Architectural Composition in the Electronic Design Studio:
Conceptual Design using CAD Visualisation and Virtual Reality Modelling

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This paper evaluates the possibilities for the use of computer aided design and desktop virtual reality technologies as tools for architectural composition. An experimental teaching programme involving undergraduate architectural students at the University of Luton, in which aspects of compositional theory are explored through the direct creation of architectural form and space in digital formats is described. In the programme principles of architectural composition, based upon the ordering and organisation of typological architectural elements according to established rules of composition are introduced to the students through the study of recognised works of design theory. CAD and desktop virtual reality are then used to define and manipulate architectural elements, and to make formal and spatial evaluations of the environments created. The paper describes the theoretical context of the work, assesses the suitability of the software used for performing compositional manipulations, and evaluates the qualities of immersion and intuitive feedback which virtual reality based modelling can offer in the design visualisation process. The teaching programme utilises standard software packages, including AutoCAD, and 3D Studio, as well as Superscape VRT, a PC based desktop VR package.

1: Introduction

Computers have been used within the field of architectural design for more than 25 years. However, informed researchers and commentators recognise that the integration of computers into the creative stages of the design process has not developed as quickly or effectively as was anticipated by the early pioneers of computer based architectural design (Lansdown, 1994). It has proved particularly difficult within the sphere of architectural education to develop functioning models for the use of CAD and other information technologies within the creative environment of design studio culture. Instead CAD orientated work has been perceived as the realm of technocrats and has been placed in a pedagogic ghetto, often isolated from the main thrust of design teaching.

Attempts have been made to develop specialist software tailored to the creative requirements of the architectural design process, but the architectural sector represents only a small fraction of the CAD market, and the development of software specifically for this sector has not always been commercially successful. The programme of work being carried out within the Computer Aided Architectural Design Unit at the University of Luton seeks to develop pedagogic models for the teaching of architectural composition through the use of commercially produced CAD and desktop virtual reality software.

The virtual reality technologies which have emerged from the defence industries offer new opportunities for interactive design representation and evaluation. VR models facilitate the analysis of the spatial, formal and functional aspects of design solutions in a highly immediate, accessible and immersive format. Designers using these technologies have recognised its potential for high quality visualisations which can facilitate an evolutionary design process, with iterative evaluation of emerging design solutions and a rapid decision making process (Bewick and Riedel, 1994). This teaching programme seeks to exploit the immersive

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design environment offered by desktop VR to assist students in the visualisation of design ideas and the exploration of theoretical compositional principles [Fig. 1].

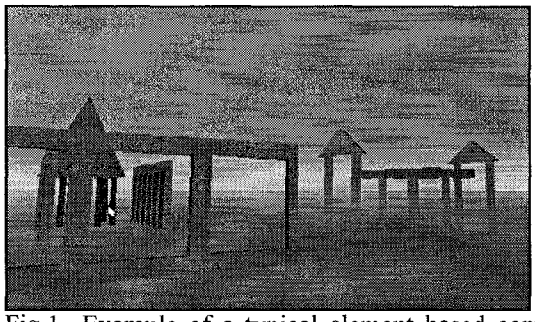

Fig.1 Example of a typical element based composition from the project generated in a desktop VR environment.

2: Theoretical Basis

There is a long tradition of architectural theory and design teaching which defines and explains the process of architectural composition through the manipulation and juxtaposition of architectonic elements according to established architectural ordering and organisational systems. This tradition has its origins in the work of J N L Durand and his definition of a taxonomy for architectural composition (Durand, 1819). A number of contemporary architectural theoreticians and teachers have adopted this elemental approach to architectural composition (Ching, 1979, Krier, 1988). The syntactic design operations which CAD technologies are well equipped to handle, such as repetition, rotation, translation etc. are those most intrinsic to an elemental approach. Anthony Radford at the University of Adelaide has developed CAD based pedagogic projects which involve the use of CAD systems to devise and manipulate abstract architectural elements in order to create compositions (Radford, 1990). In his computer based design teaching work at the University of Strathclyde, Alan Bridges has dealt with these themes (Bridges, 1990). In Polish architectural education Butelski and Kulinksi have also evolved methodologies for adapting the conventions of computer based three dimensional modelling to the process of architectural composition (Butelski, 1995, Kulinski, 1995).

