Computer Architectural Representation - Applying the VOIDs Framework to a Bridge Design Scheme

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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.

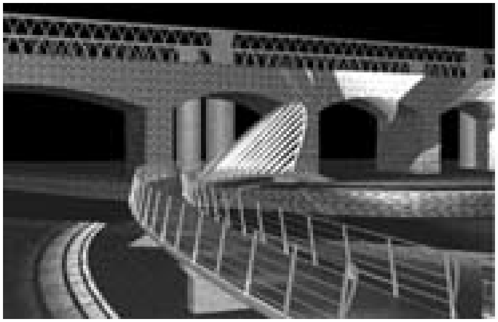
Architectural presentation is certainly not just to present the physical form of a design, but also to present the idea behind it. An alternative common view of representation which contrasts with the correspondence view is the constructivist view of representation. The constructivist view suggests that 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



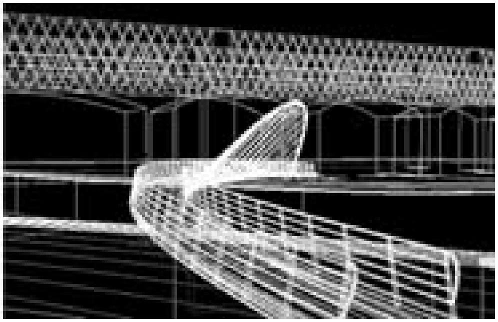


Figure 1 (top left). Different Models give different perceptions

Figure 2 (bottom left). User-controlled real-time navigation of animation

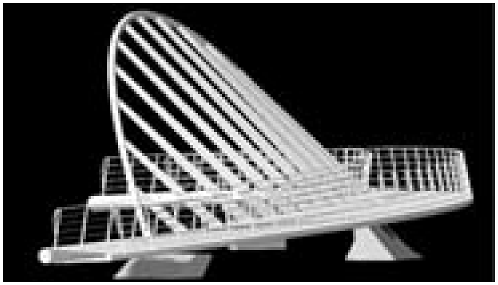
of this bridge design scheme uses a 3D motion model (walk-though & animation) together with real-time navigation. It is possible, therefore, for users to interactively control, in real-time, their viewpoint and position within any animation.

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



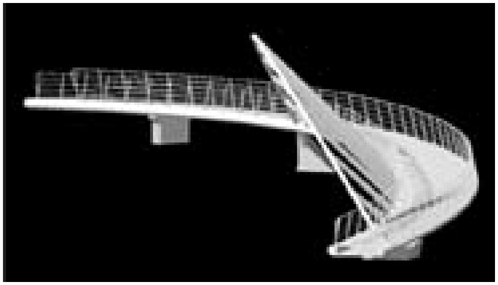
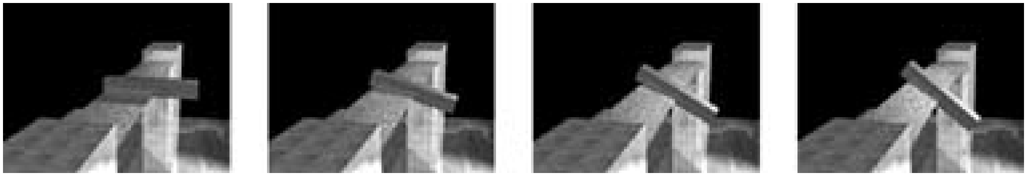


Figure 3 (right). Sequential images showing torsion force in a slip structure



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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