference them in terms of scale and form? And what of their mind and the brain that accommodates it?

The familiar image of the brain is represented by the cerebral cortex, the mass of randomly folded, soft, spongy tissue that forms the top and sides of the brain. The two halves share information to produce a co-ordinated interaction with the body. The corpus callosum orchestrates the exchange of information between the two hemispheres so that they act as one. In the frontal lobes of the cerebral cortex ideas are created. This is the home of consciousness. Beneath the cerebral cortex is the limbic system or mammalian brain and this is where emotions are generated. Further down we encounter the more primitive areas, the mid-brain and the cerebellum or reptilian brain. This part deals with the vegetative processes of the body such as breathing and heartbeat. Using modern scanning techniques to monitor brain activity we are building detailed maps of the mind.

If you were to draw a ‘you are here’ sign on our map of the mind, it is to the frontal lobes that the arrow would point. In this, our new view of the brain, echoes an ancient knowledge - for it is here too that mystics have traditionally placed the Third Eye - the gateway to the highest point of awareness.
Rita Carter, Mapping the Mind.

It has long been debated whether a computer could ultimately match and finally surpass a human brain in sheer reasoning power. In 1950 Alan Turing proposed a test for what was described as artificial intelligence. To Turing, thinking implies conscious intentionality.

When considering the capacity of a computer to accommodate consciousness, there is much debate as to what constitutes consciousness and how it manifests itself. Does consciousness have a purpose or is it merely a by-product of neural complexity? Is it a continuous stream, or is that feeling of continuity and oneness an illusion? Supposing you could download the entire contents of a human brain and store it in computer memory, would consciousness accompany it? If so, in exactly which bytes of data would it reside and how much data could you junk before that personality ceases to exist. Neil Spiller
contemplates this in the Life-Box [I].

I returned home, the window was open.
Grandfather was jingling again.
I smiled at him, his red eye blinked back.
He was where I’d left him.
As he always was, hanging from the ceiling in the
corner of the lounge.

I had a question to ask him.
I stood on a chair.
So he could look into my eyes.
He said “Dave, good morning.”
I said “Who made you? I mean, what I can see.”
“I did, with the help of two architects.”
“How long have you been dead?”
“Fifty Years,” came the reply.
“It’s not so bad,” he giggled.
“I don’t know I’m born.”
Neil Spiller, Digital Dreams

Body (Incarceration)

Ratz was tending bar, his prosthetic arm jerking monotonously as he filled a tray of glasses with draft Kirin. It was a Russian military prosthetic, a seven-function force feedback manipulator, cased in a grubby pink plastic. He saw Case and smile, his teeth a webwork of East European steel and brown decay.
William Gibson, Neuromancer.

False teeth and wooden legs are not prosthetics that most people would associate with the sexy world of the ultimate, desirable corporeal add-ons; but they were probably the first. There are an impressive number of organs and parts that can be replaced. We have artificial hands, arms, legs, feet and spinal implants. Micro video cameras have been successfully connected to the optic nerves allowing the unsighted a black and white view of the world. We have joint replacements including hips, elbows, wrists, fingers and toes. We can replace hearts and stimulate their action. We can rebuild body tissue and even implant devices to assist in penile erection. We are currently working on new materials from cultured cells to replace pancreas and liver. Artificial organs are in development. We are also developing ways in which prosthetics can be hard wired into the existing neural and nerve networks. Films like Robocop [J] have popularised the idea of combining electro-mechanical devices with genetic material to produce a hybrid - the cyborg - half human, half robot.

But, there are other considerations; aesthetic, psychological and emotive. Our concept of our bodies is not just visual, there are tactile and philosophical components. We expect our, and other people’s bodies to be soft and warm.

We have now started to understand the cellular composition of our bodies. We are able to interpret and manipulate the code that governs the construction of our cells, the description of what and who we are. It is now conceivable that we can approach the repair, enhancement and replication of the body from a cellular standpoint. Even ageing could be postponed.

A genetically engineered superhuman would be only a second rate robot and a designer would be quick to recognise the advantages of re-engineering the bodies cells using Nanotechnology rather than the traditional protein-based structures.

But why not abandon these atavistic shells in favour of virtual, soft containers for our environmental interfaces. Virtual bodies have none of the drawbacks of actual, physical, vulnerable package of flesh. With a cerebral base in the old world, hard-wired to powerful, fast machines running hyper-real software, the requirements for physical presence in the old sense diminishes. As the discarded body atrophies over time, the brain, relieved of other tasks, evolves into an advanced and enhanced state of super-consciousness, the better to sample the pleasures of its new environment.
Real Worlds

Production (and deviation)

*Ortho Mode. An AutoCAD setting that permits only horizontal or vertical input.*
AutoCAD Manual, R12

Meanwhile, back in the Real World, vision has been appropriated by followers of other disciplines. In a climate of increasing specialisation and constantly emerging and evolving technologies designers of the hard environment find themselves ever more marginalised other, more focused professionals.

Motivation and inspiration concerning digital technology is informed by half-truths and cliches. “Computer Literacy” is the touchstone of politicians and professionals, with little imagination and even less idea of the true impact of machines in education and the workplace. Aspiration is subjugated by an educational and organisational system that seeks to polarise arts and sciences. Under these conditions little surprise that we are not producing Leonardo da Vincis or Buckminster Fullers.