3: The Teaching Approach

The teaching programme encourages students to explore compositional concepts within the context of computer based design work. Students are therefore able to integrate theoretical studies with computer based work, reinforcing the concept of computers as a design tool which can be integrated with the total design process. CAD and desktop virtual reality systems are used to define families of architectural elements which are then assembled and manipulated in accordance with established architectural ordering and organisational systems to create abstract architectural compositions. This element based approach is ideally suited to a digital modelling environment, where the elements can be rapidly combined and juxtaposed to create compositions of form and space. Experimentation with a variety of modelling processes, including standard CAD packages, export of CAD models to animation and VR systems and modelling entirely within a virtual reality environment, is encouraged within the programme.

4: Computing Requirements

The project work is based around the use of AutoCAD software for basic three dimensional modelling, Autodesk 3D Studio for visualisation and animation, and Superscape VRT for virtual reality modelling and visualisation. Superscape VRT has been selected for VR applications as it is a PC based software product, and does not require any specialist hardware. The processing power of current PCs limits the size and complexity of digital model which can be effectively manipulated and animated in real-time with this type of software. However, since the projects being carried out require the creation of relatively simple virtual worlds, constructed from a limited palette of elements and without complex textures, the processing requirements are easily within the limits of this hardware/software combination. The use of software running on a PC platform has advantages in an educational exercise of this type, in which large numbers of students require access to the necessary computer hardware. The PC is a relatively economic platform, which is widely available in most academic institutions. The processing power and software complexity of high end workstation virtual reality systems is not really necessary nor appropriate for this type of teaching in the early years of an architectural degree course.

5: Project Structure

In the initial design exercise students are asked to develop a small library of architectural elements. These elements are developed as three dimensional objects within AutoCAD or within the Shape Editor module of the Superscape VRT package [Figs. 2 and 3]. One

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advantage of creating the elements within the virtual reality software is that they can be viewed from any angle in perspective projection at all times, but the Shape Editor does not offer the full modelling flexibility of a CAD system. When created using Superscape the elements are created as a series of facets, and solid modelling is not available. Normal surface modelling functions such as extrusion and rotation are possible. Some care is needed in the editing of the facet ordering, in order to ensure that the facets are rendered in the correct sequence within the visualisation, so that all objects have the correct appearance when viewed from any angle.

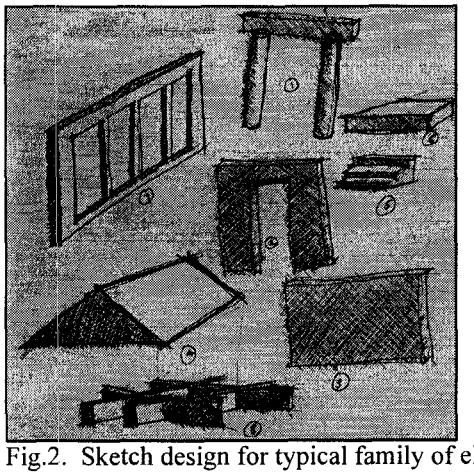

Fig.2. Sketch design for typical family of elements.

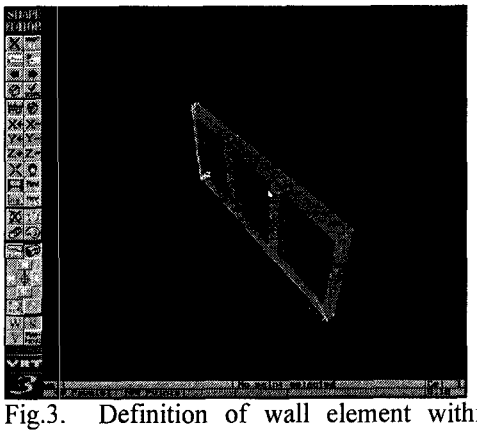

Fig.3. Definition of wall element within the Shape Editor.

