Building the Virtual City: Public Participation through e-Democracy

Andrew Hudson-Smith, Stephen Evans, and Michael Batty

In this paper, we outline how we have developed a series of technologies that enable planning information to be disseminated to affected citizens so that professionals and politicians can engage with these stakeholders in realizing more effective plans. Our main theme is based on the generic idea of the "virtual city" which is conceived in terms of the geography and geometry of the real city. This is a digital representation using a variety of software and multimedia, made interactively available over the web. We begin with a brief comment on different types of virtual city and then summarize the key problems of using such virtualities in public participation, more recently considered as part of the e-democracy movement. We outline our previous attempts to engage in such online participation in east London for these have been an essential prerequisite to the development of

---

Andrew Hudson-Smith is systems administrator and senior research fellow at the Centre for Advanced Spatial Analysis (CASA) at University College London (UCL). He has pioneered various multimedia, virtual reality methods 3D GIS, and CAD for problems of public participation in planning. He is currently the director of the Greater London Authority's Virtual London project within CASA. Amongst his recent contributions, he has published (with S. Evans, M. Batty, and S. Batty) "Community Participation in Urban Regeneration Using Internet Technologies," in *London: A Sustainable World City* and "30 Days in ActiveWorlds: Community, Design, and Terrorism in a Virtual World," in *The Social Life of Avatars, Presence and Interaction in Shared Virtual Environments*. He may be reached at <asmith@goeog.ucl.ac.uk>.eHH

Stephen Evans is also a senior research fellow at CASA. His background is in GIS and he has worked on several projects including LEO—London Environment Online, PROPOLIS—the development of GIS interfaces to urban land use transportation models, and currently on the Virtual London and Camden Panoramas projects. Amongst his recent work, he has published (with P. Steadman) "Interfacing Land-Use Transport Models with GIS: The Inverness Model," in *Advanced Spatial Analysis: The CASA Book of GIS* and (with A. Hudson-Smith and M. Batty) "Homes in Hackney Point to the Future," *Planning*, 12 July 2002. He may be reached at <stephen.evans@ucl.ac.uk>.

Michael Batty is professor of Spatial Analysis and Planning and director of CASA. He has a joint appointment between the Department of Geography and the Bartlett School of Architecture and Planning. His books range from *Urban Modelling* to *Fractal Cities*. He is editor of *Environment and Planning B*. The work of his group can be seen at <http://www.casa.ucl.ac.uk> and in the recent book *Advanced Spatial Analysis*. He was elected a Fellow of the British Academy in 2001 and was awarded the CBE for "services to geography" in 2004. He may be reached at <m.batty@ucl.ac.uk>.

Knowledge, Technology, & Policy, Spring 2005, Vol. 18, No. 1, pp. 62-85.

"Virtual London," the application reported here which is currently being fashioned for widespread dissemination of planning information by the Greater London Authority (GLA). We then argue that virtual cities should go well beyond the traditional conceptions of 3D GIS and CAD into virtual worlds and online design. But we also urge caution in pushing the digital message too far, showing how more conventional tangible media is always necessary in rooting such models in more realistic and familiar representations.

Defining Virtuality

The expression "virtual" was used long before the development of the digital computer whose origins lie in the development of electricity in the late nineteenth century. One hundred years later, by the mid-1970s when the computer revolution was quite well-advanced, dictionary definitions still did not refer to any computational meaning in the term "virtual" (OED, 1974). Only within the last 20 years has the term become coincident with those realities which are communicated graphically using desktop, network, and various immersive media powered by digital computation of various kinds. Yet for cities, the idea of the virtual is a long-standing characteristic feature, present since we first began to consciously manipulate our environment for all planning involves "imaginings" encoded as plans and designs. City plans are virtual statements, ranging from rather staid projections of the present to futures that we consciously intend to implement, to futures that are purely subconscious reflections of our utopian desires. In literature too, the city has been an icon for the virtual (Calvino, 1974) while our obsession with scaled-down replicas finds wide expression in the various scale models of buildings such as those that can be purchased as souvenirs from visits to most large cities.

With computers and computer graphics, our current concern for the virtual city has taken a new direction. The media, in which we are able to encode both existing conditions and future plans, provides an immediacy, an accuracy, and a clarity of demonstration that enables us to understand and disseminate this understanding in ways that are very different from those we have traditionally used. This movement to the virtual world is being fast embraced by many professional activities. It has its seeds in the origins of digital computers that, as soon as they left the laboratory 50 years ago, began to be used to represent text and graphics alongside their traditional, numerical content. It then took 30 years for miniaturization to reach the point where computer memories could be uniquely associated with graphics and text in a routine way, and it took the micro-revolution to make such graphics widely available, first through games. Since then, the convergence of telecommunications with computers has evolved a medium, currently the net or web, which makes these graphics widely and routinely available in a standardized one-to-many manner. We are only beginning to realize the potential which this revolution is unlocking for disseminating information about cities. This paper is about one small corner of this world which we are developing to communicate ideas about the future of the heart of a world city, London.

Computer graphics goes right back to the beginning when designers began to represent geometries using vector graphics for a variety of systems of which the building and small districts of the city were key examples. By the late 1970s, fly-throughs of city centers such as Chicago were being demonstrated, largely to visualize the impact of new, usually high buildings on the surrounding environment. These were visualizations which required mainframe and mini-computers and remained largely inaccessible to all but their designers. As such they were more part of scientific visualization which was being advanced on all fronts in the 1980s using workstations and supercomputers. Paralleling these developments were rudimentary software packages which really began with the micro-computer, *AutoCAD* being the example *par excellence*. Such software began in almost a toy-like gaming format 20 years ago but it quickly evolved into industrial strength digital design tools. By the late 1980s, graphical user interfaces (GUIs) were becoming popular, and by the mid-1990s had become routine. At the same time, the advent of such network-based GUIs from *MOSAIC/Netscape* to *Explorer* has moved graphic communication to the *de facto* standard for all computer interaction.

There are now many digital virtualities involving the city and these combine differences in technology with differences of philosophy (Batty and Hudson-Smith, 2001). Although we will not review these here, it is worth noting significant differences between the key approaches for in any distinct application, there are usually elements of more than one approach included. First, the web is now widely used to disseminate information about particular cities in terms of their services, and increasingly, these web-based cities provide the interface to government. This is something a little more than simply replacing paper documentation with its digital equivalent, for services can be delivered this way in much the same way that economic transactions can take place over the net. The second virtuality involves more professional usage, being based on graphic representation of the 2D map and its 3D geometric representation. The geography and geometry of the city are now routinely represented in GIS (geographic information systems) and CAD (computer-aided design) software with various multimedia spinning off from such usage and finding its way into the first style of virtuality, the web. What was professional speciality usage yesterday is increasingly the routine usage of today.

The third style of virtuality involves the media for representation. The web and the desktop are the main ways of dissemination with both being essential to the delivery of services and information in one-to-many and many-to-many contexts. More esoteric media, however, based on various kinds of virtual reality from the headset to theatre to CAVE to virtual world, from soft copy to hard copy, from intangible media to tangible, are finding their way into professional and even routine contexts. Network and wireless interactions are providing entirely new possibilities for the way users interact with the virtual and these are increasingly being embedded into our wider environment from how we are changing our behaviors to the ways in which we are gaining physical access to these technologies.

This brings us to a fourth style of virtuality. This involves the very penetration of this infrastructure, the software, the hardware, the orgware, and even

the people-ware, into the city itself. Cities are being wired in much deeper ways than we envisaged a generation ago (Dutton, Blumler, and Kraemer, 1987) as all the first three varieties of virtuality become reflected in the very production of urban space (Thrift and French, 2002). Hard environments are being interwoven with soft, generating simulacra, realities within realities, models of models, on all levels (Baudrillard, 1994). In a sense, this of course is the kind of cyberspace envisaged by writers such as Philip K. Dick, William Gibson, and Neal Stephenson where software and hardware are fusing with the physical fabric of the city, indeed with every artifact we engage with (Graham, 2004). Indeed a new geography is being fashioned around the way such digital technologies are being used in the production of space and, although we will not have time to dwell any further on these here, it is worth noting that our very own technical efforts in designing and using virtual cities are part and parcel of these new realities, virtual or otherwise. Nevertheless we will speculate a little on such deep recursion in terms of the virtual and the real as our argument progresses.

