Editorial Introduction

Within the social sciences, urban planning has always had a strongly visual tradition. Perhaps this is because both its successes and failures are there on the ground for all of us to see. Sometimes the results are aesthetically pleasing, sometimes not, but there is an asymmetry here in that we do not "see" the successes of urban planning when these involve decisions to prevent undesirable change.

In planning design has a long history in both education and the studio, but until recently this work was two-dimensional, limited by the paper medium either to a plan form map or an artist's impression of a three dimensional structure. Often too, developments were mapped and illustrated in isolation, separated from the environments into which they were to be placed. The basic tools used were the digital alternative to a map, the GIS and the computer aided design package.

An obvious, but nonetheless technically challenging development is to build on these tools to develop virtual reality models of actual and proposed urban developments. Once these are available digitally, it becomes possible to explore them, either singly or in collaboration with others, and to share them over the World Wide Web, and visualization becomes an integral part of these virtual cities.

In this Case Study, Andy Smith, Martin Dodge and Simon Doyle review work in this field, drawing for much of the time on their own work at the Centre for Advanced Spatial Analysis, University College London.

VISUAL COMMUNICATION IN
URBAN PLANNING AND URBAN DESIGN

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Abstract

This Case Study documents the current status of visual communication in urban design and planning. Visual communication is examined through discussion of standalone and network media, specifically concentrating on visualisation on the World Wide Web (WWW).

First, we examine the use of Solid and Geometric Modelling for visualising urban planning and urban design. This report documents and compares examples of the use of Virtual Reality Modelling Language (VRML) and proprietary WWW based Virtual Reality modelling software. Examples include the modelling of Bath and Glasgow using both VRML 1.0 and 2.0. The use of Virtual Worlds and their role in visualising urban form within multi-user environments is reviewed. The use of Virtual Worlds is developed into a study of the possibilities and limitations of Virtual Internet Design Arena's (ViDA's), an initiative undertaken at the Centre for Advanced Spatial Analysis, University College London. The use of Virtual Worlds and their development towards ViDA's is seen as one of the most important developments in visual communication for urban planning and urban design since the development plan.

Secondly, the role of photorealistic media in the process of communicating plans is examined. The process of creating photorealistic media is documented, and examples of the Virtual Streetscape and Wired Whitehall Virtual Urban Interface System are provided. The conclusion is that, although the use of photo-realistic media on the WWW provides a way to visually communicate planning information, its use is limited. The merging of photorealistic media and solid geometric modelling in the creation of Augmented Reality is reviewed. Augmented Reality is seen to provide an important step forward in the ability quickly and easily to visualise urban planning and urban design information.

Third, the role of visual communication of planning data through GIS is examined in terms of desktop, three dimensional, and Internet based GIS. The evolution to Internet GIS is seen as a critical component in the development of virtual cities that will allow urban planners and urban designers to visualise and model the complexity of the built environment in networked virtual reality.

Finally, a viewpoint is put forward of the Virtual City, linking Internet GIS with photorealistic multi-user Virtual Worlds. At present there are constraints on how far virtual cities can be developed, but a view is provided on how these networked virtual worlds are developing to aid visual communication in urban planning and urban design.

1. Introduction

Neighbourhoods, cities and regions are complex phenomena (Langendorf, 1992). The way planners and urban designers think about and communicate their ideas about urban problems and their solutions is strongly, although not exclusively, visual. Visualisation of urban planning and urban design is based on three premises Langendorf, 1992):

- To understand nearly any subject of consequence it is necessary to consider it from multiple viewpoints, using a variety of information;
- Understanding complex information about urban planning and urban design may be greatly extended if the information is visualised;
- Visualisation aids in communicating with others.

Communication and visualisation is at the heart of the planning system, the map and plan in two-dimensional form has been the norm, although extensions to the third dimension are important through urban design which acts as the interface between planning and architecture. Other visual media such as photographs and statistical presentations through charts of various kinds also supplement the way such communication takes place.

During the last decade, planning has been exposed to new methods of visualisation and some impressive examples have been demonstrated. However, progress has been slow. The culture of computing is alien to the intellectual traditions of planning as indeed it is to much of the social sciences. There are many areas where visualisation can be applied in this field but examples of best practice are rare. However, we sense a burgeoning interest which is now exploding and this is an opportune time to document and critically comment on examples of best practice so that those concerned with introducing the new media to students and researchers are aware of what is useful and possible.

The case studies explored throughout this report are grounded in the various stages of the planning and design process used to prepare plans. These stages involve: problem definition, data collection, analysis, the generation of alternative plans, evaluation, and, finally, implementation. At all these stages. visualisation can be used to communicate to various audiences involved in the process. We can array these stages against the typical technologies which are being developed at present: including desktop mapping and GIS, statistical visualisation, game simulation, 2D and 3D geometric modelling of maps and scenes, and the use of photorealistic media.

To broaden the context even further, we will consider visualisation through standalone and networked media, specifically concentrating on visualisation on the World Wide Web (WWW). We can array these items in the following way, see Figure 1. The bold circles indicate areas where quite a lot of work is going on concerning applications of these visual technologies. The open circles are areas in which some work is going on but where such technologies have clear potential. Case studies often span several of these areas. For example, once a GIS or geometric model is built for one stage of the process, it is often easy to use it in another, so that most applications are not restricted to one stage.

Figure 1 Visualisation in Urban Planning and Urban Design

This Case Study is based on three specific examples:
- Solid and Geometric Modelling
- Photorealistic Media
- Geographical Information systems

Each example acts as a separate review of both working examples and software developed within the concept of visual communication in urban planning and urban design.
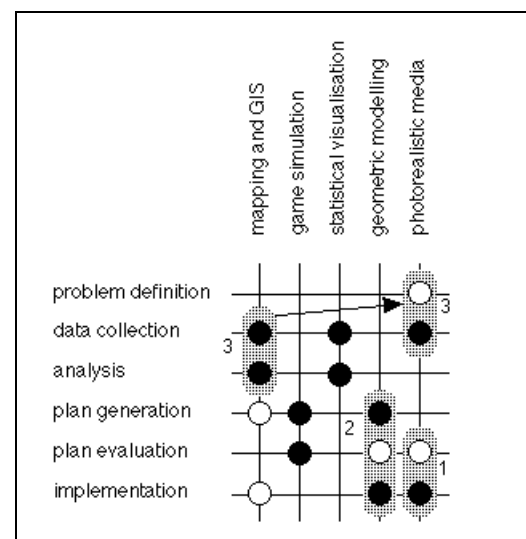
2. Geometric Models to Demonstrate Alternative Urban Designs

2.1 Solid and Geometric Modelling

Solid, geometric modelling has traditionally been seated in the domain of specialist Computer Aided Design (CAD), packages running on high end graphics workstations. These packages, whilst often achieving a high degree of realism in modelling urban environments, tend to be limited to operation on single machines running expensive proprietary software, hence restricting access, where available, to fixed problems or planning and design issues. The WWW opens up the ability to distribute these 3D geometric models widely albeit with several caveats. The first major restriction is that models need to be developed in accordance with the limitations imposed by a low bandwidth environment. If dissemination is to be effective, the home user with a modem and line rental charges, should not be overlooked - this effectively means that load times need to be efficient. To achieve a wide user base on the WWW, models need to be developed in a file size of not more than 300 Kb and preferably less than 100Kb. Such a limitation on file size therefore poses the challenge of achieving high levels of realism in a low bandwidth environment. The following sections explore issues which need to be addressed when modelling the built environment on the WWW. The use of Virtual Reality Modelling Language, and other proprietary languages are explored in conjunction with proprietary WWW based modelling software. The potential of each technique for visualising the urban environment is explored with current examples available on the WWW.

2.2 Virtual Reality Modelling Language

Virtual Reality Modelling Language (VRML) provides the basis for the majority of existing urban models on the WWW. Indeed, VRML is summarised in the introduction to the VRML 1.0 specification as a language for describing interactive simulations - virtual worlds networked *via* the global Internet and hyper-linked with the World Wide Web (Bell *et al.*, 1993). VRML was conceived in 1993, integrating WWW extensions to Silicon Graphics Open Inventor file format, (Martin & Higgs 1997). The language was designed as an open standard for integrating three dimensional worlds into the Internet. VRML, currently based on specification 2.0 (Moving Worlds), has developed into a *de jure* standard for the distribution of three dimensional models on the WWW.

VRML provides a flexible, cross platform environment to model the urban form. The user is freely able to explore a model and view details from any angle, providing a very flexible way of interpreting any given model using a suitable browser. As VRML is designed for distribution on the WWW, a block model of a large urban environment can potentially occupy less than 100Kb of file space. However, with an increase in complexity, scale and realism of the modelled objects, comes an increase in file size. Furthermore, to achieve realism in terms of being able to identify a polygon as, an "Office Block" or an "Edwardian Terrace" , VRML modellers are sometimes forced to apply textures, or photo-realistic facades to the VRML objects in the model thus increasing file size and down load time. **Figure 2** illustrates a VRML model of part of Tokyo, developed by Planet 9 Studios. In this example, the level of realism has been compromised to achieve fluid movement on a home based PC (taken as a Pentium 90 processor) with an acceptable download time *i.e.* 90 seconds using a standard 28.8 baud modem. Within the virtual scene the end-user is presented with a series of VRML polygons which have had textures added to them as an aid to visual realism.

Figure 2. VRML 1.0 Tokyo, illustrating the use of texture mapping on polygons in order to add realism (http://www.planet9.com/tokyo/index.html)
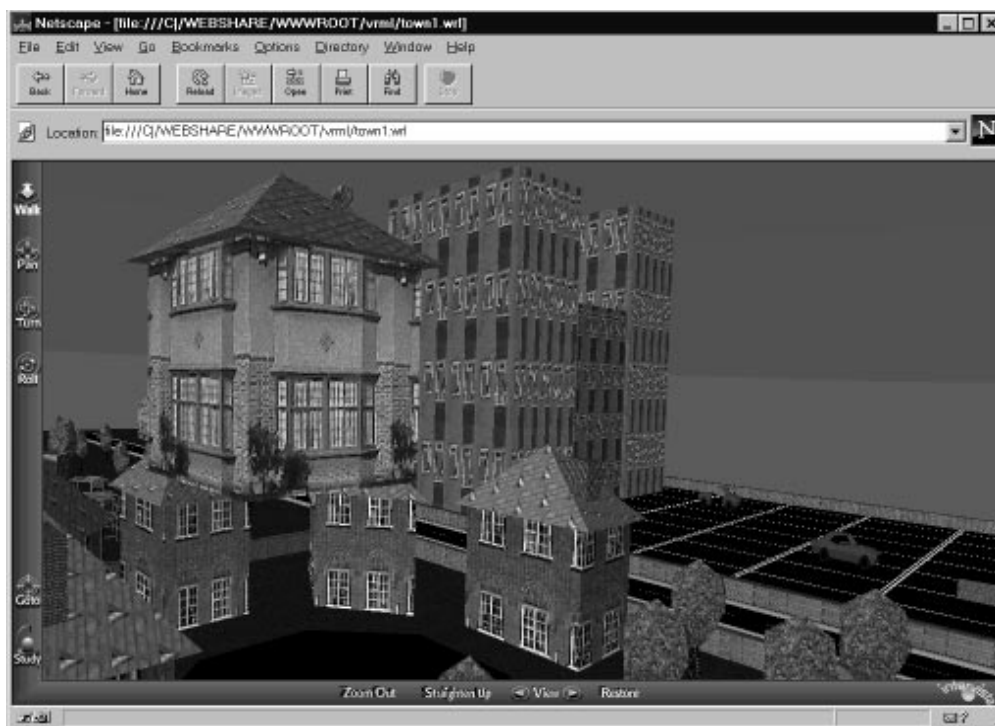

Figure 3. VRML 2.0 Interactive Model (Source Authors)

The current release of VRML (VRML 2.0) allows the developer to increase the level of achievable realism by permitting behaviours to be assigned to objects. Behaviours allow a scene to include object movement and directional sound, significantly increasing levels of physical realism and interactivity. **Figure 3** illustrates a VRML 2.0 model developed by the authors, showing elements of the VRML environment such as 'houses' and 'tower blocks'. The basic block model is

created and appropriate textures applied to aid user recognition. The model, developed for use in a design education environment, allows the user to move any aspect of the model on the x, y and z axes. The ability to move aspects of the built environment independently of one another, allows each user to create their own interpretation of any given design scenario. The use of VRML 2.0 in this manner is an important step towards the development of Virtual Internet Design Arenas (ViDA's), which will be discussed later. However, as with VRML 1.0, VRML 2.0 is texture dependent and features such as directional sound increase the overall file size and therefore the download time.