Our brave RIBA-Boys develop computerised management and production systems of great sophistication. There is much mutual congratulation and re-adjustments of profit margins as the busy hum of the plotter resounds across RIBA-land, and countless aspiring designers are consigned to the keyboard and the friendly emissions of the VDU. Computer technology has arrived, and It Is Good.

A few deviants, encouraged to believe that perhaps the machines could assist in the deeper and fuller exploration of spatial and formal issues, are mostly ignored by their peers who know that economic nirvana lays in their ability to produce.

However, when called upon to do so by patrons, RIBA-Men can demonstrate their dexterity and vision by producing glossy visuals. They are hooked on the, sexy language of slick, empty computer visuals. This language has been adopted, hijacked and subverted. The currency is “photorealism, fly-throughs, animations, virtual reality ....” and thin empty projects acquire a veneer of gloss and artificiality.

The deviants, still mostly ignored, think that it is quite a good idea to use the technology to investigate, interrogate and explore. Structures are designed in three-dimensions, issues of lighting, texture, colour and scale are studied at length. Relationships between structure, form and space are examined. Other technologies and disciplines are visited and borrowed from. Virtual spaces are inhabited and sampled. And, oddly, they still like using the pencil and making models.

Hard Choices (Soft Choices)

*Cyberspace minds may continue to learn even after the death of the wet intelligence that spawned them and on which they are modelled. Where does death reside, or, indeed, is it fully possible any more?*
Neil Spiller, Digital Dreams.

The pace of technological advances is ever-accelerating, leaving most architects bewildered. They lack the imagination and will to fully embrace the digital world. For the decreasing band of deviants the technology offers a number of choices.

Do we create softworlds and inhabit them virtually? These worlds would be copies of our current world and the soft We's would be copies of the flesh versions. We would live in familiar architecture and live familiar lives. Our bodies and neural hardware would remain in the real world whilst our minds, senses and soft bodies interacted with the soft world. We would design soft buildings.

Alternatively, we adapt our virtual bodies to an environment. In a softworld climates and bodies can be modified instead of building envelopes. Or we create virtual environments in our hard world, interacting with and shaping them at will? We can invent any number of virtual pals to share these virtual environments. In any event it is unlikely that the architect of 1999 would be required, at least not in her present form.
Meanwhile, unseen, millions of self-replicating microscopic aerobots drift through the air. They have been programmed with the AECKIL virus, they are on a mission.........

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Working in Virtual Environments through appropriate Physical Interfaces

Michael Knight and André Brown

The work described here is aimed at contributing towards the debate and development relating to the construction of interfaces to explore buildings and their environs through virtual worlds. We describe a particular hardware and software configuration which is derived by the use of low cost games software to create the Virtual Environment. The Physical Interface responds to the work of other researchers, in this area, in particular Shaw (1994) and Vasquez de Velasco & Trigo (1997).

Virtual Environments might have the potential to be “a magical window into other worlds, from molecules to minds” (Rheingold, 1992), but what is the nature of that window? Currently it is often a translucent opening which gives a hazy and distorted (disembodied) view. And many versions of such openings are relatively expensive. We consider ways towards clearing the haze without too much expense, adapting techniques proposed by developers of low cost virtual reality systems (Hollands, 1995) for use in an architectural setting.

**Keywords:** Virtual Environments, Games software.

**Introduction**

The work described here involves the development of a system to investigate and interact with an Architectural Cyberplace. The idea of Cyberplace was proposed by Szalapaj and Filho (1997). In a Cyberplace implicit meanings associated with architectural design can be expressed at either “pragmatic or emotive” levels. The act of creating and working in such environments creates a range of contentious issues for debate. The nature of such systems generates a range of social, cultural, philosophical, practical and technical matters that have been, and continue to be discussed in the contexts of environments for architectural investigation and exploration.

The social and cultural aspects involve the consideration of Nesses [otherness, groundedness, thereness (presence)]. In short Otherness is concerned with the absence, in virtual worlds, of (sometimes incongruent) aspects of reality and being a human in a real world. Matters relating to Groundedness are to do with balance, between, say the physical and the imagination. Thereness relates to how the human has a presence in the Virtual World; and that presence relates to both bodily and linguistic presence.

Our aim is to address and investigate a limited range of these issues by creating an environment which, put bluntly, might be cheap but effective. The environment involves the physical and the virtual. We describe how we created each of these aspects.
The virtual

It is a frequent criticism of conventional CAAD and rendering software that the time taken both for the creation and rendering of models is both overly complicated and time consuming. It is recognised by many [for instance, Brown and Horton (1990), Kurmann (1994), Brown and Simpson (1998) and Stellinwerff (1999)] that there is a need for better computer based conceptual sketchers and modelers. However this kind of tool is yet to become widely available.

Large-scale urban environments have been successfully modeled (e.g. Bourdakis, 1997) largely using VRML or proprietary software, but there are limitations to the range of applications suitable to this software approach. Most VR commercial systems concentrate on a personal immersion experience through the use of head mounted displays. Whilst this has advantages in the concentration of both display and position tracking hardware in one unit, it is not conducive to a shared experience. So what do we want from an alternative means of creating a virtual world?

Some goals

The requirements for a Virtual Environment system for studio use could be summarised as:

- **Ease of group participation**
  In a presentation situation, it is vital that the largest number of people can participate/engage with the VE, a form of what Gibson described as a “consensual hallucination”. This leads to the use of a large-scale projection system rather than other alternatives such as a head-mounted display or conventional monitor. The form of the projection could vary from the simple data projector to more complex three projector curved screen type.