As we have noted, our focus on the model in this project which we euphemistically refer to as "Virtual London," is inspired by both central and local government's desire to engage the citizenry in more effective and immediate forms of public participation. We begin by briefly looking at current developments in e-democracy, and we illustrate these by reviewing some antecedents. These provide the technologies and techniques as well as the social and political context which have enabled us to fashion the various media that we are using in constructing the virtual city. We outline the structure of the interface and the various components which we use to disseminate information about the city, and then digress to show how different media can be used to communicate variants of this information in digital and more tangible form. We conclude by presenting our intended uses of the models, focusing on the dilemma of participation posed by both traditional and new media in engaging stakeholders in thinking about their future environment.

Public Participation and e-Democracy

Virtual cities first became significant in the mid-1980s in two very different forms. First there was the idea that cities might be wired to enable citizen participation in a variety of home activities, particularly shopping and other forms of entertainment. This was paralleled by economic development based on high-tech networks which would enable cities to gain a new competitive advantage through the use of high tech for various forms of economic linkage. Second, there was professional usage through the development of computer mapping and computer graphics which had begun in the 1960s using remote media such as line printers, vector plotters, and primitive display tubes. Public participation was in some ways implicit in these developments but the notion that citizens could actually participate in using such technologies to enable them to understand and actively interact with those producing plans was some way off. This required the convergence of telecommunications and computing to reach a level where there was some standardization and univer-

sality of interaction. This was not achieved until the late 1990s when computers were acquired for the first time simply as devices to unlock information flowing across networks. It is this focus that is all-important to the kinds of participation emphasized here.

In fact there had been various attempts at involving the community in design using computers dating back to the 1960s. At MIT, Nicholas Negroponte's Architecture Machine group (Negroponte, 1973) fashioned many community-based experiments using computer-linked devices and this group was amongst the first to actively involve the community in projects in Boston's South End where community activists could react to designs and produce suggestions using online teletypes. In fact these early experiments have only occasionally been repeated as technologies and access have improved, with much of the action still centering on MIT, in particular the Media Lab. Only in the last decade has it become possible to generalize these early experiments, and much emergent online participation is still based on delivering information somewhat passively, rather than engaging in two-way dialogue.

The range of participatory styles and approaches which involve engaging citizens in policy and planning issues is extremely wide, from schemes to raise community awareness all the way through to formal quasi-legal involvement in the decision-making process. In the United Kingdom, there has been a statutory right to appeal against planning decisions since the mid-twentieth century and formal participation has been a requirement for local government plan preparation since the publication of the Skeffington Report (MHLG, 1969). It is virtually impossible to classify this range of participation but a useful and long-standing model was proposed by Arnstein (1969) whose "ladder" maps participatory processes onto "8 rungs." These rungs range from non-participation involving manipulation of the public by the plan, planner, or politician at the bottom of the ladder, to tokenism which reflects the one-way traffic of providing information under the pretext of consultation midway up the ladder, to different degrees of direct citizen power and control towards the top. The further up the ladder, the greater the engagement of the citizen in the process of producing a plan. It is clear that engaging the public through computers and networks is a little different from the conventional means of face-to-face contact and dissemination through hard copy which were the principal means of dissemination when Arnstein (1969) wrote her paper.

There are an increasing number of attempts at participation using the Internet through various renditions of the virtual city concept. All we can do here is note the salient features but these do guide us in what is feasible. Most attempts are not well documented and exist on a hand-to-mouth project basis as an adjunct to more mainstream work. In a sense, this has always been the case with public participation but often engagement using digital media is a spin-off from some other, perhaps more high profile and better-resourced project. Two key issues stand out: first there is often no provision for maintenance of the activity once the immediate project has ended. In the case of long-term projects, often only enough resources to begin the exercise are available. Continuity is thus always in doubt and this tends to blight such projects. Second, there is rarely any provision for follow-up to assess how effective the partici-

pation has been, as this is rarely budgeted for and if considered at all, is usually considered an added luxury. Thus a clear evaluation of effectiveness is lacking for most applications are supply-led, commissioned by agencies who have some idea of what they want but have not tested this in any way with the publics which they seek to influence.

This is an important limitation on practice, for there are very few clear examples of where such new technologies have been thoroughly tested with a view to evaluating their effectiveness for better participation. Often it is not possible to compare the use of such technologies with anything that has gone before, because there are no examples of traditional practice that have taken place already. New technologies tend to generate their own applications, which would not have happened had such technologies not been in existence. As we have implied, there are always resource constraints on such applications which tend to limit any active testing and evaluation. But the nature of the impact of such technologies on and within the wider social milieu into which they introduced is so complex that any objective or even considered evaluation is difficult, if not impossible.

One very clear point, which is emerging from the better-documented studies, is that the most effective approaches involve not only digital but many traditional media. For example, the Virtual Slaithewaite project developed by Kingston (2002) is a straightforward community plan-making exercise for a small village which is comprehensible and manageable in terms of its spatial extent. Nevertheless, even in this case where the issues concerning housing design and change were straightforward, physical models of the site were used to complement the digital and paper-map versions. Moreover the digital interface to the map design which was made available to local residents was the most straightforward available, being based on purpose-built rather than off-the-shelf generic software. Similar examples of community design developed over a decade by Shiffer (2001) also mix conventional media and much face-to-face contact with a modest degree of digital presentation. It is this mix of traditional with digital that we consider essential if virtual cities are to be used effectively in enabling a wider public to engage in community design which leads to acceptable schemes. In many ways, the other feature of digital participation and the virtual city is the dual use to which participatory systems might be put. They often contain functionalities and foci which are as useful to working planning practitioners as they are to those who are impacted by planning proposals. In short, the line between professional and lay public use is often blurred in these systems for as yet, there is much experiment and little standardization.

These styles of e-participation have been given added impetus in the United Kingdom by the development of explicit and centralized governmental initiatives in e-democracy. The idea of delivering services online is at the heart of the contemporary e-government strategy. As part of this, the e-democracy initiative aims to increase levels of participation by citizens in the democratic process at a local and regional level through the use of advanced technologies that depend intimately on notions of the virtual city and the dissemination of information in virtual fashion over the net. Technologies are seen as key in

stimulating participation in democratic processes, an essential component in creating an active sense of citizenship. The focus is on the role new technology may play in connecting policymakers with ordinary people, and whether new technology can help engage parts of the community who, for social, economic, or cultural reasons, do not take part in traditional forms of public consultation.

It is important to be realistic about how technology can be used to deliver information to make the process of planning more democratic. At one level, online delivery of information is simply a contemporary form of publication which has characterized the role of government planning since it was institutionalized in the late nineteenth century. The need to justify this in terms of assessing demand for such services does not negate in any way the public duty of providing information about what government intends. Moreover, the kind of information that public interest groups and the public in general require is not likely to be the sort that relates to broader strategic issues about urban form and environmental quality; it is more likely to be specific, case-based information about particular proposals that have quite local impact. Virtual cities can provide such localized information of a more superficial kind, and it is often this that drives participation. This potential difference between how government needs to publicize planning issues and what the public is interested in tends to blur the content of the virtual city. Such virtualities are first and foremost a visualization of environments acting as a forum for further discussion and participation rather than providing a detailed set of tools that the public can use to generate their own plans. The latter, of course, is an ideal which is often incorporated in virtual city designs. But for the most part, virtual cities deliver fairly obvious digital content in visual terms which can be used to show the impact of local change as well as the broader goals that the public agency aspires to through its planning.