2.2.1 Modelling Bath

In 1991 the Centre for Advanced Studies in Architecture, University of Bath, received a grant to construct a 3D computer model of the city of Bath. The model, constructed from aerial photographs using photogrammetry, is accurate to less than half a metre and covers the whole historic city centre, an approximate area of 2.5x2.0 km (Bourdakis *et al.*, 1997). The project was supported by Bath City Council and since its completion the model has been used by the city planners to test the visual impact of a number of proposed developments in the city. The model is the most comprehensive in the UK and as such it is useful to explore its development in terms of solid geomatic modelling in relation to the visulisation of urban form on the WWW.

The model was developed as separate units based on city blocks with each unit being modelled in a PC based CAD package. Depending on size and complexity, each block took between three and ten days for a skilled operator to construct. The whole model is composed of 150 urban blocks, occupying over 60Mb of disk space (Day, 1994).

The Bath model has been converted into VRML to allow viewing on the WWW. Four versions have been developed, to take into account varying technological and design requirements;

- **Standard VRML 1.0** version 255Kb. Building geometry only, no other landscaping information (all platforms 32MB Ram minimum).
- **VRML 2.0 version** A 240Kb (to be phased out soon) Streets and pavements on most roads in the centre of the city, no (Pentium PCs with hardware accelerated graphics, low end SGIs, 32MB Ram absolute minimum)
- **Optimised VRML 2.0** version B 330Kb Similar to version A, but with texture mapped trees. (Pentium PCs with hardware accelerated graphics, low end SGIs, 40Mb Ram)
- **Texture Mapped VRML2.0** version T 550Kb geometry plus 270Kb textures This version includes texture mapped terrain of 10KmX10Km around the city and the Bath abbey in full detail. (High end Silicon Graphics (SGI) or PCs with high end Glint cards, 64Mb Ram).

Figure 4 lllustrates a screen shot of the Texture Mapped VRML2.0 version, running on a High end SGI.

The textured mapped VRML 2.0 model of Bath is impressive and provides an interesting insight into how the urban environment can be modelled and these models distributed on the WWW. However, at the present time it is not possible to view such detailed models on an entry level home based PC. This is typical of VRML models with visulisation on the WWW limited to basic models. Basic modelling can, however, be used effectively to visualise the urban environment, as a model developed by the Architecture and Building Aids Computer Unit, Strathclyde University (ABACUS) demonstrates.
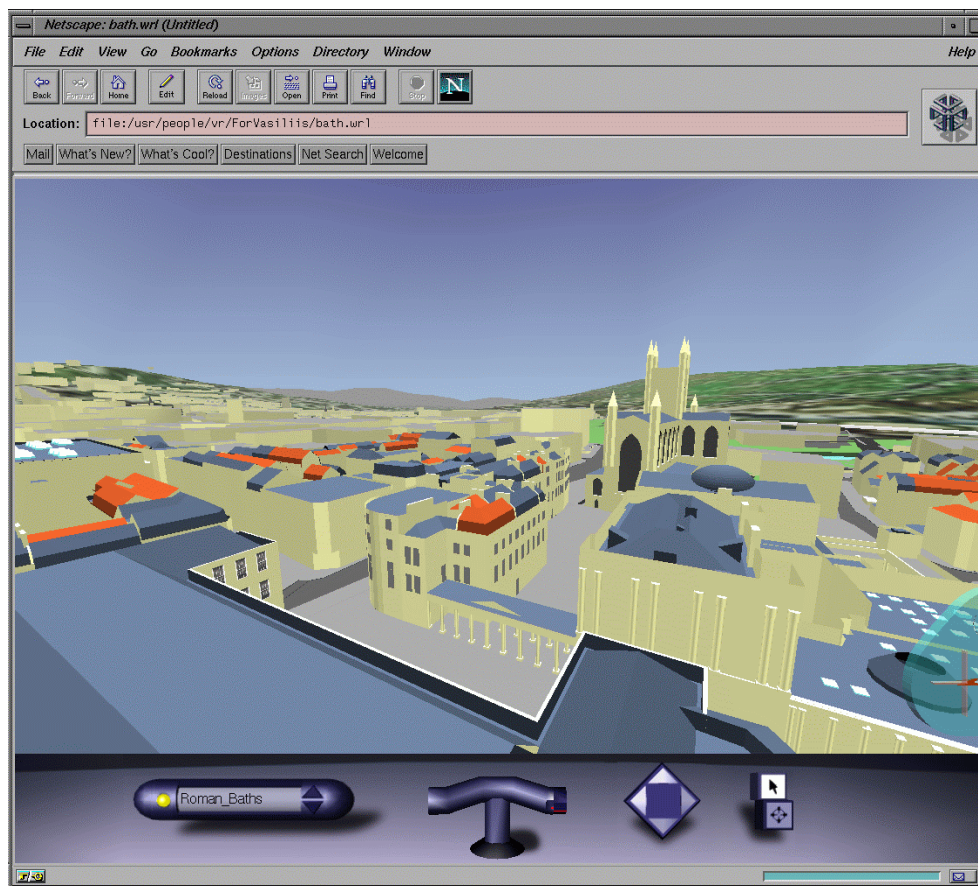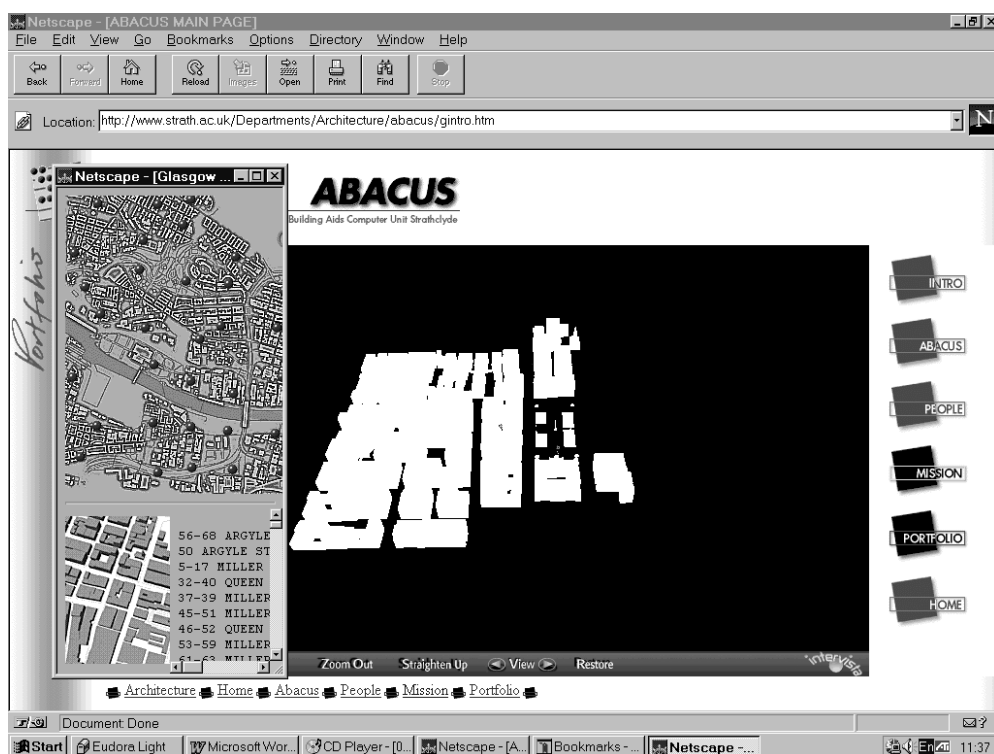
Figure 4. VRML 2.0 Model of Bath

Figure 5 ABACUS VRML Model of Glasgow.

2.2.2 ABACUS - Modelling Glasgow

During the 1980's ABACUS developed a model of Glasgow for real time animation on Silicon Graphics machines. The level of detail achieved during the 1980's is now available on the WWW using VRML 1.0. The VRML modelof Glasgow, shown in **Figure 5,** is divided into separate sectors of the city to reduce file size. Each section of the model is integrated within an innovative WWW browser interface. The ABACUS WWW interface is divided into three separate sections;

- The VRML Model;
- A Map window allowing the user to select sections of the city to view in VRML; and
- An information window; certain buildings on the model are marked by a yellow balloon, and clicking on these provides further information in the window. Certain viewpoints also contain a street sign. Clicking on the sign will provide a photograph of that view.

The use of windows dynamically linked to the VRML model significantly enhances the users ability to visualise and access information on the urban environment, but the VRML 1.0 models are of limited use because of their low level of detail.

2.3 Proprietary Web Based VR Modelling Software

In addition to the use of VRML for urban modelling on the WWW, a number of commercial vendors have developed their own proprietary modelling software. One of the most widely used of these packages has been produced by Superscape (http://www.superscape.com). Superscape's VRT software has been employed extensively in the development of the company's Virtual World Wide Web (http://www.vwww.com). **Figure 6** illustrates an example an easily identifiable "out of town" shopping centre, developed through Superscape software, with the results presented in a standard WWW browser but with need for a proprietary plug-in.

Figure 6. An "Out of Town" Shopping Centre, developed using Superscape VRT software.

The use of proprietary software often allows the development of innovative, highly realistic urban models on the WWW. However, the production and browsing of these models is often dependent on the purchasing of expensive proprietary pieces of software, as opposed to VRML which is an open standard.

2.4 Virtual Worlds

Having discussed ways in which the built environment can be visualised on the WWW, it is useful to explore the concept of Virtual Worlds and their ability to introduce aspects of interaction and social behaviour into the types of models already discussed. By allowing movement within the models we create, users can be presented with the chance to become involved with planning problems - for planners this facilitates consultation and also allows the planning community to interact in a common digital space in the pursuit of a design or planning solution.

Within virtual worlds participants are generally represented in the model by an avatar or digital *alter ego*, such as that shown in **Figure 7**. A user's avatar may take any form, although they are usually based on human form. The user is able to control their avatar, which will dynamically update their view of the world and the other participants avatars. The user sees the 3D world through the eyes of their avatar. This allows the user the ability to turn around and look at a fellow avatar, whilst holding a conversation, thus introducing a meaningful level of social interaction. The more advanced avatar systems available on the WWW also allow the use of physical, personal gestures. A prime example is the use of avatar gestures within Alphaworld (http://www.activeworlds.com), which is further explored later in the paper. Alphaworld avatars are capable of basic gestures such as 'wave' and 'jump' and gestures to indicate basic emotions such as smiling when 'happy' or raising a tantrum when 'angry'.