Having prepared a library of elements, architectural compositions are then produced based upon this object set. These compositions are assembled within AutoCAD or the World Editor module of Superscape. Elements may be transferred from AutoCAD to Superscape, but significant re-editing of the elements within Superscape is then required. In both cases elements may be edited by repetition, rotation, translation, re-sizing, distorting and grouping. One advantage of creating the compositions within the World Editor is that the virtual environment can be viewed dynamically in three dimensions during the compositional process [Fig. 4]. The virtual reality world is generally found to be a highly intuitive environment in which to perform compositional operations. The real-time viewing offered within the virtual world provides the designer with the opportunity to evaluate design decisions from any viewpoint in an environment which gives a high degree of immediacy and sense of presence. Thus composition becomes an experiential process.

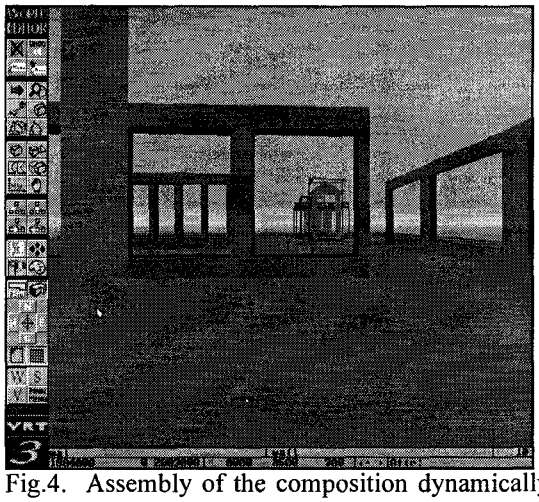

Fig.4. Assembly of the composition dynamically within the virtual environment.

In producing their compositions, students are encouraged to experiment with the knowledge they have gained from their reading in architectural theory of compositional principles and methodologies for ordering form and space. They are required to explore a variety of formal and spatial ordering systems, such as symmetrical and asymmetrical organisations, centralised and decentralised arrangements, compact and dispersed groupings, linear and radial organisations, axial and clustered systems.

AutoCAD based compositions are exported to 3D Studio for final editing and evaluation. They may also be exported to Superscape at this stage, but this requires additional editing work within the Superscape package. Virtual reality models created within the World Editor module of Superscape are evaluated within the Visualiser module of the package. 3D Studio images and animations provide high quality imagery with ray trace shadowing and multiple light sources, which gives a good sense of three dimensional space [Figs. 5-8].

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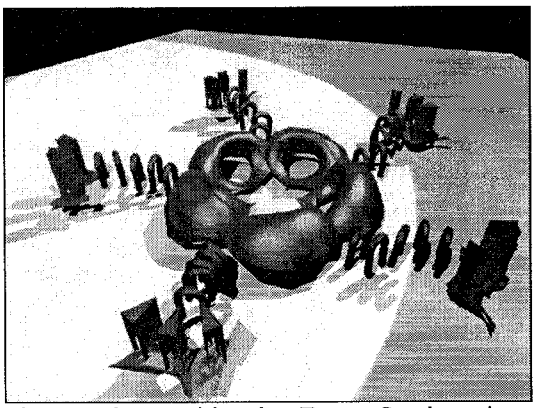

Fig. 5. Composition by Tanya Stanley viewed in 3D Studio.

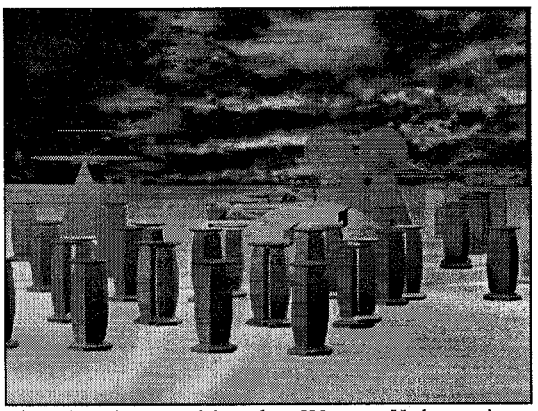

Fig. 6. Composition by Wayne Kaleta viewed in 3D Studio.

