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INFORMATION RICH 3D COMPUTER MODELING OF URBAN ENVIRONMENTS

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ABSTRACT

We are living in an increasingly information rich society. Geographical Information Systems now allow us to precisely tag information to specific features, objects and locations. The Internet is enabling much of this information to be accessed by a whole spectrum of users. At CASA we are attempting to push this technology towards a three-dimensional GIS, that works across the Internet and can represent significant chunks of a large city. We believe that the range of possible uses for such technology is diverse, although we feel that urban planning is an area that can benefit greatly. An opportunity to push this "planning technology" arose when CASA won a tender from Hackney Council to develop a dynamic website for community participation in the process of regenerating the Woodberry Down Estate. This is a run down part of northeast London that is undergoing a major redevelopment. CASA has developed a system that not only informs the local residents about the redevelopment process but it also enables them to use dynamic visualisations of the "before and after effects" of different plans, and then to discuss and vote on the variety of options.

1. Introduction

Geographical Information Systems (GIS) have, over the last three decades, revolutionised the way that spatial data is generated stored, analysed and disseminated. This information helps us to manage what we know, by making it easy to organise and store, access and retrieve, manipulate and synthesize and apply to the solution of problems (Longley et al 2001). However, this 'technology' is of little use if it is only available to those with the technical expertise or the relevant software. Access to GIS needs to be easy and widespread and this is becoming increasingly possible through Internet based technologies. This way, GIS is no longer only reserved for the technical experts or those with the relevant software. While the Internet does not change the fundamental nature of GIS (Harder, 1998), it does open the technology to an infinitely wider audience. Home users are increasingly exploiting GIS to plan a journey to work or locate the nearest cash-point. In many cases people are exploiting this software without even realising they are using GIS.

However, despite the fact that it is possible to 'tag' information to individual 'building footprints' the uptake of this technology by the housing market, property market and the planning process has been relatively slow. In terms of the uptake of GIS by councils, a recent report by the Royal Town Planning Institute (RTPI) outlined that only 56% have a fully operational GIS (RTPI 2000).

As the use of GIS technology becomes increasingly widespread and more accessible to home users, it is inevitable that its role in the planning process and the property market will increase. However, the use of the GIS as a 2-d method for representing buildings and urban areas is flawed since it is ignoring a large extent of the urban landscape (the 3rd dimension). Furthermore, if the system is used to make decisions which impact on the surrounding area these should take into account the area in it's full spatial extent (i.e. with height and shape). If several addresses share the same building footprint, as is the case with a block of flats, or a tall building with different companies occupying offices on different floors, it should be possible to visualise this information without confusion. Although this is possible with some Computer Aided Design packages (CAD), like GIS these are only within the reach of the technical experts or those who can afford the relevant software. Information can be (and often is) tagged to the geometry of these models, but it is rare that they are fully integrated with GIS derived data.

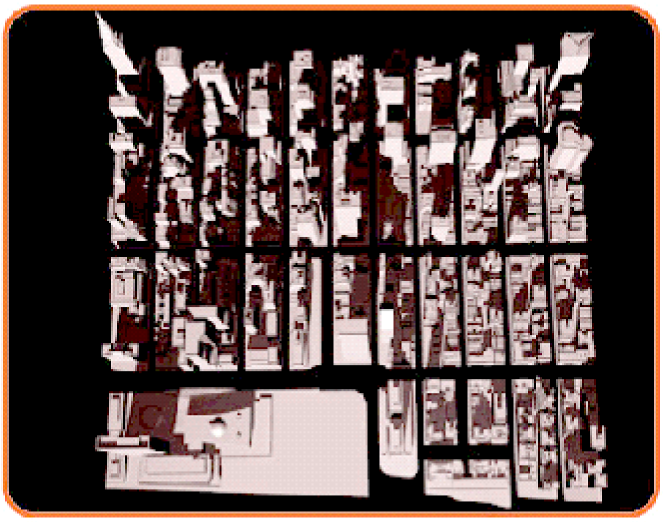

Figure 1. CAD based block model of part of New York City with shadow analysis. (image courtesy of Urban Data Solutions)

These limitations often mean that these models are not much more than the digital form of the architect's block model (see figure 1), traditionally made of balsa wood (Batty et al 2000). It is only if this spatial data and associated information can be taken one stage further and visualised in a 3d environment by home users, that we can offer a system that may be appealing to architects and urban planners alike (see figure 2).

