VRML Possibilities: The Evolution of the Glasgow Model

Gareth Ennis, Malcolm Lindsay, Mike Grant
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Abstract.

During the 1980's, ABACUS, a research unit at the University of Strathclyde developed an interest in the ability to model and manipulate large geometrical databases of urban topography. Initially, this interest lay solely in the ability to source, capture and store the relevant data. However, once constructed, these models proved genuinely useful to a wide range of users and there was soon a demand for more functionality relating to the manipulation not just of the graphics, but also the range of urban attributes. Although a number of improvements were implemented there were drawbacks to the wide adoption of the software produced.

The problems were almost all due to deficiencies in the then current hardware and software system available to the professions, and although this strand of research continued to be pursued, most of the development had to be focused on research applications and deployment.

However, the recent advent of the Virtual Reality Modelling Language (VRML) standards have rekindled interest in this field since this language enables many of the issues that have proved problematic in the past to be addressed and solved. The potential now exists to provide wide access to large scale urban models. This paper focuses on the application of VRML as applied to the 'Glasgow Model'.

1. The Abacus Glasgow Model

In the 30 years since ABACUS was formed, the group has explored many research directions, the most enduring of which has been centred on the visualisation of the built environment. ABACUS has designed and built many software applications for this purpose, the first towards the end of the 1970's was called VIEWER.