The most advanced virtual worlds on the WWW have the following features (Rockwell 1997):

Figure 7. Avatar

- Insert/ Delete objects (*e.g.* avatars) in scenes at run-time
- Merge multiple sound streams from distributed sources into the shared scene's current ambient sound (*e.g.* voices over music)
- Track and communicate the state/ behaviour of objects in real time
- Allow (sets of) objects to be "driven" by users in real time
- Let imported objects become persistent
- Protect the scene from damage by imported objects
- Assign objects to a series of different "owners"
- Support persistent roles (for people) and rules (for scenes)
- Link objects dynamically to external data/ functions
- Support the free exchange of information among objects

Within the realm of planning and decision making in the urban environment, or even the rural environment, these virtual worlds offer the opportunity to practice, simulate and visualise a design or planning issue in real time in a 'dry' environment. All that is required is a model (a replication of a 'real-world' space) and the ability to serve it to interested clients. A *schema* of how a virtual world may be organised is described in **Figure 8.**

Virtual environments are generally organised in a so called "client-server" model, as shown in **Figure 8.** They have a central "server" which contains the data for the 3D world, a range of avatar models and also acts as the communications hub for online discussions or "chat" forums. The individual participants have a "client" on their local computer which provides the tools to view and move through the 3D world and also to "chat" or communicate *via* a dialogue box. "Client" software is often in the form of a plug-in to Web browser applications like Netscape Navigator or Microsoft Internet Explorer. Multiple "clients" connect, over the Internet, to the server, downloading the 3D world and avatar model which are then held on the local computer. The server and clients communicate with each when an avatar is moved or some dialogue is typed.
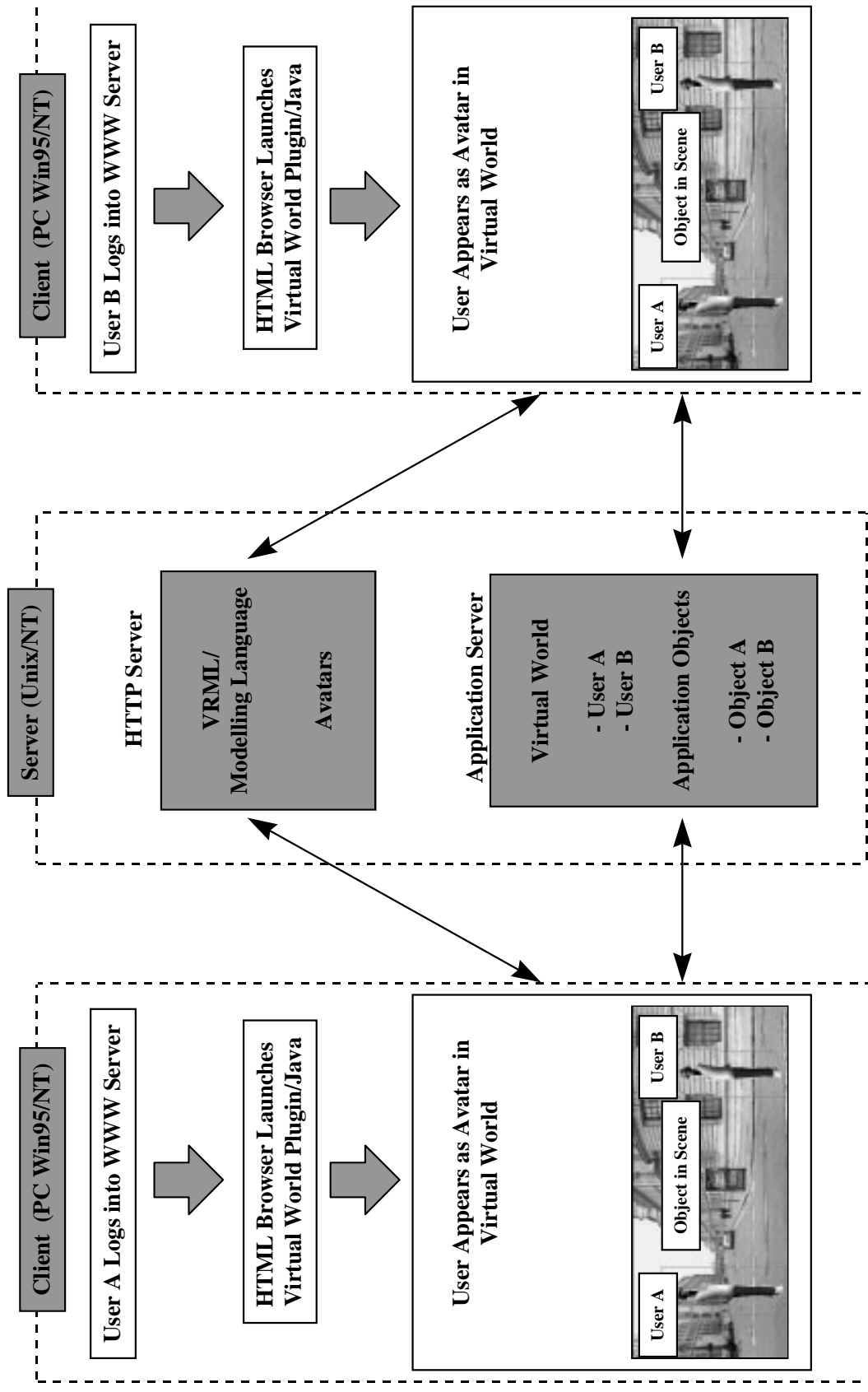
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Virtual Worlds - Client/Server Model

Client (PC Win95/NT)

User B Logs into WWW Server

→

HTML Browser Launches Virtual World Plugin/Java

→

User Appears as Avatar in Virtual World

| User A | Object in Scene | User B |

Server (Unix/NT)

HTTP Server

VRML/ Modelling Language

Avatars

Application Server

Virtual World

- User A
- User B

Application Objects

- Object A
- Object B

Client (PC Win95/NT)

User A Logs into WWW Server

→

HTML Browser Launches Virtual World Plugin/Java

→

User Appears as Avatar in Virtual World

| User A | Object in Scene | User B |

Figure 8. Virtual Worlds - Client/Server Model

2.4.1 Virtual Worlds - The 5 Stages of Development to Full Interactivity

The creation of Virtual Worlds on the WWW and their ability to be used for collaborative modelling and design of the built environment may be viewed in five distinct stages, ranging from a basic HTML Web site to a fully developed 3D collaborative simulated urban environment. **Table 1** and **Figure 9**, adapted from Rockwell 1997, illustrate these stages to full interactivity in Virtual Worlds.

Current technology lies between stage three and stage four, with the development of open based standards for the development of multi-user virtual environments. There are more than ten different software vendors developing multi-user virtual worlds, but there is considerable variation in their quality and functionality.

2.4.2 Virtual World Systems

Following a preliminary survey of the systems on offer, we are carrying out a detailed evaluation of four of the best, these are, Blaxxun Community, Sony's Comumunity Place, ActiveWorlds and Online. These systems offer powerful world servers and good client end applications.

Stage of Evolution	Description	Level of Use for Collaborative Education/ Design
HTML Web Site	No Community Development	Weak - Only Information Available.
HTML Site with 'Chat' Ability *i.e.* Internet Relay Chat or Java based Chat	Simple Anonymous Text Chat	Medium - Interaction, ability to communicate in real-time
Avatar based Graphical Interface	Personal, organised and structured interactions	Strong - Development of Design/Education Arenas based on property software
Avatar based 3D using open standards and interactions	Seamless interconnection of communities and sharing of knowledge across communities	Very Strong - Development of World Wide Design/Education Arenas
Avatar based 3D/Open Standards/Real Time Audio Synchronisation	Seamless interconnection of communities with natural communication	Very Strong - Design/Education Arenas further enhanced with real time audio

Table 1. The Five Stages Towards Full Interactivity in Virtual Worlds

2.4.2.1 Blaxxun Community

The illustration above, **Figure 10** shows the Blaxxun "virtual environment" client, called CCPRO, connected to one of Blaxxun's example worlds. The client is a free web browser plug-in which can be downloaded from the Blaxxun web site. The client comprises three elements, the 3D view, a chat window and a control panel (more details on the Blaxxun "multi-user world" system can be found at *http://www.blaxxun.com/).* The 3D aspect of the system uses VRML 1.0 and 2.0. The use of VRML 2.0 allows the ability to interact with objects within a multi-user three dimensional world. The Blaxxun CCPRO client also supports environments created using Superscape's proprietary modelling language.

System Requirements

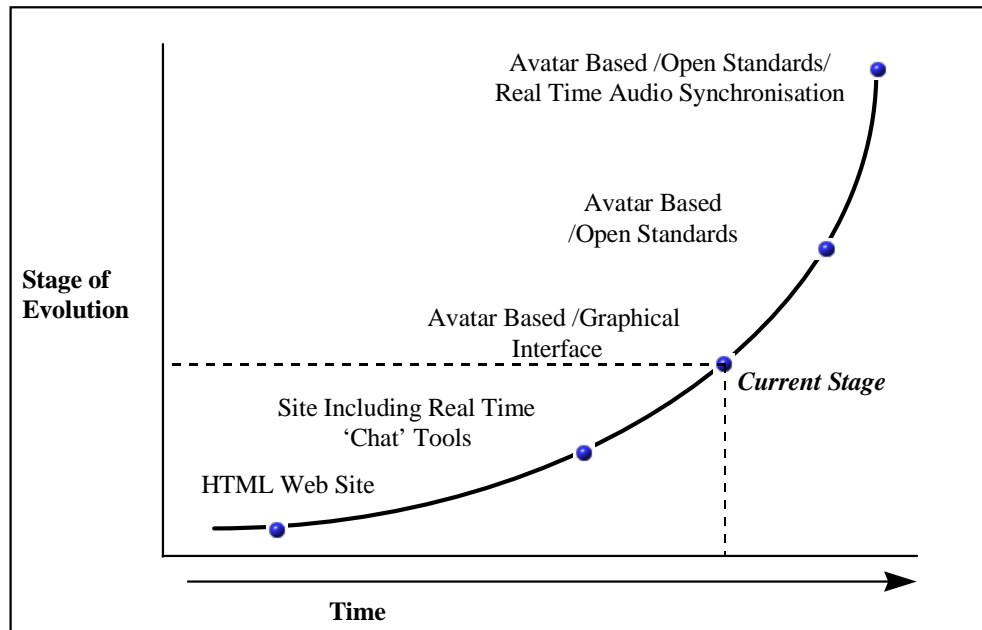|	
Operating System	Windows 95 (requires Microsoft DirectX 3 or later) or Windows NT 4.0 (requires Service Pack 3)
Browser	Microsoft Internet Explorer 3.x or later OR Netscape Navigator 3.x or later
Other	Intel RSX for sound support

Figure 9. Development Time Line of the Five Stages Towards Full Interactivity in a Virtual World.

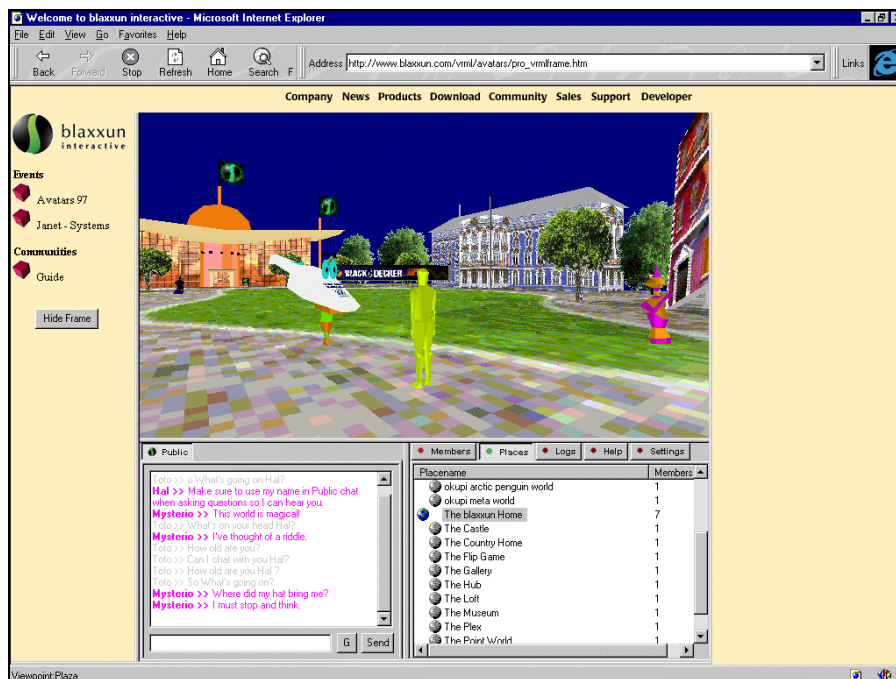**Figure 10.** The Blaxxun Community Client

Figure 11. Sony Community Place

2.4.2.2 Sony Community Place

The Sony "community place" browser is shown in **Figure 11.** This "multi-user world" client can be used as a stand-alone application or a browser plug-in. The client comprises two windows - the 3D view and the "chat" window. Further details and software downloaded from the Sony Community Place web site at *http://www.sonypic.com/vs/.* (*Note - Sony's Community Place Conductor 2.0 Preview Release 1 has recently been made available. This tool will allows the creation of VRML97/Java (supporting JDK 1.1.3 or later) worlds, in real-time, using simple drag-and-drop metaphors).*

System Requirements	
Operating System	PC running Windows 95 or Windows NT
Hardware	Pentium 90MHz, 32MB RAM
Browser	Netscape Navigator for Windows (ver2.0 or later)
	Note: Netscape Communicator will not work with the plugin CP browser. A standalone version is also available.
Other	Requires Direct X 5.0

2.4.2.3 Activeworlds

Activeworlds is a stand-alone client application, again only available for Windows 95 / NT platform. The client has a large 3D view window, plus a control panel and the "chat" window. The ActiveWorlds web site is at *http://www.activeworlds.com/* and contains further details on their multi-user worlds. The largest of the ActiveWorlds Virtual Worlds is called Alphaworld. Alphaworld currently has over 200,000 "residents" who are able to build using a simple 'copy and paste' system of object placement. Such activities allow the production of "landuse" maps of alphaworld, illustrating the 'virtual' urban sprawl in the digital environment shown in **Figure 13**.