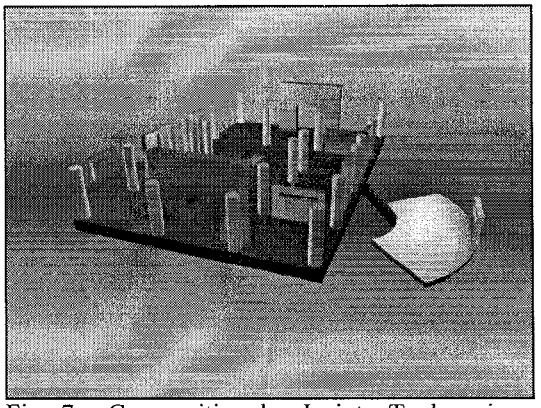

Fig. 7. Composition by Jacinta Taylor viewed in 3D Studio.

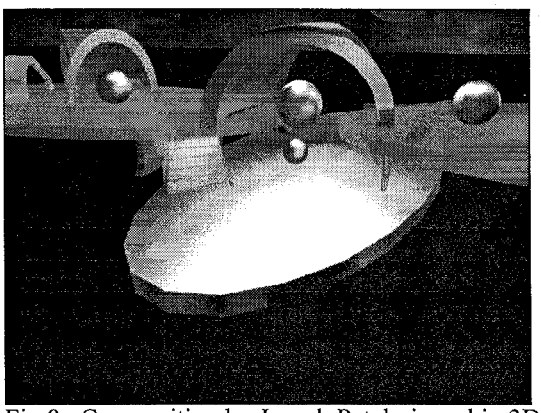

Fig.8. Composition by Jayesh Patel viewed in 3D Studio.

The virtual reality models are simpler in terms of textures and lighting but offer real-time movement and an authentic sense of presence. The students can move through the virtual spaces which have been created and evaluate the architectural qualities of the compositional arrangement [Figs. 9-12]. This interpretation and evaluation is carried out in a desktop virtual reality environment, in which the virtual world is displayed on a VDU. With the use of appropriate hardware, including a head mounted display, the virtual world could also be experienced in a fully immersive environment.

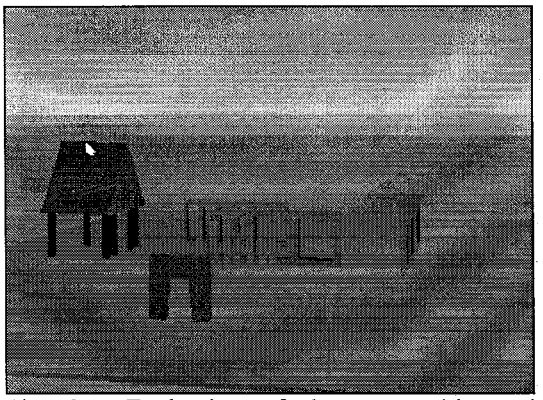

Fig. 9. Evaluation of the composition within the Visualiser module of the VR system.

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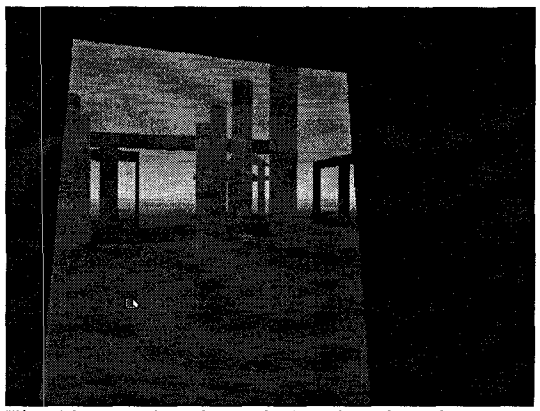

Fig. 10. Moving through the virtual environment.

Fig. 11. Dynamic exploration and evaluation of the composition within the virtual environment.