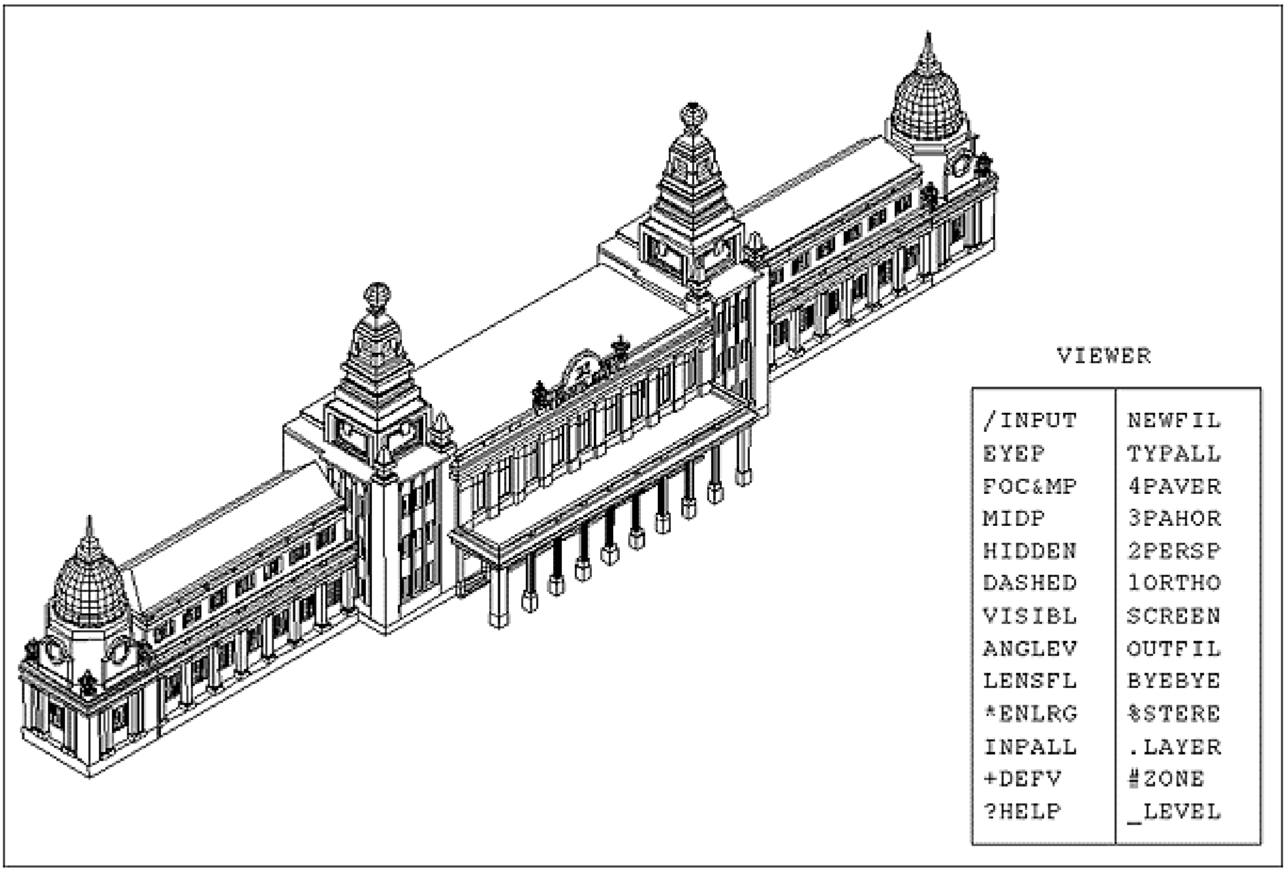

Figure 1 Abacus Software - Viewer

Using wire-frame line images, VIEWER allowed the visual appraisal of an object (e.g. a building) or a group of objects (e.g. an urban scene). Since the program could produce orthogonal, parallel or perspective projections of a scene, from any chosen viewpoint, the resulting images could be combined with photographs to form photomontages of proposed developments in situ. The VIEWER software was closely followed by VISTA, software designed to take the wire-frame model to a more advanced state, overlaying its framework of surfaces with textures to create a believable full colour shaded 'real-world' object.

In the spring of 1986, the Rutherford and Appleton Laboratory approached ABACUS, inviting the group to evaluate the capability of a new generation colour graphics workstation namely the Iris, produced by Silicon Graphics. The Iris was revolutionary in that it had a dedicated graphics engine, specific circuitry devoted to the task of undertaking large geometric transformations at speed, giving the illusion of real-time animation.

In order to stretch the capabilities of this new technology to its limits, ABACUS embarked on an ambitious method of evaluation. Using their own software, the team built a virtual model of the city of Glasgow representing an area of some 25 square kilometres, and attempted to produce interactive real-time 'fly-throughs' of the massive urban geometry data-set.

Backed with funding from 'Glasgow Action', a team of students were employed over the summer period to help with the mammoth task of capturing the necessary data.

Head of ABACUS Professor Tom Maver explains:

> "The strategy we decided to adopt was to build a model in three levels as it were... First we had to capture the terrain of the city. Secondly we digitised the road network and floated that down onto the terrain. Thirdly of course, there was the challenge of capturing the geometry of the buildings."(1)

2. Recommendations

Building the Glasgow model soon became an academic exercise in how to create, store, access and manipulate large geometric databases. Its appeal was instant, proving popular with architects and developers, who could use the model to display their design proposals within an accurate city context. Widespread use of the data-set was however limited to those organisations (mostly research) who owned similar expensive hardware and who were also prepared to struggle with the less than user-friendly software. Despite being frequently deployed by ABACUS as a design and planning aid, the model failed to directly benefit the wider community.

In April 1987, Steven King, a research student at the University of Strathclyde, conducted a critical analysis of the Glasgow Model(2). The following is a summary of his main recommendations:

1. The data set is too large to enable realistic animation, use only what is needed in each scene.
2. Different levels of detail need to be introduced i.e. the nearest block should have the highest detail and those blocks in the background should have very little detail.
3. Labelling - the data set requires labelling with street names, building names, owners, uses etc. being retrievable interactively.
4. More powerful hardware is needed.
5. The user-interface needs to be developed to provide more intuitive navigation.
6. Software is needed to allow the user's eye-point to remain at a constant height above ground level to aid the sense of 'walking' in the model, yet allowing a 'manual over-ride' for investigative manoeuvring.
7. Integrated databases containing building information should be linked directly to the model, i.e. it should be possible to stop outside a building and then call up information on that building including a detailed picture. This could be displayed in a separate segment of the VDU.