These are goals that have developed quite naturally from the diverse efforts characterizing the development of online participation over the last decade (Hudson-Smith, 2003). Virtual cities provide the obvious arsenal of techniques and concepts which might enable such democracy to be rooted in electronic media. Online voting systems may be the most obvious form of e-democracy but information about what might be voted upon is much more central than the mechanics of how such votes might be recorded. In this context, there is no real intention to establish such an evaluative mechanism relating to planning proposals. The focus is much more on how such information might be provided, and how the public-at-large might react to it both positively as well as negatively, engaging not only in critique but in constructive debate and bottom-up design. This is a long way from the original goals for building virtual cities which were largely for professional purposes and for analysis, for visualization associated with professional use rather than for a wider public. All these goals are reflected in the various projects that we have developed prior to our current applications to London. To illustrate how we have developed different approaches and medias, we will now recount our experiments in digital urban design and visualization which provide the essential context for applications in the rest of this paper.

Antecedents to the Virtual London Project

Our developments of virtual cities are based on two key requirements: that our renditions of urban geography and geometry need not be detailed to the point where architectural drawings need be prepared from them and that the material delivered through the virtual city should reach as wide an audience as possible. These principles have dominated all our work so far and they imply a relatively eclectic approach with respect to the way our digital renditions have been developed. Our emphasis has always been on low cost and wide accessibility and, from our earliest work which began some seven years ago, this has focused us on web-enabled virtuality. This does not mean that we have not tested our models using desktop environments for much of the rapid prototyping takes place in that medium, nor does it mean that we are unaware of more esoteric solutions which involve more immersive virtual realities. But it does mean that the ultimate products we deliver are primarily available across the web, largely because we consider the web to be the most widely understood graphical user interface, more so than desktop software solutions.

2D maps and 3D iconic content which represents visualization of the built and natural environment captured in the map lie at the heart of virtual city construction. This virtuality has been available since the 1970s but it was only in late 1990s that the digital map could be linked to digital photographic scenes from the actual city. This is best seen in the association of map content with photorealistic panoramas which the user can associate directly with viewpoints within the map, thus capturing the visual quality of any scene in a simple and cost effective way. Linking panoramas to maps was the technique used in our first foray into building the virtual city which one of us developed as a tour through the heart of London (Hudson-Smith, 2003; Batty, Dodge, Doyle, and Smith, 1998). We disseminated this tour of "Wired Whitehall" in a web-enabled environment from which we then began to add much more elaborate 2D and 3D visual content. Our "London Bridges" project, which coincided with the opening of the Millennium Bridge in 2000 and was developed for the Museum of London's bridges exhibit, took the panorama idea further adding to this photorealistic 3D content through which users could navigate and fly.

The production of 3D geometric form can be handled in several ways. The simplest, which we used in London Bridges, is to "sketch" the geometry onto some photorealistic rendering of the set of objects, with multiple photographs from many angles providing added realism and detail. This kind of software has been used for generating 3D renditions of the past—from old photographs or paintings of past scenes—and these provide quite evocative visualizations. Traditional geometric constructions are usually based on computer-aided design packages such as *AutoCAD* or *3D Studio MAX* which enable highly precise geometries to be developed but are data hungry for detailed built form. In the last decade, GIS and Remote Sensing packages such as *ArcGIS* and *ERDAS* have been extended to generate 3D content and the current proprietary plug-ins for GIS—*ArcScene*, for example—enable detailed content to be built which is entirely compatible to the analytical functionalities and querying capabilities of state-of-the-art GIS.

We have explored all these techniques in building geometric content. Our work with the Hackney Building Exploratory linked panoramas to maps, 3D GIS, and wire frame rendered forms to photographic detail on desktop and in web-based applications. These were targeted at raising environmental awareness amongst school children being educated to explore their local environments. Throughout these projects, we have produced the basic content off-line using a diverse range software and computer systems but with the intention that has become firmer as we have progressed, of delivering the content as snapshots, movies, and simplified fly-throughs which less experienced users can interact with quickly and easily on the web. Many of these techniques have come together in our projects with groups in Hackney where we have been involved in grass-roots community design from the bottom up, developing 2D maps, 3D geometries of neighborhoods, and panoramas using fast rendition software which has enabled us to deliver content across the web in the fastest time possible (Batty and Hudson-Smith, 2001).

We have also begun to explore different digital environments in which this information can be visualized. In parallel to the model construction, one of us (Hudson-Smith, 2003) has explored the way virtual worlds can be adapted to real urban environments. By porting the digital models into such worlds, these worlds, which have largely emerged from the gaming community, can render as if they are the "real world" of interest. In short, the virtual world can be the virtual city but users can interact with each other over the network appearing as avatars in the world in question. Many users from many remote locations can thus interact and engage in design decisions. This focus has been developed as a vehicle for learning the problems of manipulating objects in such worlds but as we demonstrate in our Virtual London project below, we are adapting such media to ways in which the public-at-large can interact and view planning information. In fact, what we show below is how such worlds can be constructed recursively with the virtual city appearing as another world within the world itself; porting the virtual city into a world which is rendered as the same virtual city and placing the model in a context which appears as though it is a material object in that world, in much the same way that it can be manufactured as a real model in the real world.

Many of these techniques of model construction have come together in the public participation project we are involved in for the Woodberry Down Regeneration (Hudson-Smith, Evans, Batty, and Batty, 2003). This project involves the regeneration of a series of public housing estates comprising some 2500 houses and flats in the London Borough of Hackney. This project is typical of many grass-roots community development schemes which now dominate the housing sector in Britain. Public housing developed a generation or more ago, is being regenerated to bring it up to contemporary standards while attempting to stabilize the rootless communities which have emerged within such areas. Public participation is central to this process with a regeneration team located on the site, involved in everything from daily problem solving for tenants to implementing a vision for the new community. The Woodberry Down web site <http://www.hackney.gov.uk/woodberry> which has a more reliable mirror at <http://www.casa.ucl.ac.uk/woodberry>

reflects the online participation that we have developed but this parallels and complements a much wider process of participation based on traditional face-to-face contact, community meetings, and communication using paper-based information. The site is largely devoted to routine concerns over services and housing conditions but woven throughout is visual information about the environment, based on panoramas loadable from zoomable maps. Part of the site is reserved for community design and some experimental 3D manipulation and primitive fly-through of the existing community and four options for the future are available.

This was our first real attempt at bringing the diverse visual content of the local environment together and representing it in a form accessible to a wide public. It has set the scene for our current project in that many of the techniques that we developed for Woodberry Down are being refined for Virtual London. Moreover, we cut our teeth on key issues of public participation in this project and we will return to these after we have described how Virtual London is being constructed. One final point before we launch into a more technical presentation: virtual city modeling has now developed to the point where once a model is built, many different variants can be spun off from it. In our Woodberry Down project, panoramas, zoomable maps, and 3D manipulable design options were all built from the same database. Such different products can thus be tailored to different kinds of software use and GUIs can be built to match the preferences of the intended user groups. Moreover the variants can be adapted to the bandwidth available. As the online population expands and as bandwidth increases, different products are required and this is the basis on which Virtual London has been created.

Constructing Virtual London

Virtual London is a partnership between the Greater London Authority (GLA), ourselves in CASA as the contractors, British Telecom, London Connects and the Corporation of London, under a central government initiative known loosely as "e-Democracy." The general goal of this initiative aims to increase levels of participation by citizens in the democratic process at a local and regional level, and to test the role of advanced technologies in achieving this. The idea is to explore a range of innovative tools which will stimulate participation in democratic processes, an essential component in creating a sense of citizenship. It will examine the role new technology plays in connecting the public-at-large to policymakers, and whether new technology can help engage parts of the community who for social, economic, or cultural reasons do not take part in traditional forms of public consultation. It will develop, experiment with, and evaluate a suite of state-of-the-art e-democracy applications. Evaluation will consider how far the new technology can help improve the quality of decision-making by improving the quality and scope of public debate. Applications developed in the project will be used in physical face-to-face sessions and remotely, via the Internet (with broadband and narrowband versions) to develop understanding of the different combinations of tools and techniques that may best stimulate citizens to participate in democratic processes.