Over a period of 15 months over 10 million building objects were placed on the digital plain (Damer, 1997). The map provides "teleport" access to any area of Alphaworld simply by clicking on the desired location. Activeworlds is the most powerful of the Virtual Worlds clients providing a flexible environment for the visualisation of multi-user urban environments on the WWW.
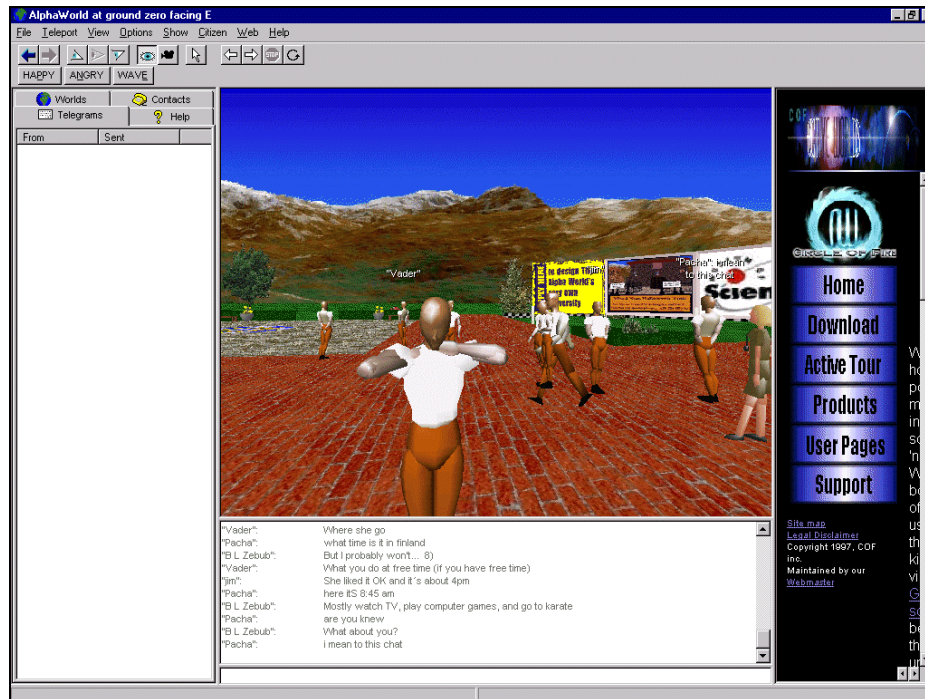
Figure 12. The Activeworlds "browser"

System Requirements

Operating System	PC running Windows 95 or Windows NT
Hardware	Pentium 90MHz, 16 megs Ram (24 megs or more will give improved performance)
Other	14.4kbps modems will work, but 28.8kbps is strongly recommended

2.4.2.4 Onlive

Onlive Technologies (http://www.onlive.com) has developed a Virtual World which moves away from the limitations of text based communications. Onlive features full voice support, allowing real time voice based communication in VRML based Virtual Worlds.

Figure 14, illustrates the Onlive "Browser". Note that the Virtual World occupies the full browser windows as there is no need for a text based communication window. Communication is achieved by using a set of speakers and a microphone connected to each users PC. To 'chat' the user presses the control key on the keyboard and talks into the microphone. The users voice is then encoded and transmitted into the virtual world using automatic voice synthesis and 3D audio. The effect is real time conversation with lip synchronised avatars. Due to current bandwidth restrictions Onlive Virtual Worlds can only be seen as experimental, as conversations are often lost due to time lag and distortion.

System Requirements

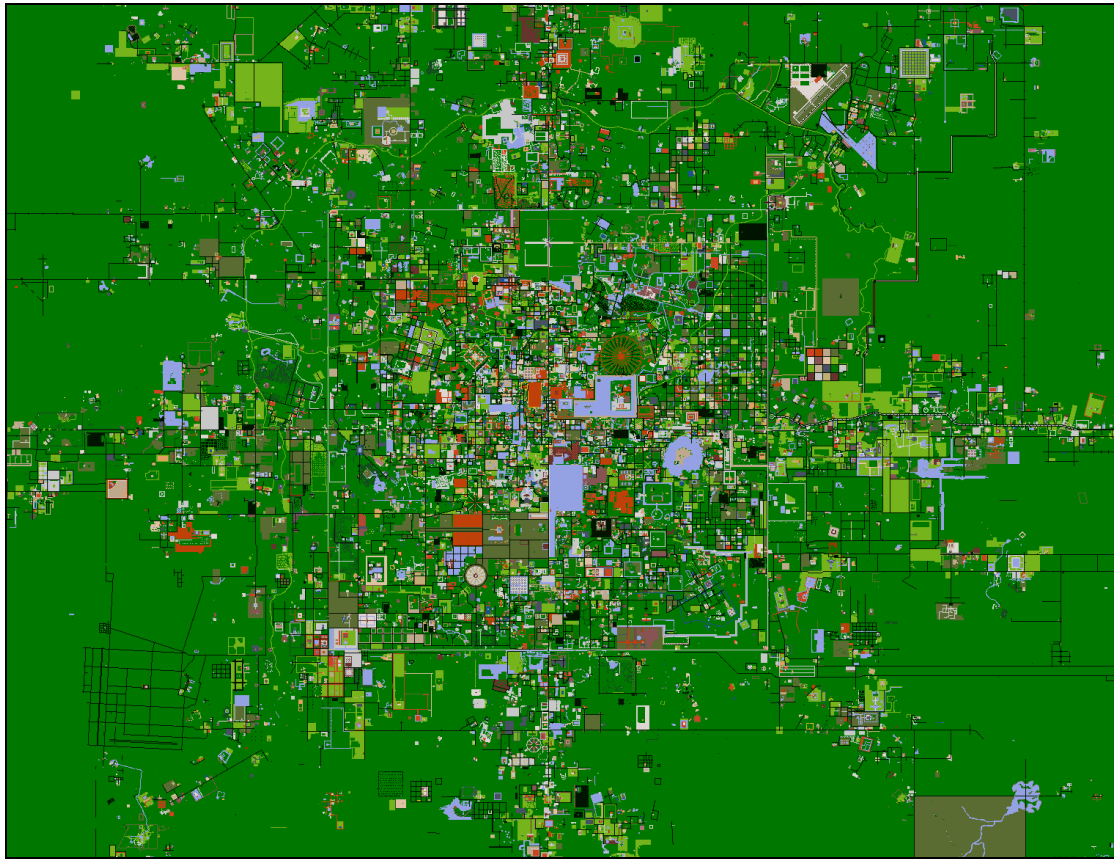|	
Operating System	PC running Windows 95 or Windows NT 4.0
Hardware	Pentium 90MHz, 16 megs Ram (24 megs or more will give improved performance)
Other	Creative Labs SoundBlaster 16 and/or SoundBlaster AWE32 recommended

Figure 13 : AlphaWorld Teleport map (http://kozmo.yakima.net/alphaworld/teleport.html)

Figure 14. Onlive "Browser".

2.5 Virtual Design Arenas

At CASA we intend to run our own Virtual World server, on which we can host small three-dimensional design scenarios. This will be used for experimental teaching and modelling of urban design and planning in what we term a *Virtual Design Arena (ViDA)*. The ViDA initiative will be a collaborative venture between VENUE, Online Planning, and the VR Centre for the Built Environment. An exploration of the ViDA initiative provides an insight into the use of Virtual Worlds for the visualisation of urban planning and urban design for both educational and practical requirements.

Within the proposed ViDA initiative participants will include;

- Urban design & planning students
- Interested academics
- Professional planners and urban designers
- Ordinary people in public participation experiments
- Planners & urban designers
- The Internet "general public"

By hosting and developing our own Virtual Worlds we will be able to run design scenarios in which many people can participate as avatars in various scenarios. We intend to create worlds for two distinct categories of design scenarios *"Virtual Real Places"* and *"Real Virtual Spaces"*. The first type, *"Virtual Real Places"*, will be scenarios using 3D models of real world places, for example real development sites in London. "Real Virtual Spaces" will be completely fictional models, not related to any particular real place. We believe that the 3D worlds do not necessarily have to be based on real places to be useful in the design and planning process. In many respects it may be easier to represent the ideas of good and bad design in truly virtual spaces. Before we go into detail about the ViDA Initiative it is useful to explore current examples of Virtual Worlds for both collaborative design and education on the WWW.

2.5.1 The Virtual Campus

The University of Colorado has developed a collection of integrated technologies designed to create a Virtual Campus. The Virtual Campus, although not specifically designed to visualise the urban environment, provides an insight into how Virtual Worlds can be used for collaborative education and therefore ultimately visualisation and design. The centerpiece of the Virtual Campus is the Active Worlds Browser, **Figure 15**.

Active Worlds allows the Virtual Campus students and instructors to use real-time communication and the exploration of content via streaming multimedia web pages in three dimensions. Users can choose one of over twenty-five Avatars to represent themselves as they travel throughout the Campus communicating with fellow students or instructors. The Active Worlds browser also connects directly to the World Wide Web, allowing instructors to incorporate their existing web pages, or enhance them with streaming audio, video, or interactive multimedia.

The Virtual Campus is divided into three specific areas;

- Academics - The main area where students enter the Virtual Campus. From this section, students are able to select various course options;
- Course Area - Each course is assigned its own 'course area'. Details are provided of assignments and virtual lectures.
- Concepts - Students able to interact in a 3D environment, the environment modelled various according to course content.

The Virtual Campus has developed Virtual Worlds for collaborative education, where as the Royanji Project provides and insight into the use of Virtual Worlds for collaborative design.

Figure 15. The Virtual Campus

2.5.2 The Ryoanji Project

The Virtual Ryoanji Project is a joint development project between the Department of Urban Engineering at the University of Tokyo, Sony Corporation and the Centre for Advanced Spatial Analysis, University College London. The Ryoanji Project's ultimate objective is to create a full-featured urban planning support system, allowing a number of people, who may have different concepts, tastes and standpoints, to gather and induce them to cooperate in creating a single space (Shiode *et al.*, 1998). The project is based around the design of a virtual stone garden. Participants are able place various stones in the virtual space, thus introducing the concept of virtual design. **Figure 16** illustrates two participants discussing the placement of the stones within the virtual space.