Without these features, King states, "the full potential of the Glasgow Model will not be realised. When these facilities become available, all manner of information will be available for reference and display, e.g. the ability to display where particular businesses are situated, could be useful in finding a bank either for a member of the public or for a rival bank examining optimum possible locations for a new branch."

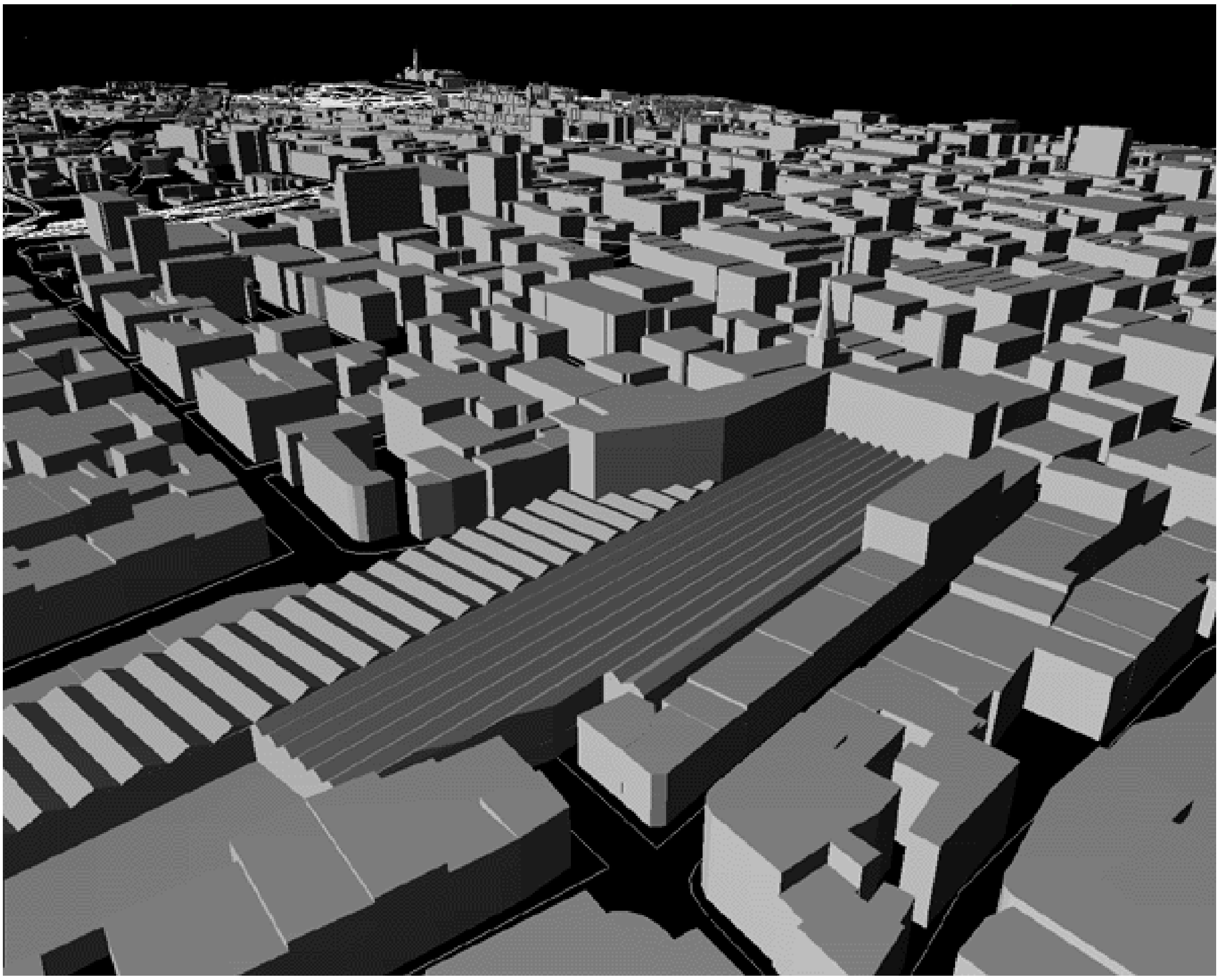

Figure 2 The Glasgow Model in 1987

At the time, ABACUS decided that the implementation of some or all of these features, although feasible, was a futile task, in terms of cost, software development, and time-scale.