- **Easy assimilation of the navigation method**
  Complex and confusing methods of moving about the model are counter-productive as the user will spend more time thinking about the controls than the experience of the model.

- **Rapid interaction and system response**
  A system that has a tardy response either in the method of control or in the display can cause frustration for the user. Whilst this can be the result of a system with inadequate power for the task in hand, it may also be the result of the expectation of the user used to the current standard of commercial games.

- **Communication**
  In an ideal situation, the ability to be able to share the ideas or the experience of using a space in real time, not just to a group, but to a remote use or group of users is a distinct advantage.

Software

It has long been recognised that the area which is both the most demanding of software, and the area which has the greatest expectation from its users is that of games software design. Manufacturers spend large amounts on developing both hardware and software to satisfy this burgeoning market for first person view 3D games that run (in current terms) on a standard PC.

Several of these games now come with ‘level editors’ to assist the avid gamer in creating yet more fanciful scenarios in which to shoot ever more grotesque creatures. For student use, games such as these have distinct advantages over conventional CAAD software. Firstly, the gaming environment is in the majority of cases the software that they are most familiar and comfortable with, most likely having spent more hours with them than any other software. Secondly, this familiarity and realisation of what can be achieved can overcome the fear of using a more conventional CAAD program. We have looked at one of these games and its associated level editor to evaluate its use in a studio situation.
Many such games fulfil the requirements that are required for an architectural VE system, particularly of interiors. The navigation systems are designed solely with rapid response and, on an initial level, ease of learning. Games such as Quake and Half-life have dubious story lines and even more questionable morals, but from a technological viewpoint are very interesting. The main thrust of the advertising and development of these games is in the ever increasing ‘realism’ of the worlds (a dubious claim given that they are portraying alien worlds) they are portraying and the speed with which the user can interact with them.

Half-Life by ID software has been recognised as a game which has both good graphics (with a high frame rate and smooth movement) and atmosphere generated by good lighting effects and textures. It also has the advantage of being networkable and multi-player. Lighting effects are created by a separate radiosity program when the game is compiled. Games can be played across the internet with the networking being optimised for multiple users. Each copy of the software is a game server. These features have great potential for architectural use.

The method of moving around the VE is very simple, user definable and easily learnt. Moving in the X-Y plane is achieved (as you may expect) by moving the mouse forward and back, or side to side. Mouse buttons can be assigned to looking up or down. Many of the controls are not immediately applicable for architectural use, although they can be used to give a heightened sense of interaction. Controls for changing weapons are of more use when they are...
reassigned to open a door or crouch down. With the most obvious relic of the game removed (the first person view of the forearm and hand holding a gun or other implement), Half-Life becomes a convincing architectural environment.

A further area which makes Half-Life stand out is the potential for the pseudo-intelligence of the creatures within the game. We have not investigated this yet fully, but there is the possibility for the use of ‘intelligent’ guides or assistants.

**Creating worlds in Worldcraft**

The creation of is carried out in a method familiar to anyone who has used a ‘conventional’ modeling program such as 3D Studio Max. Objects are created by dragging out to the required size; textures are applied by dragging. There are some omissions from WorldCraft, some of these coming from the limitations of the game itself, rather than the editor. The most serious of these is the lack of any Boolean operations and true curves, which results in rather rectilinear or apparently pixelated environments. The gaming world is eagerly awaiting the latest version of Quake, Half-Life’s marketing rival, which is being toted as handling Boolean operations to give more variety to its worlds. Probably the most noticeable, and serious, omission for users familiar with other software is the lack of any import facilities which means that there is no option but to create the whole model from scratch in WorldCraft. This would be less of a problem if there was an easily understood scale, but the program uses an arbitrary unit unique to the game based on the grid unit visible in all the windows. In fairness, the modeler is only designed to be used with Half-Life, and once used is relatively easy to adapt to. As the model quickly become quite large, slowing the display, judicious use must be made of the facility to hide entities as there is no equivalent of layers. These factors may seem to describe an overly restrictive environment in which to work. With the exception of the lack of import facilities, these are soon forgotten. Half-life can link an unlimited number of worlds together by means of ‘portals’ (similar to Quicktime VRs hotspots) which usually take the form of a door. Each world is only loaded when required. The loading results in a slight pause, but does enable apparently endless worlds to be created.

Once the world has been created, it can be viewed in the Half-Life after it has been compiled. This process is scripted by Worldcraft, the time taken dependant on the level of rendering required (i.e. draft for model checking or final for game playing). The time for compiling will obviously vary depending on the machine specification and model size, but one hour is not uncommon on a mid-specification PC.

**Using HalfLife**

Once compiled, the virtual world that has been created can be loaded into Half-life and viewed. The method of navigating the game is by default, mouse or joystick. For a screen-based presentation this is adequate, but for a projection system, a more naturalistic metaphor is required. A metaphor that links the user within the virtual environment will heighten the immersion experience.

The exercise bike was used as an initial attempt to provide both the experienced user and beginner with an object that was easy to relate to. The aim was to investigate both the efficacy of introducing a virtual environment into the studio, and the design of an easily learnt navigation tool. The bike, whilst not a new idea [A] is very well suited to an architectural use. By adapting more conventional hardware control devices such as a mouse, the bike can be used in any Windows application rather than requiring explicit joystick support from the target program.