The team has very ambitious aims for the project and the initial phase that we report here is but a beginning. The heart of this first stage is the construction of a high-resolution 3D interactive, photorealistic model of London neighborhoods, beginning with the Corporation area—the City which is the financial quarter, where excellent geometric and geographic data at site specific level is already available. Moreover, the City has had the greatest functional and visual change of any area of the metropolis in that the rate of construction there is greater than anywhere else in the United Kingdom with the turnover of office staff and movement of firms amongst the highest anywhere. This model will pioneer the techniques, which will be extended to other parts of London in due course, but once the model is complete it will be used to develop a variety of web-based environments in which real policy issues can be explored and debated. These will take the form of web-based games relating to a range of live policy issues and will reflect the use of e-democracy tools developed in structured consultation exercises with local authorities and the GLA. The team will be able to evaluate the extent, depth, and quality of participation of citizens generated by different combinations of tools in different physical and Internet-based locations, and it is hoped it will lead to a partnership of e-democracy practitioners in London.

As we have already implied, this project is unusual in that it is a "blue-skies" attempt to push e-democracy forward using ideas developed over the last decade with respect to virtual cities. This practical focus however is the only way in which such a project can be developed for it needs to be *in situ* even though there is considerable risk involved that potential participants will find the technologies strange to use. It is thus designed to test a number of assumptions about the potential of new technology to contribute to democratic renewal, to build collective knowledge about tools that work in terms of e-democracy, to develop a set of software tools for use by other public authorities, and to pioneer a method for building such models in other towns and cities. There have been a number of 2D/3D geometric models of central London, some based on work in groups at UCL as well as companies ranging from architectural consultancies to games developers working on *Playstation 2* and *XBox* consoles. Games such as *Project Gotham* on the *XBox* have brought city modeling to a new level of detail with cities as diverse as Chicago, Florence, Glasgow, Moscow, and London getting the "console treatment." It would be foolish to claim that such models compete with fully functional 3D GIS but they do enter the publics' consciousness and raise the stakes in how such models can be distributed and communicated. As such, the challenge of creating a virtual London, with the aim of effectively getting over to the public a sense of location and place as well as containing embedded geographic information, is enormous. Virtual city models, no matter however detailed, always tend to disappoint in that they do not appear "quite right."Add to this the need to distribute urban information via the Web delivering it effectively and quickly for a range of low-end users, then the challenge becomes even more substantial.

The first stage of our project is based on constructing a 2D map and extruded 3D model that is optimized for Internet-based distribution. The map is

based on detailed aerial photography onto which the geometric content in 3D is built from detailed Ordnance Survey *MasterMap* vector data at scales in the order of 1:250, using height data from several sources, largely LiDAR. The model contains three levels of detail: basic block outlines, photogrammetrically-derived sections, and photorealistic texture mapped areas. Each of these levels is designed to explore the trade-off between geometric fidelity, level of detail, and bandwidth requirements within city modeling over the web. At the general level the model is being created in ESRI's *ArcGIS* (*Version 9.1* with the plug-in *ArcScene*) using LiDAR data with Ordnance Survey *MasterMap* which allows us to extrude buildings to heights which represent the average of the cluster of LiDAR points that define the skeletal shape of the associated roof lines. The basic block model is shown in Figure 1. Deriving reliable height data and roofing shapes from LiDAR is a research project in itself, so this aspect of the model will continue to evolve as new techniques are developed and higher resolution LiDAR data is obtained. Such development routes need to be flexible allowing new versions of the model to be easily imported and exported to the relevant formats. As such the core model is composited in *3D Studio MAX*, thus allowing instances to be loaded and unloaded as and when new information is acquired, while ensuring models load into their geographically correct position.

FIGURE 1

The Basic Geometric Model Built in *ArcScene*

Photorealism is achieved either via texture mapping direct to the model or from the ground up using packages to derive heights and roofing shapes from oblique photography. The low-end solutions such as *Canoma* from Metacreations, which we used in our previous work in Hackney, do allow for quick and easy extraction of textures and models but are not suitable for the detailed constructions required in Virtual London. We are therefore using *ImageModeler* from RealViz which provides a mid- to high-range solutions, and is being used to provide low polygon count models of key buildings from oblique photography. The end result in such situations is often dependent on the quality of the photography, which in our case is provided by Jason Hawkes <http://www.jasonhawkes.com>. Some of this detail has been added to the model, which we show in Figures 2 and 3, where we fly through the model at different levels. This however is not the form in which we intend to distribute the model. The workstations involved in such visualization and animation are too specialist with respect to their graphics cards and memories than are ever likely to be available to the casual user, and in any case, the goal of this project is to make these kinds of models available across the net. As we implied above, virtual city modeling has now moved to the point where we are able to develop many different realizations from the more elaborate GIS database, exploiting different kinds of software, meeting user requirements more effectively, and utilizing available bandwidth.

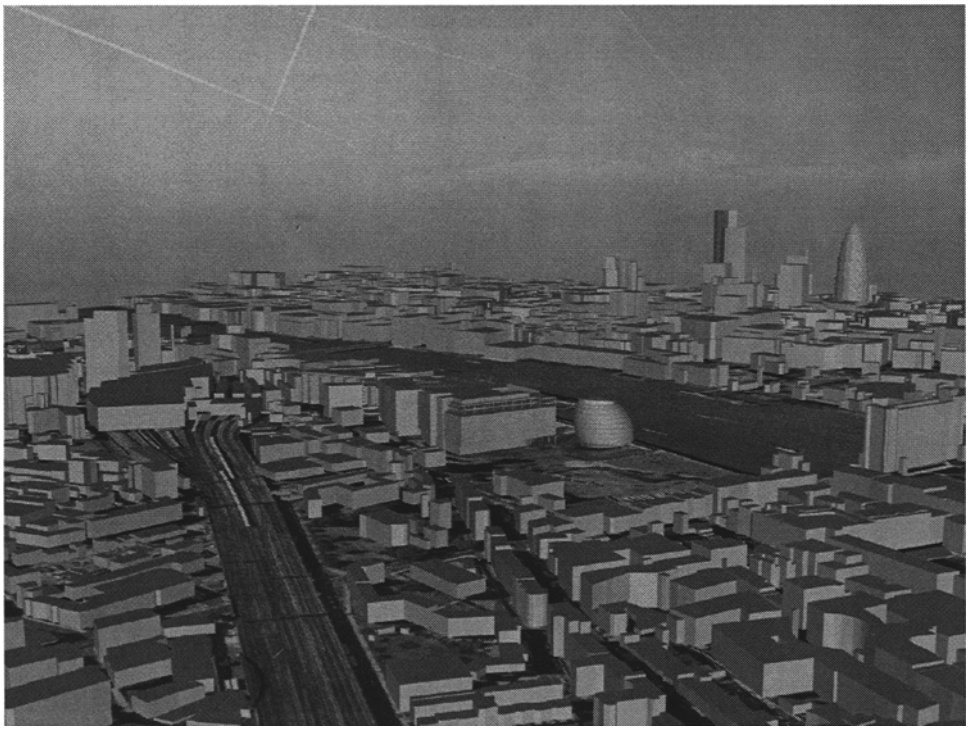
In addition to the 3D model, a series of 180 x 360 degree panoramas are being captured which are then mapped onto a globe allowing users to "step inside" and view panoramas in a true x-y-z space. We developed these initially for the Woodberry Down Regeneration but there are numerous methods for panoramic production from single-shot lenses and proprietary systems such as *IPIX*. We are using a multi-row solution capturing three rows of 12 photographs merged into a single shot using *RealViz Stitcher*. These panoramas provide a quick and easy way to augment the full 3D model as well as

FIGURE 2

The Model with Ground Detail, Roof Lines, and Rendering of Key Buildings Visualized in Viewpoint

FIGURE 3

A Typical Fly-Through across the City with the "GLA HQ," the "Gherkin" and the "Nat West" Tower (Tower 42) Clearly in View



providing a means for checking height data and roof morphology. Although panoramas provide an essentially low-end method of gaining a sense of the city, they are critical in Virtual London for they provide a unique view of the city compared to a purely 3D approach which has dominated earlier versions of such models for other large cities (Batty et al., 2001).