Today however, it seems uncanny, that a young architectural research student should predict certain 'key' modelling standards that would emerge and be deployed almost ten years later with the advent of VRML.

3. Virtual Reality Modelling Language

In comparison to other programming languages VRML is in its infancy, yet its growth rate has been exceptional. VRML is not just a 3D display language, and it is unlike all other conventional VR systems:

"The fact that VRML was designed to run within a Internet browser, such as Netscape, offers some significant advantages over more conventional VR software. The browser is available at minimal cost, the software is platform independent and models can be transferred across the Internet."(3) The need for expensive software is eliminated, and "a 100 Megahertz Pentium is the minimum CPU recommended to view 3-D worlds and a 3-D accelerator board will make the rendering smoother"(4), a specification acceptable to most users.

ABACUS have chosen to use VRML in the re-development of the original Glasgow Model. The language's flexibility enables development at both ends of the viewing spectrum. From a web-based system accessible by the general public over the Internet, to a highly detailed immersive environment as viewed in the Virtual Environment Laboratory(5), a new facility recently established by ABACUS within the University of Strathclyde's Department of Architecture.

4. The Glasgow Directory

4.1 Introduction

With the introduction of VRML1 in November 1995, ABACUS were for the first time able to incorporate 3D models of selected areas of Glasgow into their web pages.