With the control mechanism transferred to the bike the user can control movement in the virtual world, and the user regains some of the loss of “self-presence” that Shaw (1994) refers to. But then there is the nature of the image that the bike controls. This could be viewed through some kind of head set or could be screen based. But the work of Vasquez de Velasco and Trigo (1997) and Brown *et al.* (1996)
shows that, in an architectural setting, understanding and engagement with an architectural environment is enhanced by large image projection. Not only does this give the possibility of a shared experience but, perhaps more importantly, the senses of engagement and presence are improved. We feel that these are areas which merit more work in the future.

**Feedback**

We have used the configuration described above with a group of architectural students, all of whom had prior CAD experience. The scheme adopted was for a small house, the client of which was another student in the group. Each of the houses was to form part of a terraced street. It involved each student in being not just a designer, but also a client. Each of the students produced a final presentation that was a Half-life world with varying degrees of success.

The response from the observing architectural critics was largely positive when discussing the real-time interaction with the designs. It was also interesting to note the effect that it had upon their design processes. Two used the software to test their design expectations and developed them according to their experiences. It was the opinion of the students that the use of Worldcraft and Half-Life had predictably led them in directions which they would not have taken them in a 'conventional' design process. The reaction from the students concerned was that they had a greatly heightened sense and perception of the spaces that they were creating.

One of the interesting outcomes was that one student used the software only for the presentation. This particular student initially developed the design conventionally, but then built his completed design in Worldcraft, in the end using this as both the design development and design presentation environment. The anecdotal feedback from others who saw the presentations was also as they felt that it gave a heightened spatial experience, even though at this point, the presentations were on a conventional computer monitor.

**Conclusion**

The use of low cost gaming software proved to be successful within this albeit limited application and the limitations, primarily caused by its gaming origins, did not prove an insurmountable barrier. On a more ambitious scale of design scheme (or with students of a more free-form persuasion) the result might have been different with the Worldcraft editor proving to be to be restrictive and confining. On the other hand the same students would have found similar problems with most other conventional CAD or modelling applications. The interactivity that the designers found with the virtual environment helped their design process, but it would have been considerably more
useful if there had been a more rapid updating of the VE with the design in progress.

It is in this area that we are now steering our research. With the use of more powerful creation and viewing software, we will be able to update the VE directly from the modelling program without any intermediate compilation. We are continuing to develop interface metaphors in a number of areas that will allow particular and more focussed investigations to take place.

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Realtime 3D visual analysis of very large models at low cost

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Computer based visualisation of 3D models in architecture has been possible for 20 years or more, and the software technology has steadily improved during this time so that now incredibly realistic images can be generated from any viewpoint in a model, and impressive fly through sequences can bring a model to life in ways previously not possible. Virtual reality is with us and multi-media enables us to present a finished design in increasingly seductive ways. However, these forms of output from a 3D model offer much more limited benefits during the design process and particularly on large complex models because they are so computing intensive and it often require many hours to produce just one image. Anything other than a small and relatively simple model cannot be viewed dynamically in real-time on a desktop P.C. of the type commonly used by architects in a design office. Until now the solution to this problem has meant investing in expensive design review hardware and software with its inherent need for trained, skilled labour. As a result, design review products are often viewed as a luxury or costly necessity.

Keywords: Visual analysis, low cost, 3D modelling

Background

The need for a tool which can provide a totally flexible means of visualising large models in real-time on a desktop P.C. has long been the unattainable Holy Grail. To be able to visually analyse models at any time during the design process, rather than simply being able to view them, substantially enhances the interactivity of the design process so that more informed design decisions are made at an earlier stage, thereby saving time and cost as well as improving the quality of the product. In addition if such a tool was to be capable of being used without having had any training and without having any existing CAD skills then the architect can involve other members of the design team in the analysis and decision making process who would otherwise be excluded. The project manager, client or any other member of the design team could use such a tool remotely from the architect’s office and thereby be kept closely involved at all stages in crucial design decisions.

Introduction

Such a tool now exists. NavisWorks Roamer has been developed by LightWork Design based in Sheffield, and allows users to navigate smoothly in real-time through models with hundreds of thousands, even millions, of polygons - with no slowdown in frame rate. The problem with earlier software coping with very large models, is that viewing the model is either too slow or jerky or must rely on pre-defined paths through
the model. NavisWorks allows the freedom to roam the model using a range of navigating tools controlled by the mouse and a few simple key presses. In addition, many software products require extensive authoring. Designers must create multiple models of the same project, trading off detail and resolution in each model. Most often this is done at the end of the design process when it is too late to make use of the information viewed in modifying the design. NavisWorks can take data directly from a live database, eliminating the need for authoring. Therefore the user can view an up-to-date version of the model at any stage during its development. It has been Beta tested in the Department of Architecture in Huddersfield University, and its use will be illustrated on the overhead display in real-time using the work of a student who has created a model using Microstation then exported this as a series of DWG files for viewing analysis in NavisWorks Roamer.

The software has a number of unique algorithms and datastructure features which can be summarised as follows:

**Construction of the model**

A model may consist of any number of files appended to each other in any of the supported file formats. Opening a file loads a model from a file. The standard Open dialog use of Shift/Control keys allows multiple files to be selected and appended to the current set of models. NavisWorks Roamer supports multiple file formats via a plugin mechanism. In addition to its own native file formats (*.nwd and *.nwf), AutoCAD’s *.dwg and *.dxf files and 3D Studio’s *.3ds are supported.