Figure 16. The Virtual Ryoanji Project

Although in early stages of development, the project provides a useful insight into the design stages and collaborative working environment which can be developed using virtual worlds. Further details can be found at http://www.geog.ucl.ac.uk/~nshiode/ryoanji/draft.html

2.5.3 Collaborative Design - Developing ViDA's

Figure 17 illustrates the basic design process of the ViDA developed by CASA. Initially ViDA users will be asked to explore the potential of the computer-mediated virtual world, *e.g.* becoming used to moving through the 3D model world or using the "chat" tool to communicate. The initial layout of the world will draw strongly on the work of the Virtual Campus with specific sections within the Virtual World. Users will be presented with a series of virtual worlds to evaluate according to a set criteria. Eventually they will be presented with virtual worlds where they can modify the 3D models.

As the users interact with the Virtual World various powers of "modification" can be permitted such as changing building colours or textures, altering size and plot position, or removing buildings and objects (like street furniture), to creating completely new structures and layouts. Permissions can also be set in order to determine who has the power to make certain changes to the model (Development Control). All user activities in the multi-user worlds (avatar movement, action and "chat" communications) will be discretely logged on the server, thus creating extensive *metadata*. Analysis of this activity log plus conventional oral and written feedback, will provide interesting insights into group evaluations, design and working in virtual environments.
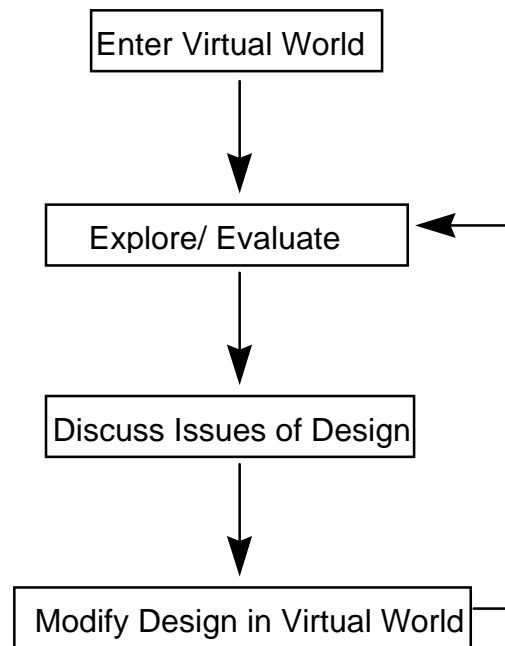

Figure 17. The basic virtual design process of ViDA

2.5.3.1 The Interface

In creating the visual interface of ViDA two specific routes have been developed:

1) Using VRML 2.0 Virtual Worlds have been developed using the Blaxxun browser. **Figure 18** illustrates the Virtual Lecture Theatre developed for the ViDA initiative. The Virtual Lecture Theatre will be used as a base for the users initially to meet in the virtual world and be introduced to the design concepts by a virtual lecturer, in a similar vein to the 'Course' section of the Virtual Campus. While the lecture theatre has been developed for ViDA, it should be noted that it has a wider use in the general context of distributed education. The lecture theatre will be made available for use by other academics during the period of the initiative.

2) Active Worlds - The use of the Activeworlds server/browser has allowed the development of the potentially powerful design interface shown in **Figure 19.** Alphaworld allows the user to import both VRML 2.0 and traditional CAD models into a virtual environment. The ability to import CAD based formats coupled with VRML 2.0 provides a degree of flexibility in the design of the environment and the ability to construct a realistic looking environment.
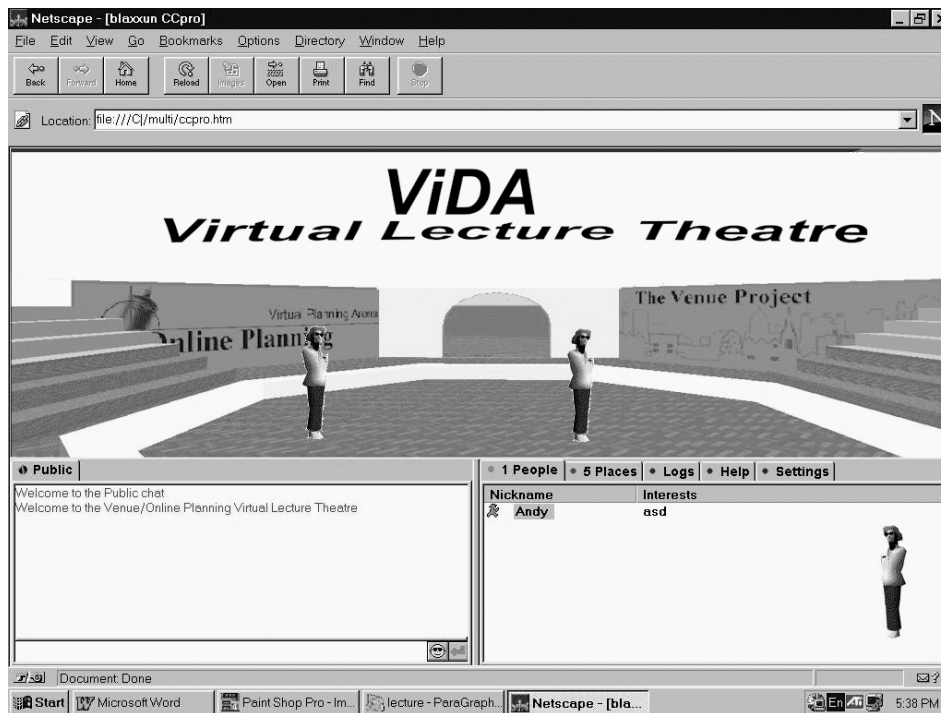

Figure 18. Prototype Client Interface - ViDA Virtual Lecture Theatre

2.5.4 Limitations

There are some limitations with using Virtual Worlds to construct ViDA's. The realism required in the 3D models to be effective for our purposes needs to be tested. In particular, the 3D modelling formats used by the multi-user world systems (section 3.4.3), do not support shadows. Clearly, this will hamper the realism which can be achieved in visualising the built environment where lighting and shadows are an important element in design.

Although the clients for the Virtual World system's are generally free, they are only available for the Windows 95/ NT platform. This is a limitation as many use systems with older versions of Windows or use Mac's. Furthermore, server software has to be bought, costing from a few hundred to a couple of thousand pounds sterling. There is also the danger of becoming locked into proprietary software systems, over which authors have little development control, which can leave them at the mercy of the vendor. This can be particularly problematic with regard to the smaller vendors of Internet software which tend to have unpredictable life-spans. The communication between participants (particularly ones at geographically separate locations) is also dependent on typing text messages in a "chat" window. This can be problematic for carrying on in-depth, lengthy "conversations", especially for people not adept at typing.
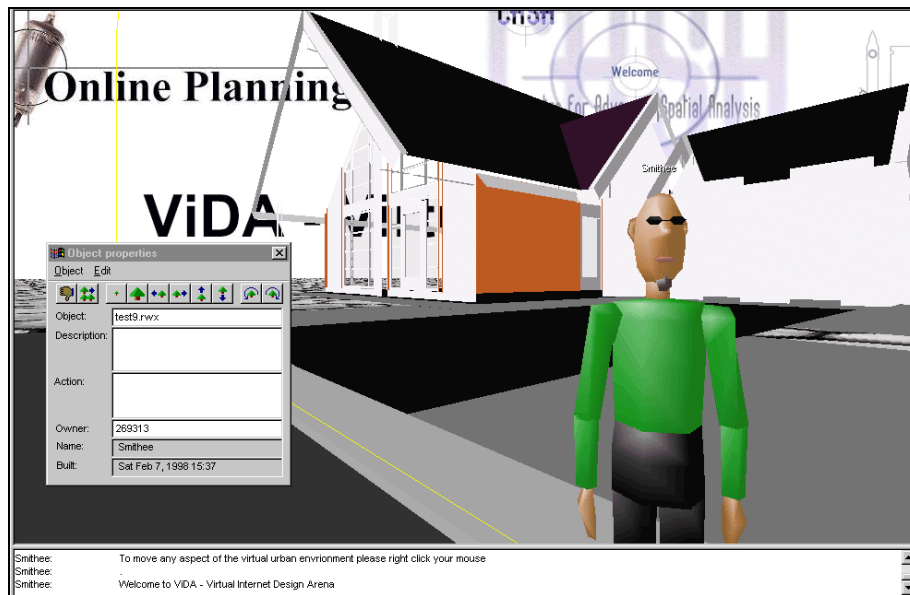
Figure 19. Alphaworld ViDA Interface.

2.5.5 Possibilities

The ViDA initiative is an experiment in using available multi-user world technologies in visual communication for planning and urban design. However, we have been considering some of the exciting possibilities that it may open up if the initial experiment proves the notion of virtual design and planning are viable. An example is the potential to construct more elaborate scenarios, with "role play" where different participants assume the "roles" of the planner, the developer, and the local resident. We would also like to explore the possibilities of embedding rules into the virtual world of what can be built where. In this way, electronic planning constraints can be implemented and enforced on the designers. In some sense, we would be adding a measure of intelligence to our 3D world. We would also like to be able to link attribute data to buildings and objects in our worlds. For example, it would be good if users could "touch" a building and get detailed information on its construction, use, age, ownership, and value. Communication between participants, particularly 'over the net', could well be improved beyond "chat" text messages using desktop video-conferencing and "whiteboard" technologies.

3. Photorealistic Media in the Process of Communicating Plans

3.1 Development of Photorealistic Media

In contrast to the solid or block modelling discussed, a number of software companies, have developed photospatial VR systems for use on a variety of operating systems. Apple's QuickTime Virtual Reality (QTVR) is characteristic of a range of WWW development tools utilising photo-realistic scenes to create navigable movies. QTVR has the largest user base, with over 3000 sites on the WWW. Realism is achieved by using photographic rendering, allowing a user to pan around the scene or *node*.

Whilst photographically rendered scenes are highly realistic, the user's view point is fixed to the original location of the camera. The user is not able to 'walk' around the scenes in the same way as in VRML, but nodes can be linked allowing users to 'jump' between scenes, creating a sense of movement. Typical file sizes for QTVR are 200 - 300Kb for each node, placing a restriction on movement as each new node is downloaded separately as the user moves around. The development

of a WWW interface featuring panoramic scenes may be viewed in two distinct stages as illustrated in **Figure 20**.

Stage one consists of the development of the panoramic scene, such as Leicester Square, London. Each scene consists of approximately 14 photographs, depending on the camera lens used. The photographs are taken, in this case using a digital camera, allowing each to overlap by approximately five percent. The images are then 'stitched' together to produce a full 360 panorama using specialist software such as PhotoVista which is produced by LivePicture (http://www.livepicture.com). Once the panorama have been produced, they can then be integrated into a WWW page, Stage two. There are currently two routes to integrating panoramas into the WWW, the 'plug-in' and the Java route. The first route uses software specific 'plug-ins' typically written for either the Netscape or Microsoft range of browsers. The use of 'plug-ins' allow the integration of additional information into the panoramic scenes but often requires the end-user to install the 'plug-in' on to the client machine. Furthermore, 'plug-ins' are usually operating system specific and therefore implicitly restrictive.

The second route to placing photo-realistic VR panoramas on the WWW is by using JAVA applications or applets. JAVA applets capable of displaying panoramas are freely available on the WWW (http://www.livepicture.com) thus allowing scenes to be integrated into platform independent WWW pages. The level of interactivity within the JAVA based scenes is at present limited in comparison to the 'plug-in' counterparts. For example, it is much more difficult to link scenes and gain 'clickable' information within the Jutvision JAVA environment in comparison to the equivalent Windows 95/ NT 'plug-in'.

3.2 Photorealistic Visual Communication

3.2.1 Virtual StreetScape

Figure 21 illustrates "The Virtual Streetscape" an example of the use of QTVR to visualise the built environment. Developed as a demonstration project of the MIT Department of Urban Studies & Planning's Computer Resource Laboratory, the Virtual Streetscape illustrates how 360 degree panoramic views can be linked to aerial photographs to create a linkage between more traditional, two dimensional images and three dimensional VR scenes.

3.2.2 Wired Whitehall Virtual Urban Interface System

Wired Whitehall integrates information relating to the built environment through photospatial scenes using hot linking software by Jutvision (http://www.visdyn.com), and as shown in **Figure 22**, is similar in concept to the Virtual Streetscape.