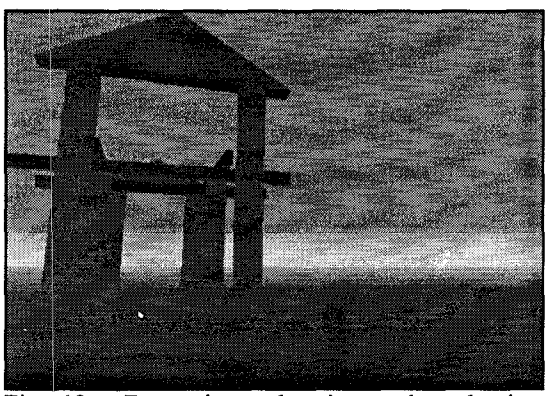

Fig. 12. Dynamic exploration and evaluation of the composition within the virtual environment.

This initial abstract design exercise enables students to explore the principles and parameters of an element based approach to architectural composition in a digital design environment. Further project work involves applying these techniques in the context of a more formal architectural programme. A range of precedental models which exhibit axial bisymmetry, including villas proposed by Claude Ledoux for the Ideal City of Chaux, are studied by the students in preparation for this work [Figs.13 and 14].

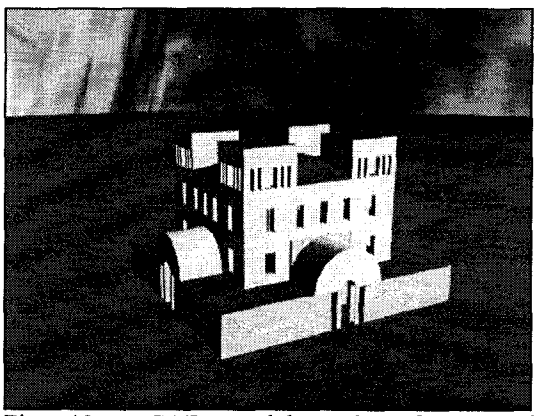

Fig. 13. CAD model study of proposal for a bisymmterical villa by Claude Ledoux.

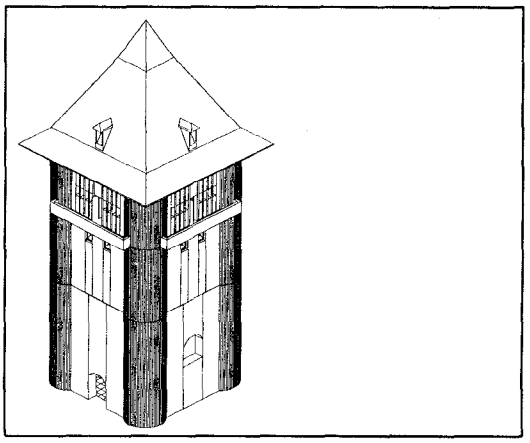

Fig. 14. CAD model of water tower exhibiting axial bisymmetry.

Students are asked to develop element based design proposals for bisymmetrical pavilions, symmetrical in plan about two axes and with each elevation in itself symmetrical about one axis. Bisymmmetrical architectural forms and spaces based upon repetitions of simple architectonic elements can be modelled quickly within a digital design environment, using generic operations such as reflection, rotation and revolution. This programme therefore facilitates the computer based modelling of a large number of compositional configurations in a short timescale, enabling evolutionary design through rapid prototyping. The computer based design is again carried out in either a CAD or desktop virtual reality environment [Figs. 15 and 16].

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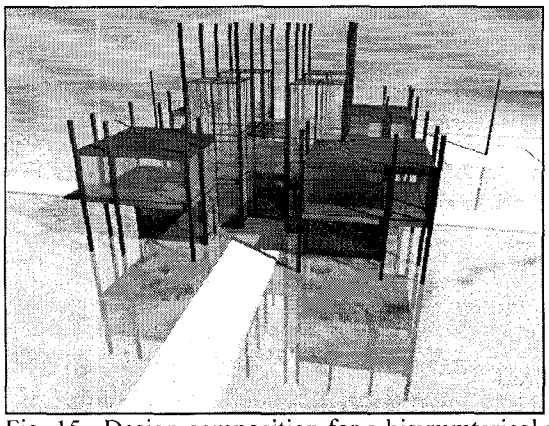

Fig. 15. Design composition for a bisymmterical villa by David Hopkins.