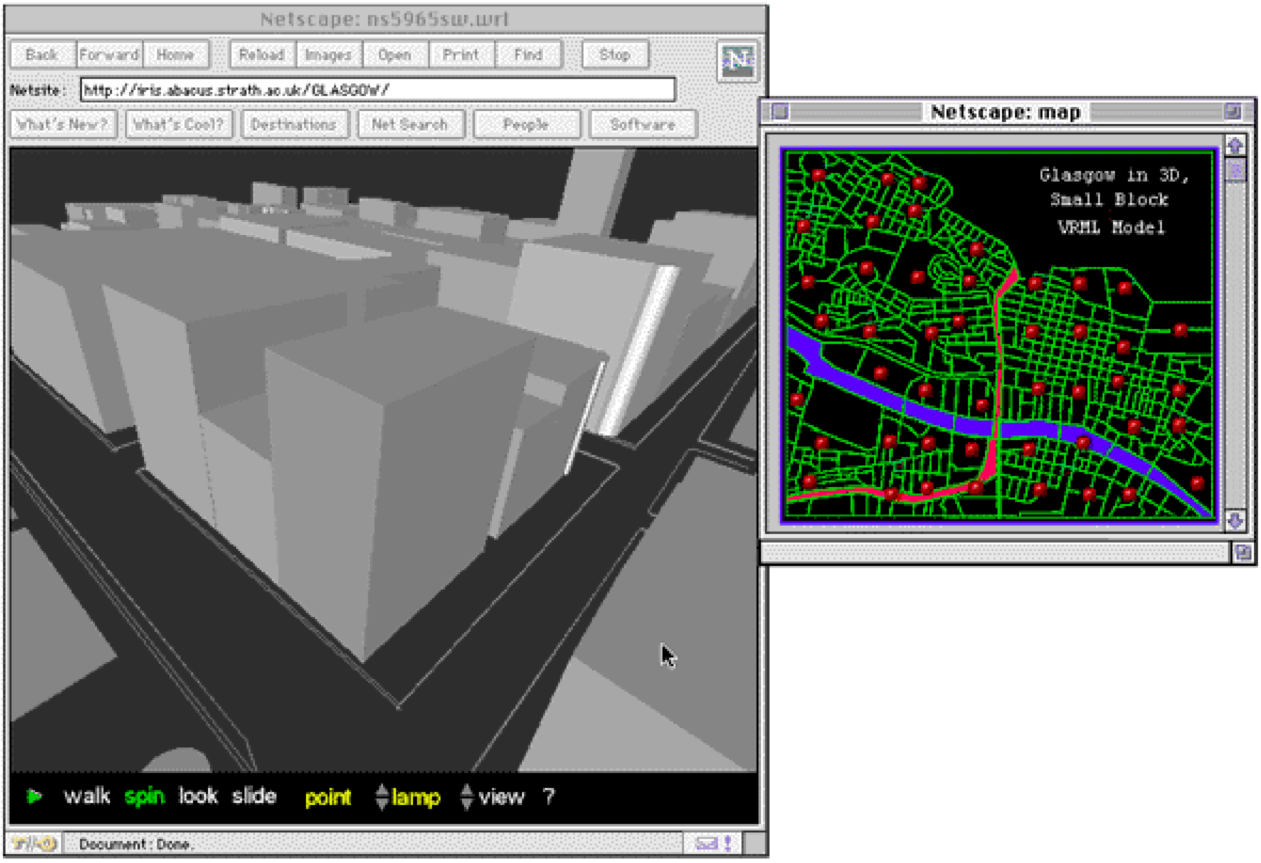

Figure 3 Glasgow VRML1 System viewed on Netscape's 'Live 3D' 1996

As the VRML standards progressed (VRML2 followed by VRML'97), it became apparent that this language could offer far more than just the ability to view 'static' models. Extended research began into how the Glasgow Model could be adapted to suit these facets, and be developed into a fully interactive Urban Information System.

In 1998, funded by 'Glasgow 1999', work began on "The Glasgow Directory"(6), an Internet-based system which allows the general public to access city information through an interactive 3D model of central Glasgow.

4.2 Construction Summary

The following summarises the construction process of the Glasgow Directory and indicates each steps relevance to King's recommendations.

[Recommendation 1 and 4]
The original Glasgow Model was converted from its native file format into VRML1 using in-house software. It was then converted into VRML2 using a freely available SGI converter. Once the model was in VRML format, it was split up into 47 different model segments allowing for faster download time and manipulation.

[Recommendation 2]
It was decided to keep the level of detail on these models to a minimum, except where individual buildings were considered 'landmarks'. These would be given more detail to help navigation within the scene.

[Recommendation 5]
An intuitive interface was designed to house the VRML model, allowing easy integration of 'frames' hosting different data types. This was achieved through the use of Javascript, added to both the HTML files and the VRML model. This enabled the automatic display of certain content in one frame as the user explored certain aspects of the VRML model.

Figure 4 The Glasgow Directory Interface

[Recommendation 6]
A number of defined 'Viewpoints' were programmed into the VRML code, allowing quick access to places of interest within any model segment. Using the 'collision' and 'gravity' option within the VRML file, the user may walk around the environment while remaining at eye level height above the terrain.

[Recommendation 3 and 7]
An Interactive Menu Bar was programmed into the VRML code allowing a range of functionality. This included the ability to activate street labelling, as well as identify a range of building types within the city by hyper-linking to an external database of property information.

4.3 Content

The Glasgow Directory allows users to explore the 'virtual city', search under a range of headings for items of interest, and discover some of Glasgow's finest architecture.

It achieves this by linking to a number of information sources, accessible through conventional Internet components such as lists, tables and search engines, as well as in-directly through the VRML. Unlike many Internet systems, there is no pre-set route to follow, or list of 'useful links'. Information is accessed through intuitive exploration of the site, and therefor varies depending on both the user, and the chosen route. In this manner, the user becomes familiar with the virtual city, in much the same way as they would become familiar with the physical city. He or she may identify particular areas of interest, which can be revisited using familiar routes, or accessed via browsing.