Wired Whitehall is being developed to integrate real world planning data behind its visual interface into a Virtual Urban Information System. The user will be able to 'click' on a building within the photorealistic scene and obtain detailed planning documents.

While the use of photo-realistic VR scenes on the WWW provides a visual way to communicate planning information its use is limited. To be able truly to communicate planning and urban information, the end user should be able to interact with objects within the same environment.

To allow this, representations of real world objects can be placed within the panoramas. This object placement augments the *actual* with the *proposed* thus allowing an end-user to simulate or visualise proposed change in a specific location. This technique is encompassed within the broad term of Augmented Reality (AR) (Tuceryan *et al* 1995).
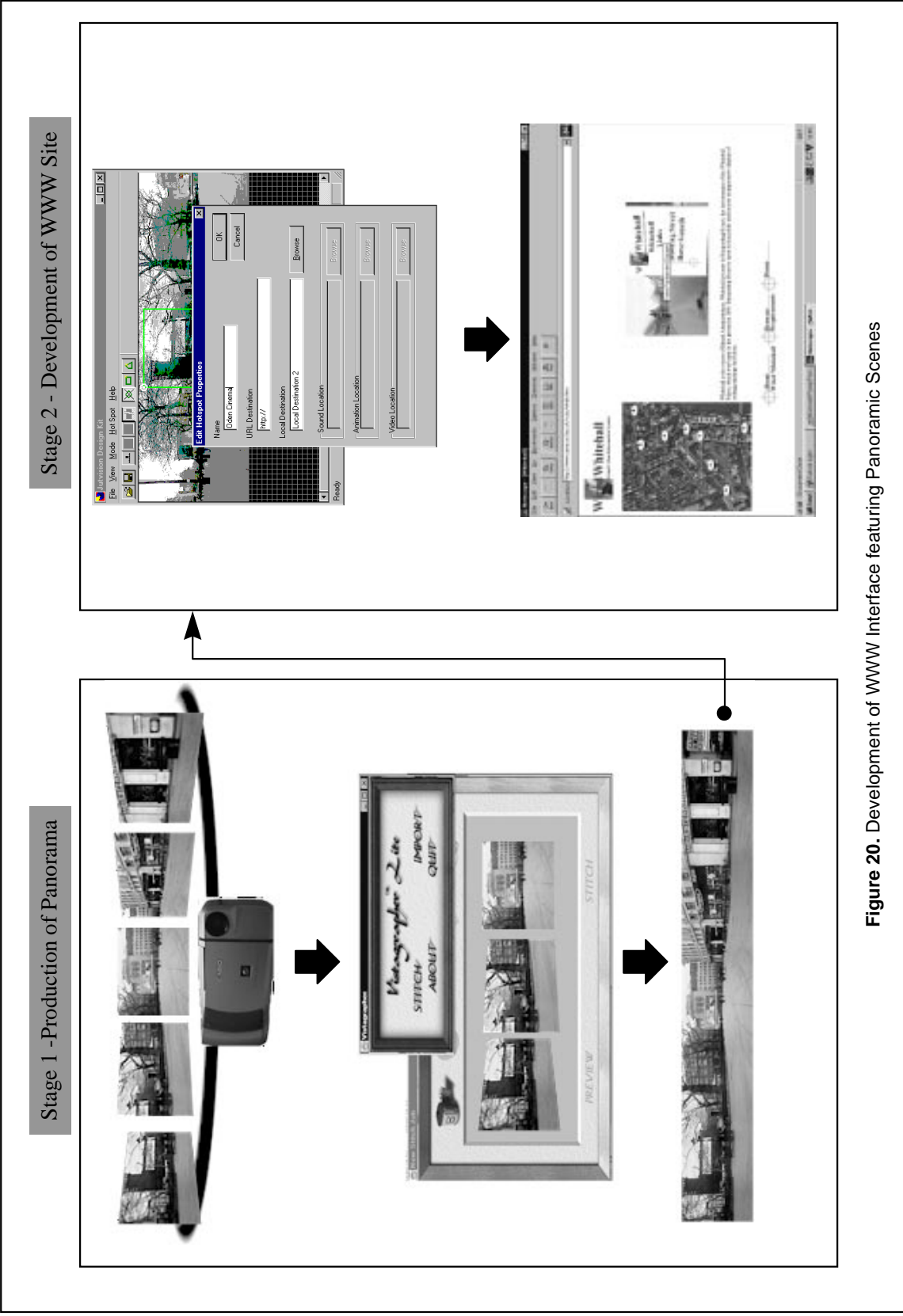
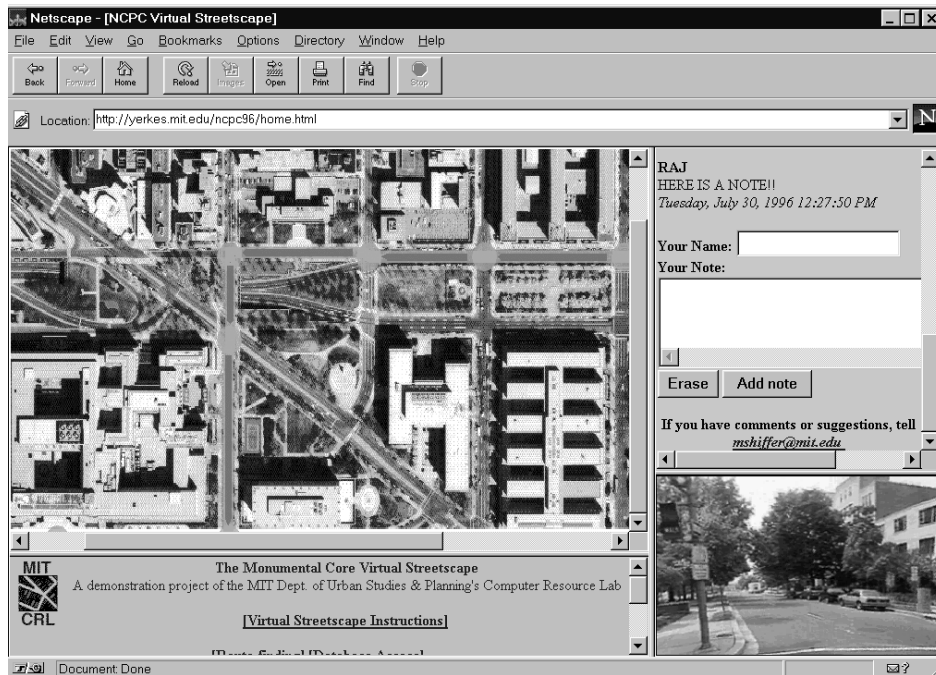**Figure 20.** Development of WWW Interface featuring Panoramic Scenes

Figure 21. "Virtual Streetscape" (Computer Resource Lab, Dept. of Urban Studies & Planning, MIT)
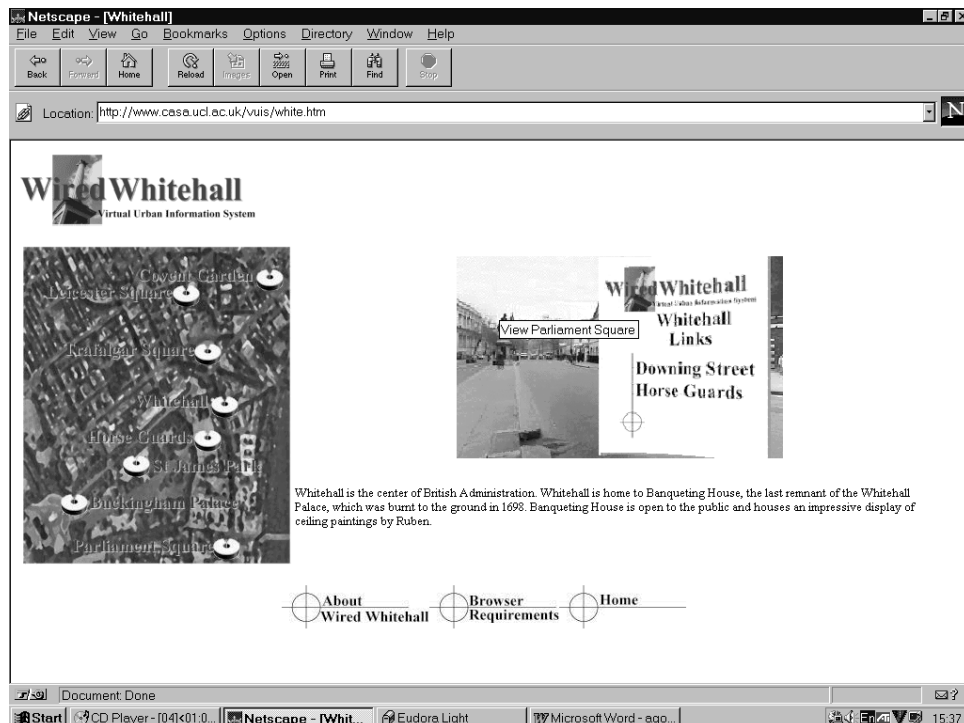

Figure 22. Wired Whitehall Virtual Urban Interface System

3.3 Augmented Reality

Augmented Reality (AR) is a technology in which a user's view of the real world is enhanced or augmented with additional information generated from a computer model. The enhancement may take the form of labels, 3D rendered models or shading modifications. The uses of AR in modelling the built environment are numerous, from the placement of a piece of street furniture into a photo-realistic scene to the overlay of new urban form. To a limited extent, 'Wired Whitehall' is a basic example of AR, in that virtual billboards are created within photo-realistic panoramas, in order to create hyper-links of relevance to the urban scene. For example, a virtual billboard near Downing Street allows access to the "No. 10 Downing Street" Web site. A degree of interactivity within the urban scene is desirable if various planning schemes are proposed. This can be achieved by combining VRML 2.0 objects and photospatial scenes giving AR on the WWW.

Figure 23 illustrates the placement of a VRML 2.0 object into a 360^0 panorama using RealVR. RealVR (http://www.livepicture.com) is a 'plug-in' for the Netscape browser that allows the insertion of VRML 2.0 objects into scenes. Once an object has been placed, augmenting reality, the user is able to move the object into and out of the panorama.

3.3.1 *Virtual Reality Studio*

An important aspect in the development of Augmented Reality with photorealistic media is the ability quickly to create realistic looking representations of the urban environment. LivePicture are currently running a Beta version of their Virtual Reality Studio software, allowing VRML 2.0 objects to be easily placed in Photorealistic scenes.
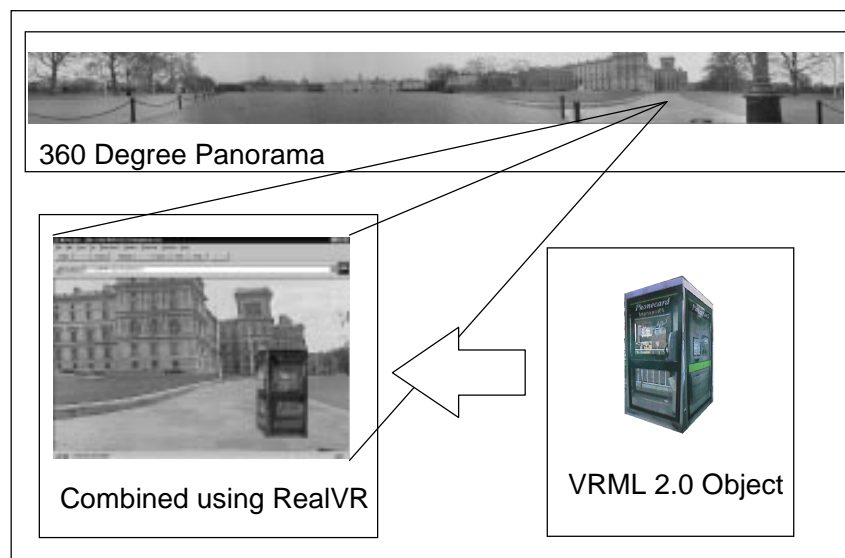

Figure 23. Augmented Reality on the WWW: Object placement.