Append adds a model to the current set of models. The combined set of models may be saved as a NavisWorks file (*.nwd) or as a NavisWorks file set (*.nwf).

When saving to a NavisWorks file (*.nwd) all loaded models, the scene’s environment, the current view and favorite viewpoints will be saved to a single file. When saving to a NavisWorks file set (*.nwf), only a list of the files currently loaded is saved, along with the scene’s environment, the current view and favorite viewpoints.

NavisWorks Roamer allows multiple models to be loaded simultaneously into the same coordinate space. Each file loaded is added to the root of the tree view. Individual files can be edited in the same way as objects within the file and can also be deleted from the set. When a *.dwg, *.dxf, or *.3ds file is loaded, NavisWorks Roamer creates a cache file (*.nwc). When the *.dwg, *.dxf, or *.3ds file is next loaded NavisWorks Roamer will read data from the corresponding cache file rather than re-converting the original data. If the original file is altered, NavisWorks Roamer will re-create the cache file when it is next loaded. Cache files speed up access to commonly used files. They are particularly useful for models made up of many files of which only a few are changed between viewing sessions. Cache options can be edited from the Options dialog box under the Edit menu.

**DWG/DXF Reader: Supported Entities**

The reader currently supports all surface (shaded) entities (3D faces, rectangular meshes, polyface meshes, circles, extruded lines etc.), including Proxy Graphics, but excluding ACIS based entities (3D Solid, Region). Line, point and complex entities (shapes, dimensions, text) are not supported. The structure of the drawing is preserved including blocks, inserts, AutoCAD color index, layers, views and active viewport. The NWExport plugin for AutoCAD supports the same entities including ACIS based ones.

**3DS Reader: Supported Entities**

All entities are supported from *.3ds files. An entity’s color is taken from its material rather than its wireframe color from 3D Studio and any maps, such as texture, applied to this material will be ignored.

**External References**

External references are shown in NavisWorks Roamer’s Tree Manager as an inserted group. NavisWorks Roamer looks for the externally
referenced files (xrefs) in the same place as AutoCAD. If the unresolved xref dialog is shown, then this link has somehow been broken and the referenced .dwg files need to be relocated to where AutoCAD would expect them to be.

If these xrefs are not important for the current session, then you can ignore the reference and the file will load without that xref inserted. Similarly, ignore all will load the file with all unresolved xrefs unloaded.

**NWExport ARX Plug-in operation**

NWExport is an AutoCAD R14 and AutoCAD 2000 plugin capable of exporting NavisWorks data files (*.nwd) and NavisWorks cache files (*.nwc) directly from within AutoCAD. NWExport adds three new commands to AutoCAD:

- NWDOUT, NWCOUT, NWOPT

The plugin currently supports all surface (shaded) entities (3D faces, rectangular meshes, polyface meshes, circles, extruded lines etc.), including proxy graphics, custom entities and ACIS based entities (3D solids, regions). Line, point and complex entities (shapes, dimensions, text) are not supported. The structure of the drawing is preserved including xrefs, blocks, inserts, AutoCAD color index, layers, views and active viewport.

A partial menu called LwNw_Export.mnu is available in the same location as where the nwexport.arx file was installed. One can then use AutoCAD’s menuload command to browse to this menu and load it. A NavisWorks menu will then position itself as the penultimate menu on the current menu bar and will persist across sessions until unloaded. The NWDOUT, NWCOUT and NWOPT commands are available through this menu.

**Navigating the model**

There are several different Navigation Modes which control movement in the main view.

These are based on the cursor keys and mouse drags with the left and middle mouse buttons. The shift and control keys modify the movement. The mouse and cursor keys perform the same sort of movements, with the mouse giving finer control. The shift key usually speeds up movement. Dragging with the left mouse button and the control key down performs the same actions as dragging with the middle mouse button (useful if you only have a two-button mouse). Right clicking on any item in the tree view or main view displays a context menu.

Modes are: Select, Pan, Walk, Orbit, Look Around, Examine, Zoom, Fly, Zoom Box, Turntable

There are also several Navigator Tools for altering, resetting or changing the type of camera.

Tools are: View All, Focus, View Selected, Perspective Camera, Section Plane, Orthographic Camera

**Sectioning the model**

Section Plane on the Navigation Tools toolbar displays the section plane slider control:

- The section enable toggle enables and disables the section plane. When enabled, the slider controls the positioning of a section plane in the model parallel to the reference plane, and the edit box displays the distance from the reference plane. Each button on the slider bar aligns the section with a different reference plane. The first is the current viewpoint. The remaining reference planes are positioned at the origin normal to each of the axes. The model is only visible on one side of the section plane. Moving the plane through a model is a good way of inspecting internal detail.

**Editing functions**

Editing allows the display of selected objects in the model to be Hidden or Required. The use of the Hidden or Required editing options assists the user
to navigate more easily in a very large or complex model. When elements are neither Hidden or Required then NavisWorks Roamer decides which objects are displayed. This depends on the viewpoint at any particular frame.

Options enables Selection, Caching, 3DS and DWG/DXF global options to be edited. These options are persistent across sessions. Scene enables editing of Lighting and Culling and these are saved with each file.