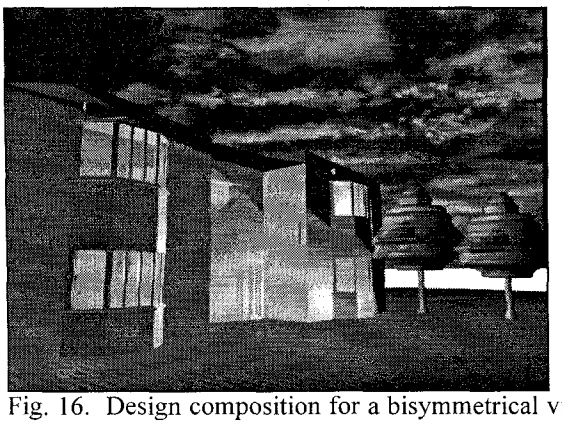

Fig. 16. Design composition for a bisymmetrical villa by Wayne Kaleta.

6: Pedagogic and Creative Benefits

The computer based design techniques described in this paper enable students to experiment with combinations of architectural elements with greater speed than is possible with manual drawing and physical modelling techniques. This generally leads to consideration of a greater number and range of prototypes before compositions are finalised, in comparison with the traditional design process. The element or object based nature of the projects is essential to achieve increased speed of prototyping, and this design philosophy is fundamental to the programme of work. This only represents one of many possible compositional models, and the relevance of the programme is therefore limited to a small part of the overall spectrum of design methodologies. It is suggested , however, that the recent emergence of object orientated CAD technologies and design databases makes such an approach worthy of further study. Students undertaking this programme are able to explore the opportunities and limitations of object orientated techniques.

Although restricted in terms of subtlety of modelling and sophistication of imagery, virtual reality environments have been found to offer added value to the design process. The student can assemble architectural elements within the virtual world and test a number of compositional arrangements in a highly immediate and immersive design environment. The ease with which the elements within the virtual world can be manipulated, and the effects of these modifications immediately evaluated in a three dimensional context with a high degree of spatial presence, is a unique feature of a virtual reality modelling approach to architectural composition.

7: Conclusions

The CAD and virtual reality technologies utilised in this teaching programme are evolving at a fast pace. It seems sensible for architects to exploit the immense research and development budgets of the hi-tech industries and use these generic technologies, rather than attempting to evolve new software solutions aimed exclusively at the architectural market. Emergent object orientated technologies have their development origins in design process applications, albeit from the air and defence sectors, and offer much to the architectural designer.

Neo-classicists in the French tradition, including Boullée, Durand and LeDoux, developed a highly refined approach to architectural composition which can be interpreted as an element or object based design philosophy. This body of theory has been influential in the evolution of much post-modern architectural theory, and these architects are a frequent source of reference for post-modern architects and critics such as Krier, Jencks and Venturi. This design tendency has inherent connections with the intrinsic methodologies of object based digital architectural modelling. Such an approach represents an alternative model for computer based architectural design, which contrasts with the systems based software solutions which have pre-dominated in the past and have tended to be related to functionalist design theory.

Integration of computer based design work with studies in architectural theory may be an appropriate strategy for bridging the gulf between the design studio and information technology orientated work. Our experiences with desktop virtual reality indicate that,

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although the models created are not as sophisticated as those produced using traditional CAD and rendering software, the immersive real-time environment assists students to utilise computers as an active design tool in conceptual design, rather than simply as a modelling system for visualisation purposes. Desktop virtual reality provides approximately 80% of the functionality of full virtual reality systems, and is likely to emerge as the most appropriate format for undergraduate work.

Advanced computer based design and electronic communication technologies are now being adopted by the construction industry on a wider scale. Object orientated, digital design data is likely to become the dominant format for construction information generation and exchange. Distributed virtual reality models over electronic networks are developing as a realisable model for collaborative design work, and informed commentators forecast that this teachnology will rapidly become available at sufficiently low cost to make possible its widescale use in the educational and commercial sectors (Hedberg, 1996). Introducing architectural students to object orientated virtual reality modelling has an important role in terms of preparation for future professional practice. We are seeking to develop an approach which utilises these technologies as a tool with applications at each stage of the design process, so that design in a digital environment can be conceptualised as a creative and integrative methodology.

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