As noted, the 2D element of the work is already aimed at early Internet distribution and it utilizes the Viewpoint product *Zoomview* which we show in Figure 4. The 3D element is however non-optimized in its holding environment of *3D Studio MAX*, resulting in an initial file in excess of 1GB for the basic model and data. File sizes vary according to the format chosen for export and in our case we are using the native Viewpoint format of *.MTX*. Viewpoint has a number of advantages over other options such as *VRML*; firstly it is considerably more compressed than an equivalent *VRML* export file, and secondly it is *XML*-based allowing data integration and modification. Without getting tied down by file size, it is important to ensure the data is suitably compressed for modem-based distribution. With this in mind, the model is further optimized in third-party software, while ensuring its overall integrity. Currently this results in file sizes below 400K. It is still early days but a clear

route has been defined in which we can optimize the model sufficiently to distribute large "chunks" of London across the Internet.

In terms of making use of the model to view and comment on changes in the built environment, the model is animated and distributed as "non-fixed" for full public participation. Animations such as options to insert new skyscrapers are easily added at the production end in *3D Studio MAX* and then exported as a series of "buttons" that are attached to the model. Clicking on these buttons results in the coded animations being triggered, allowing a clear and easy way to compare various development options. These options are then linked to a bulletin board that facilitates discussion of the issues involved. For more open design options, the whole model can be made interactive, allow users to freely rearrange buildings and then "post" set views via the website along with comments.

In addition to the 3D browser-based model, the aim is to port sections of London into a multi-user environment, samples of which we show in Figure 5. This is seen as a key ability to effectively communicate changes in the city. Users are then able to walk around an interlinked gallery as avatars (digital representations of themselves) containing visual, audio, and 3D media. The main draw of using a multi-user environment is its collaborative nature and the ability to communicate with users via either voice or text regardless of physical location. Traditionally cities are visualized at full size, that is, users are able to walk around the streets or fly around the buildings using Virtual Reality but as we note in the next section, this is far too high end and nowhere in sight with respect to its distribution and access across the net. We are taking a different approach by using the model within a gallery environment. This allows various options to be loaded and unloaded depending on the user's choice. Our experience of virtual worlds and the need to limit these to the exploration of planning issues and design options, rather than enabling them to be used as extensive visual chat rooms, as in *AlphaWorld* for example, is based on our experience with engaging users in these kinds of forum (Smith, 2002).

There are a number of multi-user environments available on the Internet that allow users to construct their own worlds. Despite our long-standing experience of such worlds (Schroeder, Huxor, and Smith, 2001), this is still a rapidly emerging field based around companies such as *ActiveWorlds* <http://www.activeworlds.com>, *There* <http://www.there.com>, and Adobe <http://www.adobe.com/atmosphere>. At the present time, we are developing these worlds using Adobe's *Atmosphere* environment due to its close integration with the Viewpoint format, which is the basis for viewing the main model. In addition to this, *Atmosphere* has the ability to be embedded seamlessly in an Acrobat document which removes the user's need for separate plug-ins and allows 2D information to be easily integrated with the 3D. The ability to import models, complete with animations, opens up the ability to hold public meetings in the virtual environment and discuss issues relating to changes in the built environment. In addition, maps will be integrated in each scene by placing *Flash* or *SVG* animations in a similar manner to the way a picture might be hung in a gallery but with the ability to interact in the same way as in a standard 2D web page.

FIGURE 4

The Map Extent (a) and the Detail of Zooming into a Landmark Site (b)