**Viewing analysis**

This is controlled by two parts to the screen window:

**Main View**
Displays a 3D rendered view of the model in the right-hand part of the window.

**Tree View (Tree Manager)**
Displays a hierarchical view of the structure of the model in the left-hand part of the window. The currently selected object is highlighted. The selection can be changed by clicking on items in the view or the rendered image in the main view. When clicking in the main view the selection criteria under Options in the Edit menu determine which items in the tree view are selected. There are several different tree icons representing the types of element which make up the structure of a model. Each of these element types can be Hidden (gray), Unhidden (dark blue) or Required (red).

The structure of the file as shown in tree view can be expanded or collapsed as required. The named item from the open file is displayed along with an icon indicating the type of item. The name and icon is displayed in a “grayed out” form if the item has been hidden and the name and icon are displayed in red if the item has been selected as required.

**The tree structure has the following hierarchies:**

- A model, e.g. a drawing file
- A layer
- A group, e.g. a block definition from AutoCAD.
- An inserted group, e.g. an inserted block from AutoCAD
- An item of geometry, e.g. a polygon
- An instanced item of geometry, e.g. an instance from 3D Studio

Note that if a group is selected as hidden or required then all instances of that object will be hidden or required. If you wish to operate on a single occurrence of an object then one can make the inserted group hidden or required.

**Viewing the model:**

Viewing the model is controlled by selecting Viewpoint and different Rendering and Lighting options. A variety of viewpoints can be set up to view the model from known positions and alignments. These can then be saved with footnotes and listed and selected as favorites.

Rendering applies the object colors and any scene lights which form part of the model. The model can be viewed as a Shaded Render view, a Wireframe view or a Hidden Line view. If a more photo-realistic image is required from a particular viewpoint then the stored viewpoint parameters can be passed across to another application such as 3D Studio.

If there are no Scene Lights then a single Head Light or No Lights view is available and Scene Lights is disabled. The intensity of these lights can be set using the Scene options under the Editing controls.

**Conclusion**

In conclusion we have found, for the first time, that students and professional designers are able to use a tool like NavisWorks in conjunction with any of the 3D modelling systems, to interactively analyse -
visually - any combination of models, of any size, real-time on a standard P.C. This has enabled much more effective design tutoring in the department and will, I am certain, provide the design team in practice with a powerful new tool for reviewing design progress at critical stages.

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Virtual Site Planning
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This paper looks at the potential for the Virtual Reality to be used as a medium for the development of teaching tools in Architectural and Urban Design Education. It identifies examples and lessons learned from the development of teaching tools in other disciplines.

The paper outlines a prototype system developed at Cardiff University to help Town Planning students understand the three dimensional nature of site planning and design. This was developed following difficulties encountered by students in using CAD which was seen as insufficiently intuitive to allow effective use within the short timespan available.

The prototype system allows students to access their site through the familiar environment of a Web Browser. A number of ‘Standard’ house types are available which can be selected and inserted into the design space. Once in the space the houses can be viewed in three dimensions, moved and rotated in order to form any configuration that the students may wish.

The system is easily customisable; it need not be limited to uses in urban design, but could be used in many situations where component parts are arranged in space.

**Keywords.** Virtual Reality, Teaching, Learning, Site Planning,

Virtual Reality as an Educational Tool

The potential for the use of Virtual Reality techniques within design education is well recognised, with the technique increasingly being used as a way of visualising students design work in order to obtain immediate feedback on design decisions. This may be done using an immersive environment, with a head mounted display or projected CAVE environment; or more commonly using a desktop set up running Virtual Reality Modelling Language, or a proprietary system such as Superscape. Networked computers lend themselves to the possibilities of Collaborative working, with examples such as the Collaborative Virtual Design Studio developed at University College London (Smith 1998). In this desktop based system, one enters a simulated city scene and can meet and converse with other inhabitants. It is possible for an inhabitant to build within that city, though this may involve collaboration with others, thus replicating processes that occur in urban planning. The Conceptual Design Space (CDS) at Georgia Institute of Technology (Youngblut 1998) allowed students to work collaboratively within an immersive environment in order to modify elements within a pre-developed virtual world, although major changes to geometry proved less easy. More commonly VR is being used to create a record of individual buildings (past or present), or of whole cities.
Virtual Reality also has potential as a medium for the development of teaching tools which can be actively used as part of a student’s learning process. These are more likely to have a focussed purpose, in that they are designed to illustrate a particular point, perhaps simulating a concept that would be difficult to explain by traditional means. Despite its great educational potential, there is little evidence of the use of this type of tool within built environment education, with the more open ended design related options taking priority.

Bricken (1990) and Kalawsky(1996) describe the many benefits that Virtual Reality can have upon a student’s learning experience. These can be summarised as follows:-

- Virtual Reality is experiential in that it enables one to build upon real life experiences within a familiar (albeit virtual) environment. This constructivist approach to learning has been advocated by a number of educational theorists for many years.
- It assists students in the conceptualisation of abstract concepts, through visualisation.
- It facilitates 3D interaction which is seen to aid understanding.
- It enables manipulation of 3D objects within space.
- It enables collaborative learning between users in remote locations.
- It allows new experiences to be simulated that may not be possible within the real world, including those that would be too dangerous or costly for real life experience, or would happen over an excessive time span.
- VR learning environments can be tailored to fit the particular learning style of individuals.
- They are intuitive to use, as in theory no additional skills are required to operate within a virtual environment than are learned through real life.
- They can provide a real life sense of scale.