Current information sources include:

- **Multimedia database of General Tourist Information.**
  This includes entertainment venues, shopping centers and transport facilities. Each item in the database contains a photograph, an address, and further information.
- **Multimedia database of Glasgow Architecture.**
  A selection of Glasgow's finest buildings are archived with a photograph, address, architect, date and further detailed information. In many cases a Quicktime VR interior is included.
- **Alphanumeric database of property addresses and street names.**
- **External Web-sites.**
  The system can take advantage of the many Glasgow based web sites that exist on the Internet such as those offering local news and weather.

A special feature within the system allows architects and designers to download appropriate sections of the 3D model for use in proposed developments. Future additions to the system will permit design proposals to be integrated into the system allowing the audience to explore a number of possible urban design alternatives.

4.4 Recognition

Recognition of the virtual city is aided by the use of certain key 'Lynchian Elements'(7). As with the physical location, landmarks, streets, edges and nodes play an important part in comprehending the virtual environment.

- Extra detail is given to buildings in the model when they are perceived to be landmarks.
- The streets can be easily identified by clicking on them.
- Each model segment is terminated at a distinct edge such as the river or a main street.
- Specified viewpoints (nodes) at junctions etc., help users understand their location in the virtual city.
- The subtle use of basic colours - blue for river, green for parks etc., enhance the urban fabric.

Fig.5 Detailed Landmarks

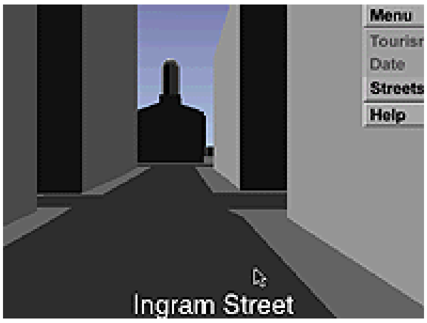

Fig.6 Street Names

Fig.7 Use of colour

Recognition of individual buildings is achieved through the use of 'layered' data. Since the model of the building itself may be nothing more than a basic block within the city context, the facade is expressed as a photograph displayed in another frame. This frame also displays some introductory text about the building, as well as linking to more detailed information such as QTVR interiors. In this way, the user can recognise the building by collating all the relevant information that is automatically displayed on screen as the building is accessed within the VRML model.

4.5 Uses

There are many potential applications for the Glasgow Directory, covering a range of interest and user requirement. Its flexible user interface means that the information gained from each access session will be unique to each user. Here are three examples of system application:

4.5.1 Tourism:

A prospective visitor to the city of Glasgow can explore the virtual city before arrival in the physical, resulting in a greater knowledge of where to go and what to see. Browsing the virtual city can influence choice of hotel, entertainment or shopping area, and transport networks may be examined for choice of optimum route. Places of interest worth a 'real' visit can be identified and details printed out for use during that visit.

Subsequently the virtual city can be revisited and attractions that were missed in the physical city can be enjoyed at leisure through the VRML city model and imaging technology.

4.5.2 Education:

The Glasgow Directory can be used on various levels in an educational context. From primary school pupils, who may be given access and tasks such as, 'explore their city', 'find their school' or 'count and locate the museums', through to university or college students who could by exploring the model be introduced to the concept of computer modelling application and virtual reality.

The models educational potential is of course enhanced because it is easily accessible via the World Wide Web, using platform independent Internet Browsers.

4.5.3 Architects:

Using the Glasgow Directory, architects may access and download parts of the city model which relate to design projects. These sections may be downloaded in a variety of file formats and used to enhance the presentation of new building or urban designs. By displaying design proposals within the context of the city, the architect and their clients, can understand and therefore assess a scheme more clearly.

Once the design is complete, the architect can submit it for integration into the virtual city model, providing public access to the new proposal, as well as contributing to the evolution of the system.

4.5.4 City Planning:

Proposed change to the urban fabric can first be evaluated by simulating the change within the model. Any number of proposals can be analysed in parallel, with the public being given the opportunity to vote for their favourite, a process similar to that used in the Netherlands at Ljburg(8).