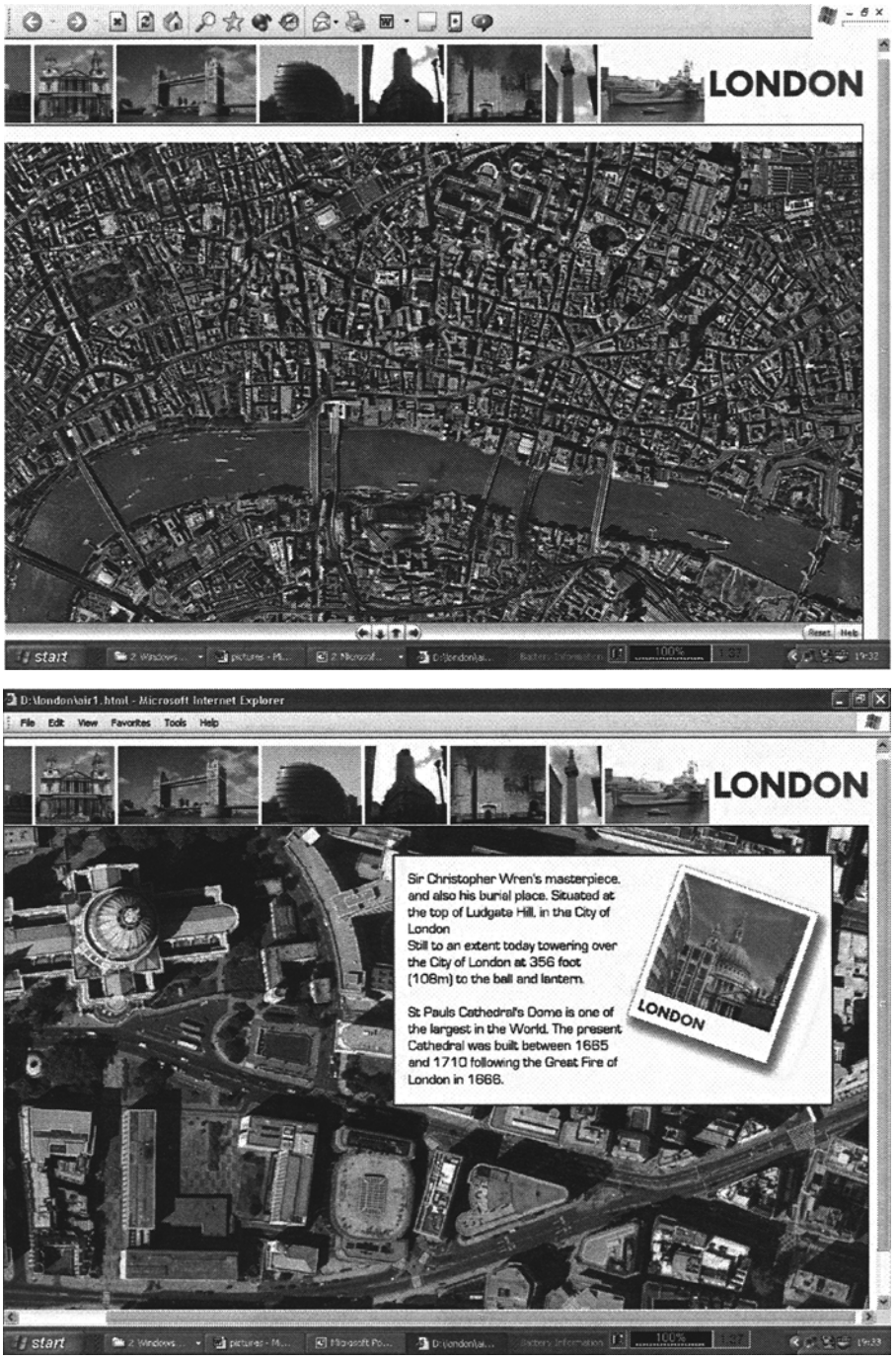
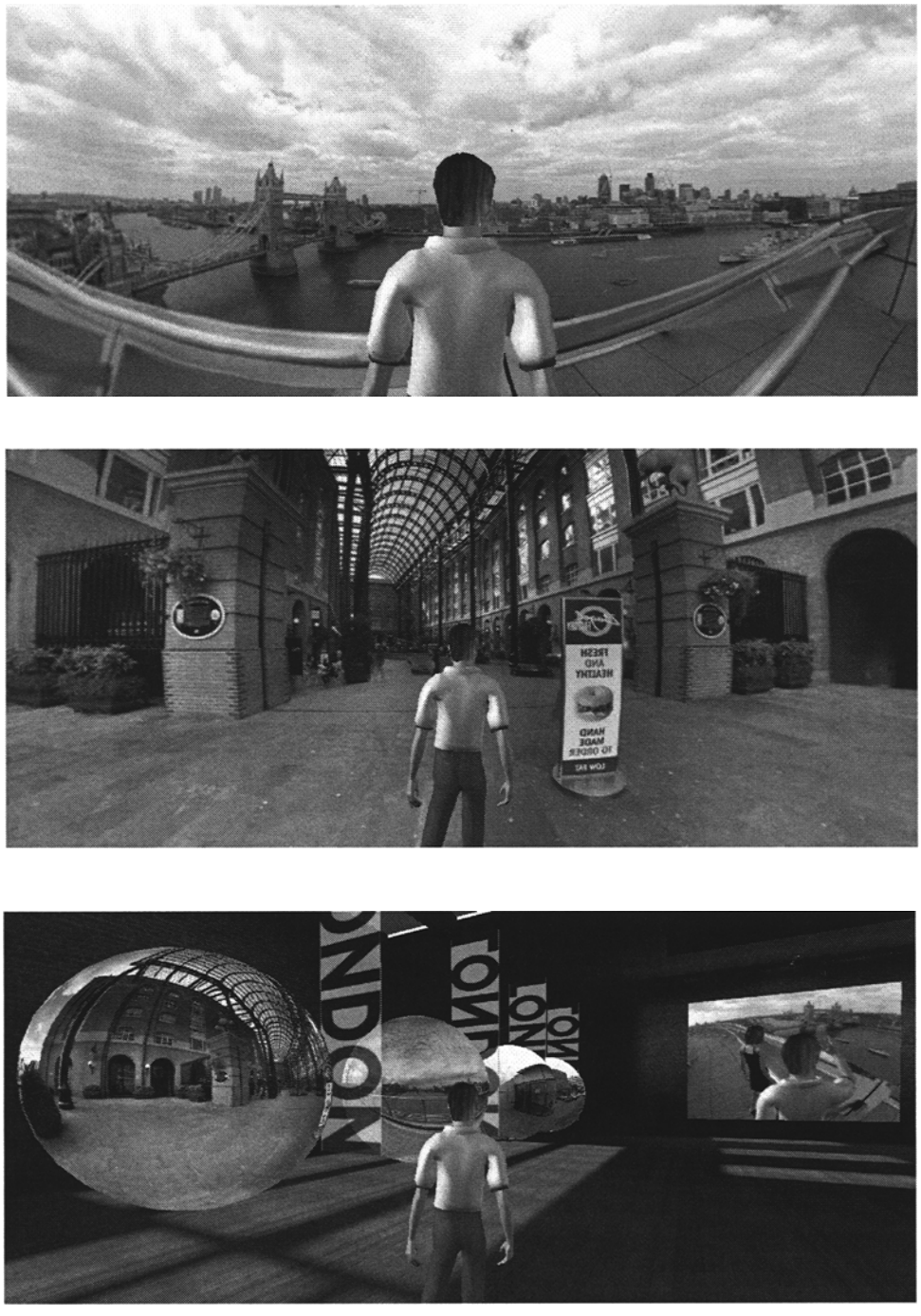


FIGURE 5

Porting the Digital Model and Various Panoramas into a Virtual World



New Media for Display and Dissemination

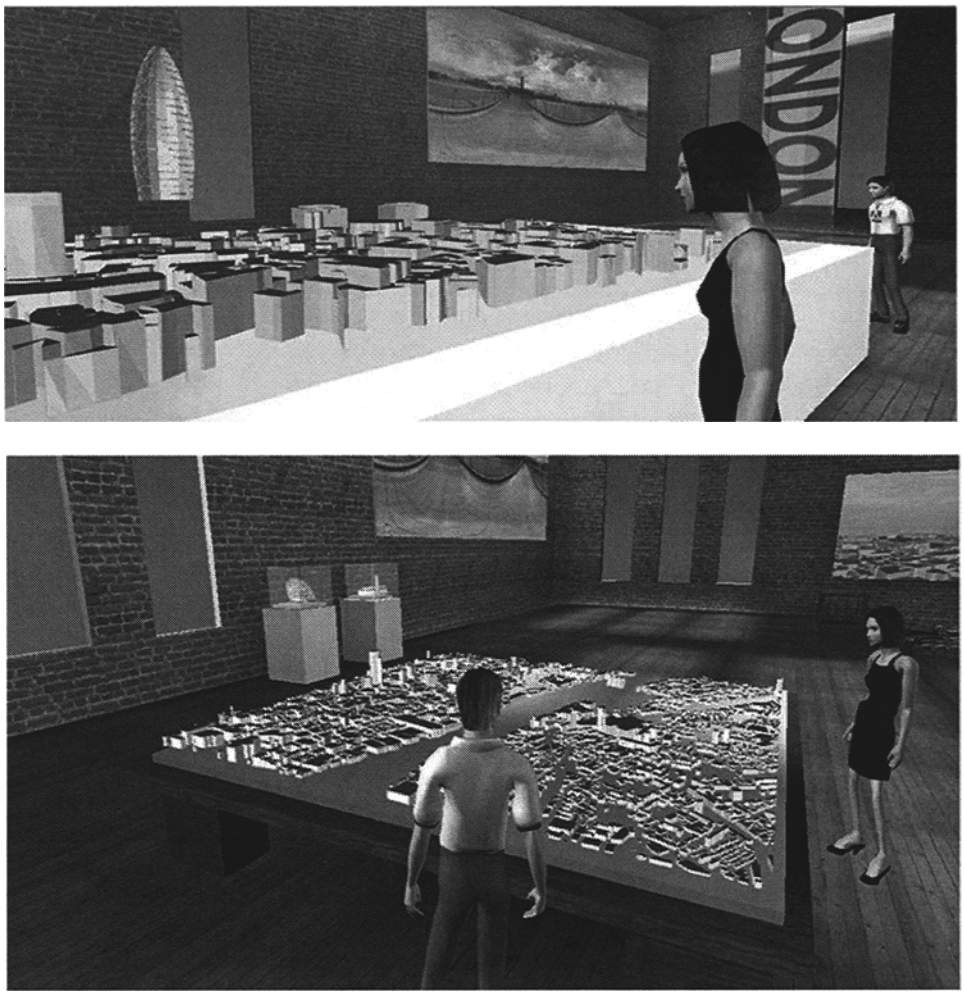
We will indicate how we intend to stitch all this visual material together in a seamless web-enabled interface in the final section but, before we do this, we will digress a little, sketching its implications for the media in which virtual cities might be distributed and utilized. The medium we are working with is, of course, the net that lets us communicate with potentially millions of users. This restricts the level of detail that we can show but it massively enhances the range of communication that is available. The virtual worlds' software based on *Atmosphere* lets us make such a world from the virtual city model itself or make a different world—an exhibition space—where we can place the model as an exhibit. The key advantage is that whatever is in the virtual world is seen from the vantage point of the user as an avatar with the users collectively or individually manipulating the objects that comprise this world.