The latter two points specifically refer to fully immersive Virtual Reality which Psotka (1995) argues to be a more effective educational delivery mechanism than the lower cost, desktop computer based system, where the interaction is through the unnatural interface of mouse and keyboard. This is especially true of some of the most popular web based browsers which are particularly difficult to use.

At the present time, it is unlikely that most teaching institutions would have access to the facilities required to use fully immersive VR as a teaching tool, and a desktop system is a more likely option. Newer versions of the Virtual Reality Modelling Language (VRML) are becoming increasingly comprehensive and provide a number of features which allow it to be used as the basis for the development of learning materials. Such features include those that allow objects to be dynamically added to a scene, manipulated and even animated. These interactive elements of a Virtual Reality learning tool are seen as being of particular importance in the educational process. Experiments by Byrne (1996) suggest that interactivity may be more important than immersion.

Work in other disciplines has shown that Virtual Reality can be a particularly useful media for developing teaching tools. An extensive evaluation of a number of these has been compiled by Youngblut (1998). A further example of the potential for VRML as a teaching tool is the ‘Visible Human’ project produced by the Northeast Parallel Architectures Center (NPAC) at Syracuse University. Here the user drags a section plane through a 3D human body, and then is able to see an image of what that cross section would look like in reality. Although this is a relatively simple tool, it shows the potential for describing something that would be difficult to achieve using traditional teaching techniques. The ‘Visible Human’ will not replace traditional teaching, but provides a mere point of reference, from which students can learn. With this and most VR teaching
tools there still remains a key role for the teacher in providing a guiding framework within which the software is integrated.

**Site Planning at the Department of City and Regional Planning**

The teaching of site planning and design within the Department of City and Regional Planning at Cardiff University is conducted through a series of practical modules. These aim to explore the application of design theories to site analysis and planning, building on general knowledge of design control and area-based studies of urban character and design quality. Students receive an introduction to the site planning process and are asked to prepare a site plan for a new residential and/or mixed use development. The modules are seen as an important source for the development of skills and therefore are generally taken by students who have little experience at both drawing and design.

Since 1997, Computer Aided Design has become an integral part of the site planning teaching within the Department. This was initially seen as a means of developing drawing skills that would be used later in professional practice. However it was soon realised that CAD had the potential for strengthening students’ generally weak 3D visualisation skills. CAD was initially introduced into the course at first year level, but has now been expanded to an option at diploma and M.Sc level. MiniCAD was chosen as the most appropriate software to use, as it contained all the drafting tools necessary for the professional skills element, as well as allowing simple block models to be created, and viewed in perspective and moved around the site.

Students were given a brown field site near to the City Centre of Cardiff, within which to develop a layout for 60 housing units together with associated areas for public and private space, vehicular access and parking. Students worked in groups of 8-10, each working in pairs to develop a quadrant of the site. Groups had to work together to ensure continuity and consistency of design between each quadrant. It should be noted that the time allocated to preparing these layouts was approximately five days, including initial training and necessary research. Therefore there was little time for students to develop design skills. The solution was to adopt a Planning For Real™ approach (Gibson 1991) where people with relatively few design skills can experiment with (and comment on) different layouts created from a kit of parts. Students were given a library of pre-designed standard houses and other symbols which could be inserted into their drawings. The house types were selected from those typically being used by housing developers and were primarily 3D block representations, with few details such as windows and doors. This allowed emphasis to be placed on massing and the spaces created between buildings. Students were also encouraged where necessary to produce their own house types, but in most cases this was not accomplished.

As the course progressed it became clear that students were struggling to master the technology in the short timespan available to them. They appeared to have few problems in developing 2D drafting skills, but had difficulty in using the three dimensional side of the technology in an effective manner. It had been hoped that the students would use the CAD system to move and rotate objects in 3D, experimenting with different arrangements, thus allowing them to gain instant feedback on their decisions on which they
could reflect and make amendments. In reality moving objects within a 3D space proved to be more complex, as it is difficult to judge in which plane objects are being moved, whilst looking at a 2D computer screen. When trying to move objects whilst in plan view students became more concerned with aspects of neat drawing than with experimentation. Generally, designs were produced by hand, on paper in two dimensions, and the three dimensional CAD work tended to be used as a presentation tool only. The difficulties encountered by the students also led to a significant strain on technician resources.

Because of these problems it was suggested that in future the CAD work would be concentrated upon the development of the necessary drafting skills. This left a gap as to how students would learn about the crucial three dimensional aspects of their work. Therefore there was a need to investigate the development of a simple tool that could assist students in their understanding of the three dimensional built environment. The criteria for the development of this system were that:

- It should be simple to use and require a minimal degree of training in order to use the product.
- It should allow students to rearrange buildings whilst looking at them in three dimensions and thus immediately see the spatial implications of their changes.
- Its use need be no more than an outline ‘sketching’ tool, as detailed work would still be carried out using CAD.
- It could allow groups of students to collaborate on design decisions, in reality this would be achieved by sharing a single computer, but it should be possible to collaborate over a network or internet.
- The software should be easily customisable, so that different sites or housing designs could be inserted.