This feature would be particularly beneficial during the initial stages of a project, where numerous members of the design team must collaborate on design issues before advancing to the construction phase. This method of increased access to design alternatives would reduce the need for group viewing of physical models.

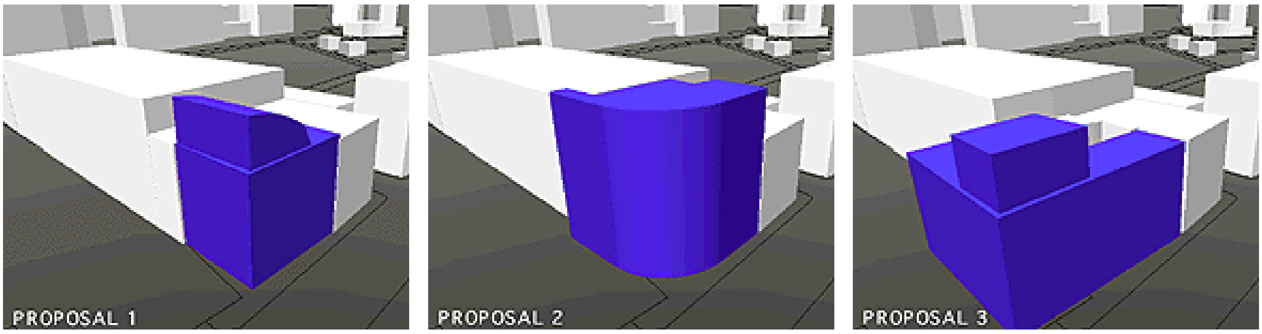

Figure 8 Planning Proposals

4.6 Maintenance and Updates

In the initial development stage of the Glasgow Directory, the addition or upgrade of building information and urban elements was a laborious task. Consequently, a partially automated update module was developed, which automated the editing or creation of 6 separate files of various content and output the data in the required four different programming languages.

This method has been recently improved by the development of a fully automated update module, requiring only that the user input certain key details such as building name, architect and date of construction. Model viewpoints can also be automatically created using this module, and user does not need any knowledge of the programming languages deployed.

This module is written entirely in PERL, enabling additions to be made by remote contributors through a standard Internet browser.

The ABACUS "Viewpoint Creator"(9), which is now on-line for public use, is based on the elements used in this automation system, and allows the creation of VRML viewpoint nodes from any VRML model. A task that usually relies on trial and error. User feedback from this and other "ABACUS VRML Tools '98" has been positive.

4.7 User Feedback

Throughout its design stages, ABACUS has welcomed evaluation from the general public as to the development of the Glasgow Directory. This has been achieved through posting 'Requests for Comments' (RFC's) on many appropriate Internet Newsgroups(10), asking users to 'test-drive' the project and return their ideas and recommendations by way of a simple on-line 'Feedback' form. To date, over 100 forms have been returned, with users offering from the simple "congratulations on the project", to a complete list of suggested improvements and samples of programming code.

Collecting feedback however is simply not enough. Suggestions must be analysed, evaluated, and where appropriate put into practice. This process will play a critical role in the future evolution of the system.

5. The Virtual Environment Laboratory

The most recent stage of research and development associated with the Glasgow model has been the construction by ABACUS of the Virtual Environment Laboratory (VEL). This visually immersive facility is powered by advanced Silicon Graphic computer technology and makes use of advanced projection systems. The laboratory seats around 15 people and the 160 degree curved screen fills the viewers' cone of vision, thus giving them the impression of being immersed within the projected environment. The processing power of the Onxy2 Silicon Graphics machine allows interactive manipulation of large computer models, thus enabling real-time navigation of detailed building interiors or urban landscapes with relative ease.

This facility enables two aspects of virtual reality to be addressed, namely interaction and immersion. Development in these areas in the past has been hampered because of a lack of computer processing power. However the graphics processor at the heart of the VEL can interactively display the Glasgow City model which not only represents around 10,000 properties, but also the appropriate topographical data covering an area of 25 square kilometre. Currently the machine displays this model at up to 25 frames a second, compared with one frame every few minutes 10 years ago, and a rate of processing equivalent to a frame ever day or two 20 years ago.