Figure 24. Virtual Reality Studio Interface

Figure 24 illustrates an article of Street Furniture, in this case a telephone box, being placed into an urban scene. Any number of objects may be placed within the scene, allowing the introduction of comparative design on the WWW. Whilst AR and photorealistic scenes do not have the same degree of interaction as do Virtual Worlds, they provide and important step forward in the ability quickly and easily to visualise urban planning and urban design information.

4. Visual Communication of Planning Data through GIS

Geographic Information Systems (GIS) applications are powerful graphic "tool-boxes" for the visualisation of spatial data integral to the work of urban planning and urban design. Conventionally GIS uses a two-dimensional cartographic interface to the data on a graphics workstation platform. However, recent developments in the field are greatly increasing the power of the graphic tools to visualise spatial data, as well as again easy access to it. These developments are Desktop GIS, Three-dimensional GIS, and Internet GIS.

4.1 Desktop GIS

In the built environment community there has been a steady growth in the use of spatial data to describe features of the built environment. This is due to the rise in sophistication of GIS and the migration of powerful applications from expensive graphics workstations to more widely available desktop PCs. Two of the leading GISs available on the PC desktop are MapInfo (MapInfo Corp.) and ArcView (ESRI). These offer powerful cartographic visualisation tools and are widely used in urban planning. This migration of power to the end user and the increased availability of detailed digital map data has allowed planner and designers to think 'spatially' more often in analysing and visualising solutions to built environment problems.

4.2 Three-Dimensional GIS

There has been considerable research effort into developing the capabilities of GIS to handle three-dimensional visualisation of the built environment data (Faust 1995). This has often been achieved through the linkage of CAD technologies to a GIS database (Liggett, Friedman & Jepson 1995). More recently there has been interest in using virtual reality techniques to produce 3D solid geometry models that the user can interactively explore and interrogate. The practical implementation of this has been achieved using VRML, with the 3D models being viewed in separate "browser" applications. In this sense, the 3D GIS is created by the "loose coupling" of virtual reality with 2D spatial database. Examples include the research by Martin and Higgs who

linked ARC/INFO GIS to VRML to visualise urban property information (Martin & Higgs 1997). Similarly, Smith has created an extension to MapInfo GIS called Pavan which creates VRML models (Smith, S. 1997) and Dodge has developed scripts within ArcView GIS to produce VRML models of small scale urban scenes (Dodge & Jiang 1997). **Figure 25** shows this approach of "loose coupling" GIS to VRML.

Figure 25. The "loose coupling" of GIS to VRML within a Web browser - to the left is a CASA developed dynamic Internet Map of Whitehall and linked to it on the right, is the corresponding 3D model.

To create a 3D model from 2D data, four distinct processes are applied. In stage one, the conventional 2D GIS database is used to map the desired spatial information. The user then runs a program or script, usually with in the GIS, that generates a VRML format output from the 2D geometry and attributes. This output is stored in a data file external to the GIS, which is then loaded into a suitable VRML browser for viewing. The browser provides the functionality for the user interactively to explore the 3D model by "walking" and "flying". The user is unable to modify the model in the browser. Modification of the model requires going back to stage one, making changes to the 2D GIS database, and then generating a new VRML model. So there is only a one-way link between the GIS and the VRML, with no means of feedback. Despite this limitation, there are several key benefits to using VRML to produce 3D models from GIS. First, it is a relatively low-cost option in terms of time and money, particularly as the VRML browsers are largely free software. Also the VRML language is an agreed Internet standard and is not proprietary and cross-platform. It is therefore very easy to distribute models to the web community.

Many of the commercial GIS vendors are now realising the possibilities of 3D GIS using virtual reality technologies. For example ESRI Inc. will soon be launching a powerful 3D extension to their desktop GIS ArcView (ESRI 1997). This will provide 3D visualisation capabilities within the GIS itself allowing a degree of modelling and analysis in three dimensions. We have mentioned VRML and the ability to employ it by coupling it to GIS. For the benefit of the reader the following section describes VRML and solid and geometric modelling in greater detail.

4.3 Internet GIS

On the World-Wide Web, raster images have been used to display two-dimensional cartographic data for a number of years. In fact, in the early days of the Web, one of the first popular interactive services was the Xerox PARC Map Viewer (Putz 1994) which is still available at *http://mapweb.parc.xerox.com/map.* Whilst these images of maps are useful in certain instances,

they offer little of the interactive functionality normally available to the GIS user. This reduces the ability of the end user to interrogate a given set of spatial data. The ability to zoom in and out of a map and to identify objects and be presented with useful attribute data is extremely useful to interested end-users. If, for instance, planning applications were placed 'on-line' within a Web site which incorporated an interactive map of an area, interested parties could glean information on previous developments, site or land ownership, contact details in order to voice an opinion, and so on, thus democratising the general process through interactive consultation. To date, two broad types of Web-based interactive mapping solutions have been developed by the commercial GIS vendors: the static map and the dynamic map (Plewe 1997, Toon 1997).

4.3.1 Static Map

This kind of interactive map relies on user input to select a set of variables, which in turn generates a map image at the server side. This map is then returned as a 'result' of the user input. In broad terms, the functionality and scope of the graphic user interface (GUI) are reduced in comparison to the dynamic interactive map but the query capabilities are usually more advanced. This kind of application can prove to be more complex for a 'public' user to come to terms with if developed at too high a level. ESRI's Map Objects package is a tool box which enables this kind of application to be developed for the web. With competent programming many GIS functions can be created. At ESRI's Web site *http://maps.esri.com/* there is a range of these query based applications ranging from a toxin release inventory to a geo-demographic thematic map application.

It should be noted that to date the most developed of these applications are US based. This not only reflects the physical location of the major vendors, it also reflects the level of accessibility which exists in the US with reference to digital data and freedom of information. In the UK many similar applications could be built, but for the stifling legal constraints applied to digital data and its dissemination through electronic media. Notwithstanding this, interactive mapping within the browser is a rapid area of development for the GIS community. Anyone who has installed Microsoft's Internet Explorer 4.0 will realise that the desktop is destined to transform itself into a quasi-browser, whereby more and more information and applications will be web enabled or optimised for browser viewing. It seems that the GIS community are moving with the times, this can only be a good thing, not just for the planning community or spatial decision makers, but for the wider geographic information user community with an interest in involving public consultation or the dissemination of information.

4.3.2 Dynamic Map

The Dynamic Map is a basic GIS embedded within a client web browser. The user will typically be able to zoom, pan, identify objects, hotlink to other data and turn layers of data on and off. User actions will be responded to in real time by a map 'server', thus giving the 'client' or end user a diluted GIS. Within the market place, several GIS vendors have dynamic Internet mapping systems within their product range. ESRI produce MapCafe, Autodesk have Map Guide and Intergraph and MapInfo have their own proprietary applications. Whilst not designed with extensive analytical capabilities these applications are empowering the web community by making spatial data more readily available. The functionality is at a level where pre-determined data may be queried and examined in such a way that the typical end user is not overwhelmed by unfamiliar technology but is still capable of learning about, or contributing to, any given discussion. **Figure 26** illustrates an example of a dynamic map which has been developed by the authors. Within the browser, the end user is able to zoom, pan, examine attribute data, switch vector and raster layers on and off and hotlink to related web sites and to multimedia clips. This example is typical of the kind of WWW based mapping which is being developed by GIS vendors. In this instance JAVA is used to serve the map information to the end user. This is advantageous in that any JAVA enabled browser could

view the application. Alternative approaches include the use of plug-ins, or applications which are incorporated into browsers. Intergraph's GeoMedia and Autodesk's MapGuide are examples of the plug-in approach. The immediate disadvantage of using a plug-in is that software has to be installed into the browser at the client end prior to data access. This requires some expertise and the appropriate permission to alter the clients configuration. Furthermore many plug-ins are platform or operating system dependent which in turn may restrict the number of possible end users.
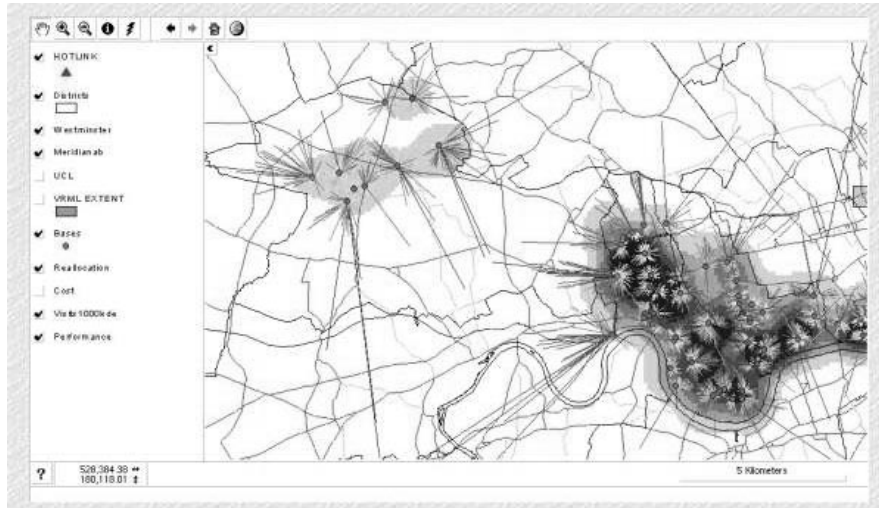

Figure 26. An interactive WWW GIS application (ESRI's MapCafe) which has been embedded within a Web Browser in order to disseminate spatial information.

The ability to provide two dimensional cartographic or thematic spatial information to the web community is a useful tool and few would dispute the potential of such an approach. Internet GIS will be critical component in the development of virtual cities (Smith 1998) which will enable urban planner and urban designers to visualise and model the complexity of the built environment in networked VR.

5 Future Developments

5.1 Towards the Virtual City

As can be seen from the previous sections, there are numerous ways of visualising digital environments which can facilitate planning, and the simulation of processes which affect the urban environment. These digital environments can obviously vary in terms of the way in which they are constructed and presented. Furthermore, the underlying real world information can be tailored to serve a variety of tasks within the planning and urban design. The uptake of digital technologies in this context range from the visualisation of change to collaborative online planning and so on, thus pushing us towards the creation of virtual cities or towns.

Virtual cities is a term which has been used to describe a diverse range of information interfaces, that are particularly prevalent on the World Wide Web (WWW). To date there are four main online environments which have had the label attached to them;

- Web Listing Virtual Cities
- Flat Virtual Cities
- 3D Virtual Cities
- True Virtual Cities

Figure 27. Virtual Bologna's "flat" map interface
(http://www.nettuno.it/bologna/Mappa/Welcome.html)

Of these it is the third and fourth which have most relevance in the visual communication of geometric models or designs. The first two forms of virtual city are misleading in that *Web Listing Virtual Cities* such as "Virtual Brighton & Hove" (http://www.brighton.co.uk) are simply listings or what's on type guides and *Flat Virtual Cities* are images in which icons or pictures are used to represent aspects of real place. The Virtual Bologna site (**Figure 27**) is a good example of this second kind of interface to real urban environments. Whilst information can be gleaned from these first two types of virtual cities, their applicability to real urban environment problems may be deemed as limited due to their abstraction from the actual physical places they represent (Dodge, Doyle & Smith 1997).

The third and fourth types of virtual city are the ones which planners and urban designers can utilise in decision making processes. By modelling aspects of the built environment in VRML or by using photospatial panoramas, vivid models can be created which can be applied to a variety of planning and design scenarios. By creating *3D Virtual Cities*, such as Virtual New York (**Figure 28**) where real world objects and entities are modelled to a given level of accuracy, a reasonable visual forum can be created for professional decision making purposes.