Clearly a kit of parts approach is not appropriate for the development of comprehensive design proposals, however it has a role as an elementary teaching tool, to assist students, who are unlikely to become designers in their understanding of the built environment. The approach is similar to that developed by LEGO for their latest LEGO Creator product [ii], where a complete model can be built from a series of individual elements.

Virtual reality seemed a particularly suitable medium for the development of this teaching tool, as it requires relatively little training to be used effectively by students. CAD packages are designed to allow one to draw accurately, and therefore for every operation that a student performs, the computer will ask for a certain number of parameters. For instance in order to rotate a building, the user would need to choose the building to rotate, indicate a centre of rotation and then an angle of rotation. For students with limited knowledge of drawing or design, this mode of operation does not lend itself well to intuitive sketching. In a Virtual Reality environment, one could simply pick up an object and rotate it around as would happen with a real life model. To gain the full benefits of working in this way would require a fully immersive VR system, in reality however this is difficult to achieve with a large group of students, therefore a desktop system was chosen, using VRML. This has the advantage of being run through a web interface, with which students are familiar and also being free of charge. VRML contains sufficient scripting capabilities to enable full interaction with the model and also lends itself to the possibilities of collaborative working.

The Prototype

A prototype [iii] has been developed using a combination of VRML and Java, to run within a web browser containing a VRML97 plug in. Initially the user is presented with a blank VRML world possibly containing site information, surrounding buildings etc. It is useful to have a series of pre-set views within this world, as this allows students to quickly reorient themselves if they become lost. A Java applet,
contained within the same web page, is responsible for adding components into the scene. This is done through VRML's External Authoring Interface [iv] which allows a Java Applet to interact directly with a VRML world. Each of the standard components which can be added to the scene is saved as an individual VRML file. The Java applet takes a selected component and dynamically writes a short piece of VRML code that allows it to be inserted into the scene.

As the object is inserted into the scene, it is assigned a plane sensor. Plane sensors are one of a number of VRML sensors that track user activity when the mouse or viewer is positioned near to an object. When the mouse button is pressed over an object with a plane sensor assigned to it, the object is able to track the X and Y co-ordinates of the mouse, and a simple piece of scripting allows the object to be moved with the mouse. This has the effect that regardless of which angle the scene is viewed from, objects will always move parallel to the ground plane, thus avoiding any of the confusion related to working on a three dimensional model, whilst viewing on a 2D screen, where students may inadvertently move objects into the air. The Java applet also contains routines to rotate the currently selected object, by means of a small slider which forms part of the applet. It would also be possible to add a similar slider to change the scale or vertical elevation of individual components, if for instance a sloping site was adopted.

As the Java applet contains all the working data about the positions of each building within the scene, it should be possible to use the system to give students instant feedback on abstract matters such as likely population densities, which are seen as a key design criteria for the site planning project.

The system is designed to be flexible in its use, and could be easily adapted to suit particular site situations or to add in new components. In order to achieve this, very little is 'hard wired' into the Java Applet, as making changes here would be a complex process. The buttons required to insert and delete buildings are simply HTML links within a web page. A simple JavaScript function contained within the page header takes the name of the selected component and passes it to the Java applet. Thus the system can be customised by anyone who has a basic knowledge of HTML. Creating additional components can be done using any proprietary software for generating VRML worlds.

It is possible to foster collaborative working over a network using the prototype, although at the time of writing this is only possible by using the application sharing features of Microsoft Net Meeting or Netscape Conference. Attempts were made to use Blaxxun CCPro as a means for collaboration, but problems arose when participants joined a scene, midway through a session, as the new participants were unable to see the modifications previously made. This could be solved by regularly saving new versions of the scene to the server, using CGI or similar technology, but it was not felt necessary for initial evaluations.

At the time of writing it has not been possible to run a comprehensive evaluation on the software in use in a teaching situation, and it is hoped that this can be carried out during the forthcoming academic year. However initial informal comments have been positive, although difficulties in navigating within the current generation of VRML browsers (such as Cosmo Player 2) are likely to be prevalent until an easier interface is developed. An evaluation strategy with
some of the group using the tool and others continuing to use CAD is the most likely scenario.

Conclusions

This paper has examined the ways in which Virtual Reality can be used as a medium to develop tools that will be of assistance within the teaching and learning process and why this media may be particularly appropriate. It has looked at a specific teaching project and has identified a concept with which students have difficulties, that being the ability to understand and visualise 3D space. While CAD has not proved particularly successful in this light, Virtual Reality presents a potential means to assisting the students achieve understanding of this concept.

It has also become apparent that a tool where a kit of parts can be rearranged within space may have a potential benefit elsewhere within Architectural Education. Possible other uses might include

- The fitting out of office space
- Simulated assembly of parts of construction details
- Exercises in the manipulation of building geometries, as part of an architectural analysis project.
- Collaborative development of plans for urban areas using the internet as a means of communication (a kind of Planning for Real™ over the internet).
- Rearrangement of furniture within houses (as a sales tool for housing developers)

It is important to note that educational tools of the type described are not intended to be self teaching packages which would provide an alternative to the teacher. It is envisaged that VRML simulations would primarily be used to supplement existing teaching and learning activities, by assisting in those areas of the teaching and learning process where concepts were difficult to explain or understand. The teacher retains an important role in promoting a guided integration of the software into teaching. When considering the development of any tool of this type it is important to ask what is the added value of its use, as unless there is no added value the tool is unlikely to be used.

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