Visual immersion is achieved as a result not only of the screen size, but also due to its curvature. It therefore feeds the viewers peripheral vision with the correct visual clues and thus invokes the sensation of being surrounded by the projected environment, city scene or architecture. So although it is a 2D moving image that is being projected onto the curved screen, viewers report the feeling of being immersed within a 3D environment.

Figure 9 The Virtual Environment Laboratory

5.1 Applications

5.1.1 Architecture

The VEL is currently used by architects and designers to test designs prior to the construction phase of a project. Architects can 'experience' their designs in a new way and clients can 'walk though' a building at an relatively early stage of the design process in order to gain an insight into the attributes of the environment that they are commissioning. One of the pleasing aspects of experiencing the industrial use of the facility is that virtually no explanation needs to be given to the design teams during these sessions regarding how to use the VEL, since they are immediately able to see their models clearly on the screen and to navigate them with ease.

For example, one French based designer has commissioned some modelling on an urban scale, in order to assess their design in situ. In this case the Glasgow model was revisited, and two streets identified for detailed modelling. This was achieved by the addition of modelled street furniture, and the inclusion of facade detail by texture mapping. The client's design was converted from ArchiCAD to VRML using 3D Studio Max, and integrated into the scene. During sessions in the VEL, the client's design could be seen either on its own or in context, and design changes were suggested as a result. These changes were subsequently built into a new version of the model, and approved during the next design appraisal session.

The VEL development team are currently modelling the new parliament buildings and surrounding area for viewing in the facility. Again this Scottish Office project is on an urban scale and will be constructed using a new version of the ABACUS modelling package, specially designed for VR projects. This package makes use of the graphic processing capabilities of the Silicon Graphics machines to provide a modelling environment that is interactive in nature, enabling ease of movement through prototype models during construction. It is hoped that this 'fly-while-you-build' software will speed up the development of large-scale VR environments.

In the next six months the VEL also hopes to test the wheelchair motion platform, which is currently being designed and built by the Department of Bioengineering (at the University of Strathclyde). This platform will be able to interpret wheelchair movement and thus control motion through virtual environments. Using this system, architects will be able to test wheelchair access to buildings and urban spaces prior to their construction or redevelopment.

5.1.2 Other Applications

The VEL currently hosts several different types of marine related models, which address areas such as, vessel design, ship evacuation and accident investigation. The ship evacuation model uses the facilities ability to control the inclusion of 'fog' or 'smoke' in the environment, where as the accident investigation work depends on clear visualisation of specially constructed engineering models.

Other areas of interest or research include:

- Civil Engineering
- Prosthetics & Orthotics
- Rapid Prototyping
- Tele-presence
- Biology
- Psychology

Future research issues include:

- optimisation of VR modelling and data transfer
- impact of visual immersion on the design process
- role of stereo visualisation in immersive VR
- role of 3D sound in immersive VR.

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6. Conclusions

The Glasgow Directory is due to be officially launched during June 1999. The combination of its functionality linked to a massive 3D city scale urban data set has only been possible due to the emergence and versatility of VRML, and the parallel improvements in computer processing power and communications infrastructure of the Internet.

Where as this type of data was once confined to the realm of state-of-the-art research laboratories, it can now be viewed remotely from a 'standard' personal computer in the home. Already the prototype version of the directory has 322 registered users, providing a rich source of feedback for the development team.

To date applications of the system include tourism, education, architecture, and planning, with the area of virtual shopping and e-commerce currently under investigation. Other future additions may include the use of avatars, so that visitors to the virtual city may communicate with each other during their visit.

VRML has proved to be a rapidly evolving programming language, which is easy to implement since it does not require compilation, and is platform independent. Its open architecture and Internet compatibility will encourage and sustain its use, and its versatility will see further implementations such as those under development in the VEL.

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