By digitally modelling the physical world in 3D we begin to create facsimiles of our own environment. The level of realism required or achieved obviously depends upon the end purpose and also on technical and institutional considerations. Nonetheless the creation of what we have described as *true virtual cities* is possible. There is a wealth of spatial digital data available to planners and urban designers, brought to the desktop *via* the growth in use of GIS and CAD packages. Data providers such as Ordnance Survey and Experian (Goad) hold accurate digital geometric information down to the building polygon level. By exploiting this kind of footprint information we can begin to construct the foundations of our *true virtual cities*. Creating such models from quality assured datasets, we can really begin to bring the physical world onto the desktop. Whilst problems do exist in that buildings are usually complex structures and are not merely extrusions of their footprints, the facility to produce generalised representations exists. This is perhaps more applicable to wider or strategic scale applications at the urban rather than the building scale. This leads to the question, how real do virtual reality or virtual models have to be? **Figure 29** shows a section of a model of Westminster which has been created by the authors. In it

Nelson's Column is visible and identifiable by context. At an urban scale we probably need to do little to represent this element of the built environment. At the building scale, however, it may be important to add more detail or textures to the Trafalgar Square area. It may be the case that a new kind of paving is to be put in place, at this scale textures and rendering become more important.
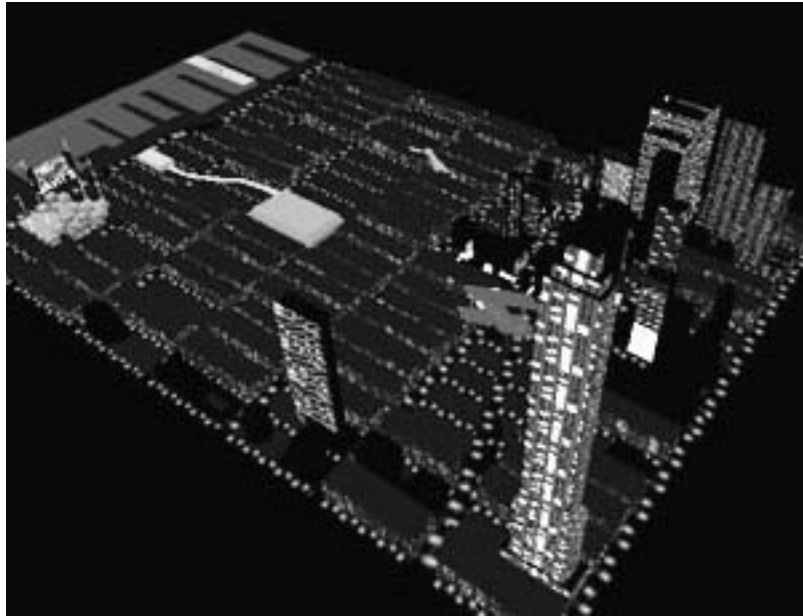

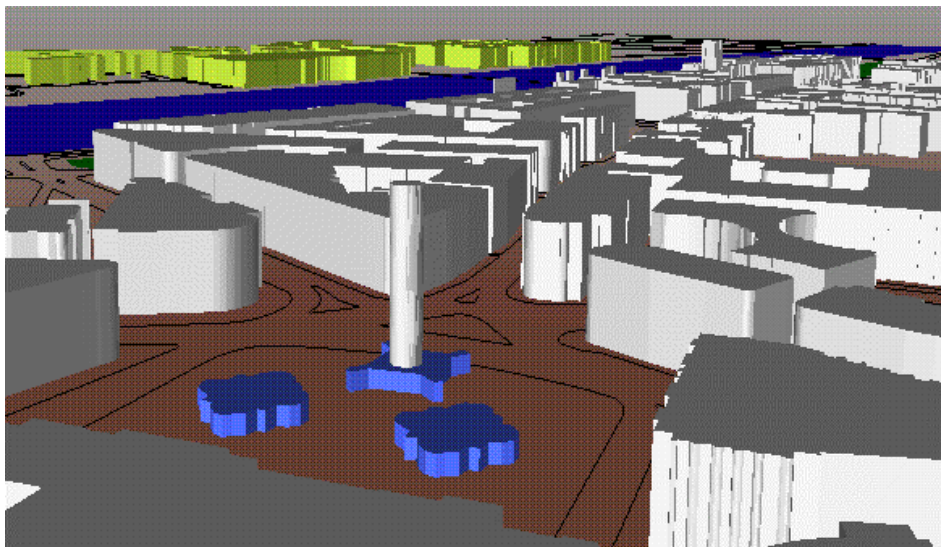**Figure 28.** Planet 9 Studios' Virtual New York (http://www.planet9.com/earth/ny/index.htm)

Figure 29. Trafalgar Square within a VRML model (source Authors)

Whilst we can obviously link GIS to VRML there are still problems in attaching roof detail and embellishing building detail, although recent applications such as PAVAN (Smith, S 1997) has made progress in this area. In this respect, data providers need to examine ways of incorporating height, and roof shape information into existing or new datasets such as LandLine. Whilst there is little prospect of a virtual London Model in the short term specific areas of the capital can be generated very rapidly in a GIS-VRML environment as shown in **Figure 29**. As data become more

sophisticated in terms of 3D referencing, and as desktop computing increases in power, there will no doubt be a rise in the number of professionally useable 'real' virtual places for urban designers and planners. Like a 2D thematic map we can colour land parcels and building polygons according to rateable value, occupancy levels, value per square metre or by any other attribute ordinarily found in a GIS environment, thus encapsulating the idea of 3D GIS in terms of data visualisation.

Beyond this convergence of GIS and VRML or solid modelling, we can also embrace techniques which are currently browser oriented in order to solve planning and design problems. By taking our digital geographical data and placing it within a multi-user world we can, again, help planners plan and designers design. If an accurate, realistic context can be set, the design/planning process can become more digital and also more democratic in terms of its ability to be distributed in digital form (over the WWW or *via* a Planning Department's Intranet). With the web browser facilitates we have been discussing with GIS, VRML, multi-user worlds enabled, we are able to interact with objects and information in a more completely than if the applications were in isolation. This holistic approach may result in an object-oriented database being created within a given urban environment, which populates the virtual space with both structures (plus or minus building textures) and attribute information. Avatars can then be introduced, as in the Virtual Design Arenas (**Section 2.5**). Information could be obtained by 'touching' building polygons or by crossing into various land parcels where the data is served through a web hotlink or from an underlying data store. Whilst *true virtual cities* are really still in an embryonic stage, the ability to simulate urban interaction within a VR context is now in place. As in a real place, social interaction can occur as can planning and design changes to physical layouts in real time. Laws can also be applied and enforced in terms of personal and professional behaviour and permissible actions.

Figure 30. Possible GUI for a *true virtual city.* A section of Whitehall, London is displayed within a Blaxxun browser.

The concept of the virtual city information system has a great deal of scope. **Figure 30** shows a Graphic User Interface (GUI) which will be developed further in an academic context by the authors. Within the world, which is constructed by building polygons (GIS/ CAD derived) which are rendered with photo-realistic textures and avatars representing professionals and the public, communication and interaction is available at a one to one, one to many, many to one and many to many level and building permission is granted by development controllers. This kind of application

can be tailored to end-user requirements. Possible modes of development may incorporate real-time systems such as pollution meters, CCTV, or traffic sensors from the building scale to the urban level. At present there are constraints on how far *true virtual cities* can be developed but nonetheless, **Figure 30** is a glimpse of the networked, multi-user virtual worlds which are developing to aid visualise communication in urban planning and urban design.

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7. World Wide Web Resources

These WWW addresses listed were correct when the report was compiled in February 1998.

ABACUS   http://www.strath.ac.uk/Departments/Architecture/abacus/gintro.htm
ActiveWorlds   http://www.activeworlds.com/
Blaxxun   http://www.blaxxun.com/
Centre for Advanced Spatial Analysis, University College London.
                    http://www.casa.ucl.ac.uk
Centre for Advanced Studies in Architecture, University of Bath
                    http://www.bath.ac.uk/Centres/CASA/
Community Place

	http://www.sonypic.com
ESRI	http://www.esri.com
Hot links to the Virtual Worlds Industry	
	http://www.ccon.org/hotlinks/hotlinks.html
Jutvision	http://www.visdyn.com
LivePicture	http://www.livepicture.com
Online Planning	http://www.plannet.co.uk/olp/
Planet 9 Studios	http:www.planet9.com
Onlive Technologies	http://www.onlive.com
Quick Time Virtual Reality	
	http://www.apple.com/quicktime/sw
Wired Whitehall	http://www.casa.ucl.ac.uk/vuis/
Virtual Cities Resource Centre	
	http://www.casa.ucl.ac.uk/planning/virtualcities.html
Virtual Reality as an Interface to Geographical Information (ViRGIN)	
	http://www.casa.ucl.ac.uk/virgin/
Virtual Streetscape	http://yerkes.mit.edu/ncpc96/home.html

8. Virtual Urban Environments on the World Wide Web

Austin by Planet 9 Studios illustrates the use of VRML to represent urban form. Planet 9 is the biggest producer of 'virtual cities' on the WWW and all their models follow the same form. Simple VRML is used to create the urban layout and basic textures add detail. The use of textures, although enhancing the visualisation of urban form significantly increases the overall file size of the model.
URL: http://www.planet9.com/worlds/austin10.wrl

Boston by Planet 9 Studios - details as above.
URL: http://www.planet9.com/worlds/boston10.wrl

Bath produced by CASA at Bath University, funded by a grant J. Sainsbury plc to construct a three-dimensional computer model of Bath. The project was supported by Bath City Council and since its completion the model has been used by the city planners to test the visual impact of a number of proposed developments on the city. This is good example of the use of VRML to produce virtual models of cities.
URL: http://www.bath.ac.uk/Centres/CASA/bath/bath_low_B.wrl.gz

Helsinki Helsinki Telephone Company project has developed the Helsinki Arena 2000- consortium project in collaboration with the City of Helsinki. The project aims to develop a Virtual Helsinki into the Cyberspace and the project has received a widespread support of business and public organisations. The project will culminate in the year 2000, a festive year for the City of Helsinki. The Current VRML model (662k) makes good use of viewpoints to create a virtual tour.
URL: http://www.helsinkiarena2000.fi/maailmat/wrl/stocka_y.wrl

Las Vegas by Planet 9 Studios, is heavily texture dependent as is characteristic of models by Plannet 9.
URL: http://www.planet9.com/worlds/lasvegas/lvlite.wrl

New York by Planet 9 Studios, as above the model is heavily texture dependent, but the end result is a detailed representation.
URL: http://www.planet9.com/worlds/newyor10.wrl

New York by Sony Corporation, not as detailed as the Planet 9 model, but using Sony's Community Place Browser it allows the use of avatars. The use of avatars dramatically increases the depth of the representation by introducing social interaction.
URL: http://sonypic.com/WORLD/CITY/NEWYORK/models/newyork.wrl.gz

Ottawa by Wizard Solutions The VRML model includes good use of viewpoints and embedded URL links to WWW pages. The VRML 2.0 version also features a 3D sound source and tour based viewpoints. Although no social aspect is included in the model, the use of embedded information and moving tour viewpoints illustrates a good representation of a basic virtual city.
URL: http://www.intoronto.com/cities/ottawa.wrl

Siena by Construct makes good use of textures to create the atmosphere of an Italian City. Construct have made imaginative use of hyperlinks and level of detail to create one of the few representations of urban form which creates a true sense of place.
URL: http://www.construct.net/projects/planetitaly/Spazio/VRML/siena.wrl

Tubingen the primary result of the The Virtual Tübingen Project- Applying virtual reality technology to psychophysics at the Max Planck Institut. The model uses VRML based on basic input data consist of architectural drawings provided by the city administration. The project is developing techniques to simulate the urban form in VRML.
URL: http://www.mpik-tueb.mpg.de/projects/vrtueb/final/markt/vrml/markt.wrl

Toronto by Wizard Solutions, similar in development to the Ottawa model by Wizard solutions, good use of Viewpoints and embedded URL links to homepages.

Warsaw by M. Jacek Szamrej University of Warsaw, one of the first representations of urban form on the WWW. The model is basic, but is a good illustration of how streets can be modelled using VRML.
URL: http://andante.iss.uw.edu.pl/cgi-bin/modzel