What we found when we produced our worldwide surveys of virtual cities for the Corporation of London in 2000 (Batty et al., 2001) was that many users and clients were uncomfortable with the new digital media. They wanted some form of tangibility, some link to the material world which is the subject of their interest. The Corporation of London, for example, postponed their decision to acquire virtual city models despite demands by its various departments due to the fact that their material model was regarded as forming an important medium for discussion and negotiation in ways they considered a digital replacement could not. A halfway house is to use the digital model in a context that makes it appear in material form. By producing a simulation of a place where negotiation and discussion of planning information can occur and by putting the digital model into the place as an artifact which can be manipulated by those in that place, a digital rendition of the traditional forum, or "simulacra" in Baudrillard's (1994) terms, can be emulated. We show such a simulation in Figure 6 where we see the *ArcScene* model placed on a virtual table with avatars around it, manipulating the "Gherkin"-shaped building, which is one of the contemporary icons in the City of London. This is a fairly experimental context but our past experience with *AlphaWorld* and our own laboratory version suggests that this way forward is worthwhile.

At the other extreme, it is now possible to produce traditional media from digital. In sense, this is an extremely obvious use of digital technology as contemporary photography now demonstrates. Map-making in fact is one of the major uses of GIS where low cost printers can be used to enable perfect maps to be produced in that one can experiment over and over again adding more and more refinement. The ultimate product of course is still the paper map. So with 3D digital media. Hard copy printers, which print the artifacts in near traditional form, are now increasingly available. We are a long way from producing anything that compares with the Corporation of London's wood and plastic model, for what can be printed from a digital version is small, intricate, and expensive. In Figure 7, we show a section, which has been printed from our Virtual London model, from the 3D file that is used in *ArcScene* and in *3D Studio MAX*. This is a tiny model section and it took two days to print. But it does show what might be possible from such models and it evokes

FIGURE 6

Constructing the Simulacra: The Digital Model as a "Material Artifact" in a Virtual Exhibition Space

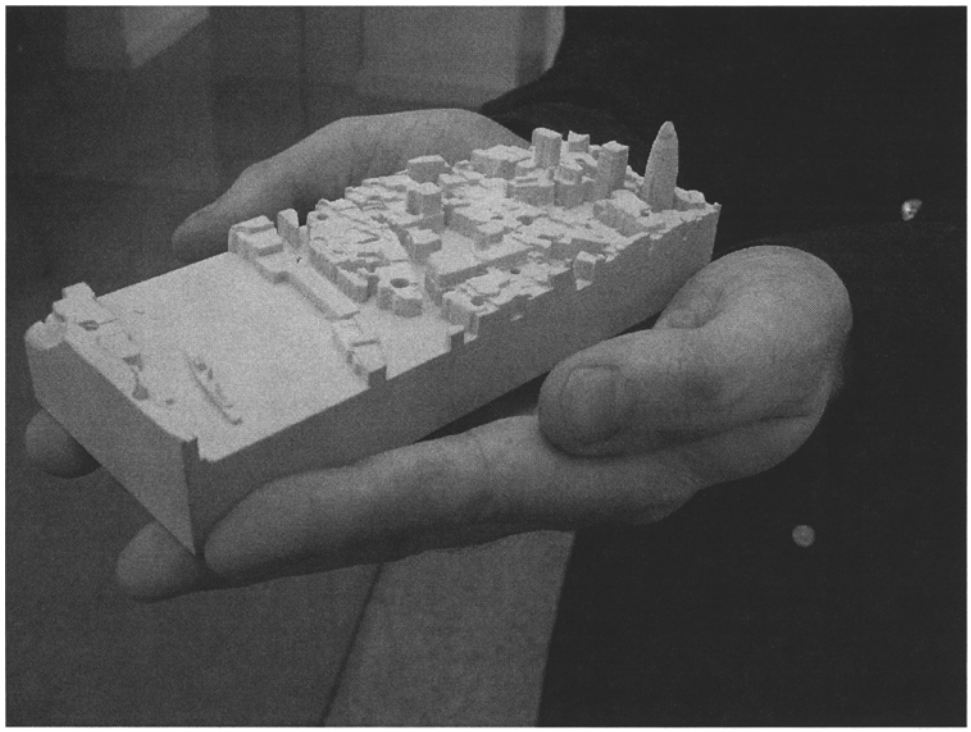


enormous interest when displayed alongside the digital equivalent on the desktop, the web, in a virtual world, and in its traditional material form.

The third kind of media is still digital but takes us into new developments of immersive or augmented reality. Headset technologies have traditionally been used for the user to immerse themselves in some virtual scene, or in an industrial context to display some virtual version of an object that a user might be working on in some kind of eye glass display. These are finding important usage in precision engineering, in surgery, or in working in hostile environments where information needs to be supplied to the user continuously. There are now, however, versions where many users can be immersed in the same

Figure 7

Printing the Virtual City Using CAD/CAM Technology



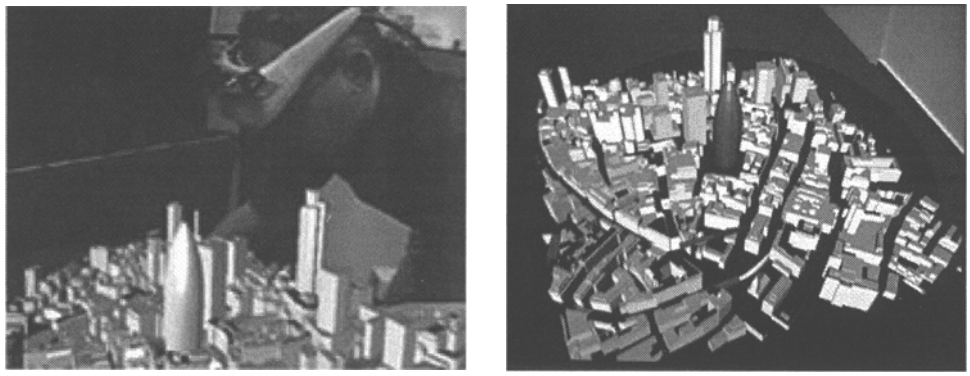
environment. Instead of the user appearing as an avatar, the user views the model in a headset which is coordinated with images on the headsets of other users. Users can still see each other interacting with the model but their interaction is now coordinated. The *ARTHUR* project (*A*ugmented *R*ound *T*able for arc*H*itecture and *UR*ban Planning) has developed new kinds of wireless headsets for this purpose, and as their key example is the City of London with one of the key manipulations the positioning of the "Gherkin" building, we show this example in Figure 8. This is yet another media in which these kinds of virtual city can be used. We could add more—the CAVE, the VR Theatre, various kinds of holographic display but the point is made. The media or the use of several media to display planning information is all-important to the process.

Using Virtual London

The biggest problem in building virtual cities is enabling potential users—professional users such as planners and architects, or wider public interest groups and the public-at-large—to relate to the content in the most effective way. Although there is a digital divide, in that there are groups that do not have access to networked computers, the level of penetration in western soci-

FIGURE 8

The Arthur Interface: Viewing the Virtual City in a Multi-User Wireless Headset Fully Immersive Environment



Source: <http://www.fit.fraunhofer.de/projekte/arthur/index_en.xml>)

eties is now very high, approaching in London for example the level of telephone penetration some 40 years ago. Over 50 percent of households now have access to the Internet and half of these have access to broadband (GLA, 2003). This is not to say that the unconnected 50 percent should be ignored, but at any point, it is more likely the way planning information is distributed over the net than access *per se* will determine the usage of this new medium. In the longer term as more and more people get connected, different digital models will be possible reflecting the preferences, interests, sensitivities and ideologies of different users, and it is even possible that the models will be constructed on-the-fly as users indicate their requirements when they log on, in much the same way that desktop software used routinely is beginning to configure itself to the user's keyboard behavior.

The way we intend to stitch this digital media together through the web will be organized in three forms. An overall web interface will guide navigation through the site to three different areas. These are based on a *navigable map* which in itself represents a map of the web site as well as a map of the city, the *virtual city* itself through conventional geometric interaction based on fly-throughs, panning, zooming, and manipulation of objects in the virtual scene, and *the virtual room* which we refer to as a "virtual planning observatory." This incorporates all the features of the virtual world in that users are able to interact with the virtual city as laid out in table form (see Figure 6) as well as visualizing different scenes from the existing and future city. At a series of key locations within each of these areas, a user will be able to navigate to one of the other virtualities, thus enabling these three different perspectives on the virtual city to be fully integrated. We will now deal with each of these in turn.

The map-based interface which we show in Figure 4, is zoomable and pannable and the various landmarks which are positioned along the top represent a "film strip" that eventually can be pulled across the screen locating

many key features of the city. Point and click on these and the user is taken to the place in question as we show in Figure 4(b) where information is displayed about the place. This is a kind of virtual tourism and the usual hotlinks to associated web sites are embedded in the interface. We also plan to let users enter the virtual city or virtual room at points within this map (and within the virtual room or virtual city), presenting a choice of media in which to interact with planning proposals. In the first instance, our focus is on individual changes to the city, in particular on the impact of high buildings, of preservation and conservation, and of proposals for transport, and various forms of spatial taxation such as congestion charging. We also envisage that the interface would act as a showplace for the City in attracting inward investment for the basic 3D GIS model will contain all kinds of site-related information that can be displayed using the usual form of spatial querying. We intend for this functionality to be somewhat separate from the main site for it indicates that ultimately the virtual city would enable not only lay but also special interest groups such as developers and business interests to use the system.

The navigable map will also enable various panoramas to be called up at different locations, associated with entries into the virtual city which we intend to be largely based on abstractions and simplifications from the full 3D model. As in Woodberry Down, we will produce movies and enable pre-determined options for new developments to be loaded and manipulated, and in some cases we will let the user move key landmarks. All of this will be pre-planned. Moreover, as the site is meant to be active in real time, this function will require constant attention in that there needs to be continual interaction between professional planners and policy makers and the web site designers in enabling appropriate content to be put on the site. The virtual city interface will also parallel the virtual room. So far, the web site is only navigable by a single user but the virtual room enables any user who is logged on individually to enter a forum where they can talk with others, and engage various forms of interaction such as discussion of design proposals. In Figures 6(a) and (b), we show the virtual room with the city laid out on a table and an avatar moving the position of the 'Gherkin'. This is typical of the interaction that is possible in this part of the site. The virtual room is also full of related media in that the user can point to areas of the model and load panoramas which will display in the "allegorical" windows of the room.

As yet we have not explored how we script this web site for we are still developing the media, but we will need to be very careful with respect to how users interact with it and each other. It may be necessary for collections of users to "book" the virtual room in advance if certain design possibilities are to be explored collectively. Moreover, this introduces the idea that for this kind of e-participation to be most effective, it may need to be paralleled with more conventional forms of participation. We have already noted that providing users with the virtual city (Figures 1 to 3), the navigable map and its panoramas (Figure 4), its tangible model equivalents (Figure 7), the virtual room (Figures 5 and 6), and headset interaction with the model (Figure 8) all provide different perspectives on virtuality which deliver diverse information in different ways. We will focus on such issues in the next stage of develop-

ment once we begin the process of integrating the different media but, suffice it to say, that we need to develop different strategies for such stitching. It is entirely possible that we will consider different types of web site that can be called up by the user from a master site which determines a palette of web interfaces most appropriate to the user, groups of users, problem or purpose of the interaction in question.

All this is under intense development at the present time. What we have shown here is how virtual city concepts which remained somewhat flat and superficial when they were first proposed a generation or so ago, are coming alive in many different ways. The focus is no longer on getting the geometry right and building a single virtual city but on developing many different variants which can be tailored to various purposes and delivered to a diversity of users in different ways using different media. The challenge is to devise ways of making such delivery both effective and relevant: to develop virtual cities in which the preferences and abilities of the users with respect to their interests in the problem in hand, can best be augmented through these virtual realities.

Acknowledgments

The authors wish to thank Alex Bax and the GLA for support and advice concerning this project. All opinions are solely those of the authors.

References

Arnstein, S.R. (1969). "A Ladder of Citizen Participation," *Journal of the American Institute of Planners, 35*, 216-224.

Batty, M., Chapman, D., Evans, S., Haklay, M., Kueppers, S., Shiode, N., Smith, A., and Torrens, P. (2001). "Visualizing the City: Communicating Urban Design to Planners and Decision-Makers, in R. Brail and R. Klosterman (Eds.), *Planning Support Systems: Integrating Geographic Information Systems, Models, and Visualization Tools*, ESRI Press, Redlands, CA, 405-443.

Batty, M., Dodge, M., Doyle, S., and Smith, A. (1998). Modelling Virtual Environments, in P.A. Longley, S. Brooks, R. McDonnell, and B. Macmillan (Eds.), *Geocomputation: A Primer*, John Wiley and Sons, Chichester, UK, 139-161.

Batty, M., and Hudson-Smith, A. (2001). Virtuality and Cities: Definitions, Geographies, Designs, in P.F. Fisher, and D.B. Unwin (Eds.), *Virtual Reality in Geography*, Taylor and Francis, London, 270-291.

Baudrillard, J. (1994). *Simulacra and Simulation*, University of Michigan Press, Ann Arbor, MI.

Calvino, I. (1974). *Invisible Cities*, Harcourt Brace and Company, San Diego, CA.

Dutton, W.H., Blumler, J.G., and Kraemer, K.L. (1987). *Wired Cities: Shaping the Future of Communications*, G. K. Hall, Boston, MA.

GLA. (2003). *Londoners On-Line: An Analysis of Levels of Home Internet Access from the London Household Survey 2002,* Greater London Authority, Queens Walk, London.

Graham, S. (2004). *The Cybercities Reader*, Routledge, London.

Hudson-Smith, A. (2003). *Digitally Distributed Urban Environments: The Prospects for Online Planning*, unpublished Ph.D. thesis, University of London, London.

Hudson-Smith, A., Evans, S., Batty, M., and Batty, S. (2003) "Experiments in Web-Based GIS," in P.A. Longley and M. Batty (Eds.), *Advanced Spatial Analysis: The CASA Book of GIS*, ESRI Press, Redlands, CA, 369-390.

Kingston, R. (2002). "Web-Based PPGIS in the United Kingdom," in W.J. Craig, T.M. Harris, and D. Weiner (Eds.) *Community Participation and Geographic Information Systems*, Taylor and Francis, London, 101-112.

MHLG. (1969). *People and Planning*, Report of the Committee on Public Participation in Planning (The Skeffington Report), Ministry of Housing and Local Government (MHLG), HMSO, London.

Negroponte, N. (1973). *The Architecture Machine*, MIT Press, Cambridge, MA.

OED. (1974). *The Concise Oxford Dictionary*, Oxford University Press, Oxford, UK.

Schroeder, R., Huxor, A., and Smith, A. (2001). "ActiveWorlds: Geography and Social Interaction in Virtual Reality," *Futures, 33*, 569-587.

Shiffer, M.J. (2001). "Spatial Multimedia for Planning Support," in R. Brail and R. Klosterman (Eds.), *Planning Support Systems: Integrating Geographic Information Systems, Models, and Visualization Tools*, ESRI Press, Redlands, CA, 361-385.

Smith, A. (2002) 30 Days in ActiveWorlds: "Community, Design and Terrorism in a Virtual World," in R. Shroeder (Ed.), *The Social Life of Avatars: Presence and Interaction in Shared Virtual Environments*, Springer, Berlin, 77-89.

Thrift, N. and French, S. (2002). The Automatic Production of Space, *Transactions of the Institute of British Geographers, NS 27*, 309-335.