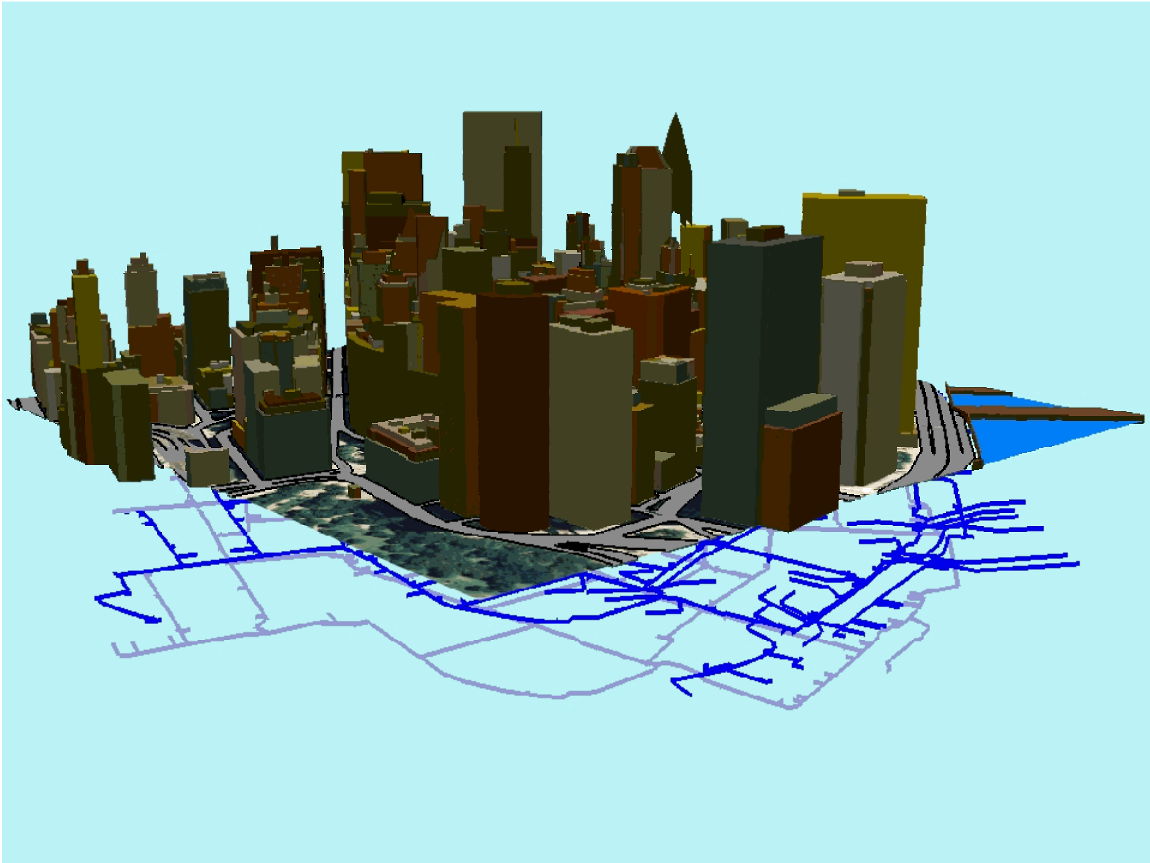

Figure 2. A sample section of a pilot project for Lower Manhattan. This is photogrammetrically derived 3d-GIS of New York City complete with the sewage system represented underneath the city. (image courtesy of ASI-Technologies)

2. Different modeling techniques for putting the 3d into web-based GIS

Over the past few years, researchers at CASA have explored a variety of different methods and techniques that enable us to send three-dimensional visualisations of cities across the Internet. One quick solution to delivering three-dimensional information about an area is to use 'Panoramic' images. Although panoramic visualisation is not three dimensional, it can rapidly give the user the feel of what it would be like to stand on a particular location and look around. Panoramas consist of a series of photographs or computer rendered views stitched together to create a seamless image (figure 3). Rigg, 1998, defines a panorama as an unusually wide picture that shows at least as much width-ways as the eye is capable of seeing, if not a greater left-to-right view than we can see (i.e. it shows behind you as well as in front). Figure 4 illustrates a sample 360° panoramic image of Piccadilly Circus in Central London.

Figure 3. The creation of a panoramic image

Figure 4. Panoramic Image of Piccadilly Circus (image courtesy of Plannet Visualisations Ltd www.plannet.co.uk)

Although panoramic images are two dimensional, as they are constructed from a series of photographs, the effect is considerable realism (Cohen, 2000). Panoramic images are not a new concept brought about by the rise of the digital age, indeed they have been made since the 1840's with the introduction of the first dedicated panoramic cameras. However, it was not until 1994 and the introduction of QuickTime Virtual Reality (QTVR) for the Apple Macintosh that panoramic production, from the stitching of a number of photographs, became available on consumer computers for the first time. QTVR works by taking a sequence of overlapping images and automatically aligning and blending them together to create a seamless panorama. The resulting picture is a photorealistic capture of a scene taken over the time required to capture the images, typically between 30 seconds and two minutes. Panoramas are viewed online via either a 'plugin' or Java applet. The viewer renders a section of scene allowing the user to pan and zoom the panorama using a combination of the mouse and keyboard. Each single panorama is defined as a node, and 'hot-linking' between a series of panoramas creates a multi nodal tour.

Providing that the location where the panorama was taken can be georeferenced, these images can then be cross-referenced back to a GIS. The location where these panoramas were captured can then be added as a point location on the map. The user can browse to a location on the map, observe that there is a panorama captured, say on a street corner, and trigger the panorama for more of an 'interactive experience' of that particular location (see figure 5). It is now becoming possible to develop a 'tight coupling' between the GIS and the panorama where by the direction that you look in the panorama is shown by a small arrow in the GIS. As you rotate the panorama, the arrow rotates to represent your new viewing direction. It is also possible to label elements within the panorama, such as buildings, streets and objects, which allows for a more information rich experience.

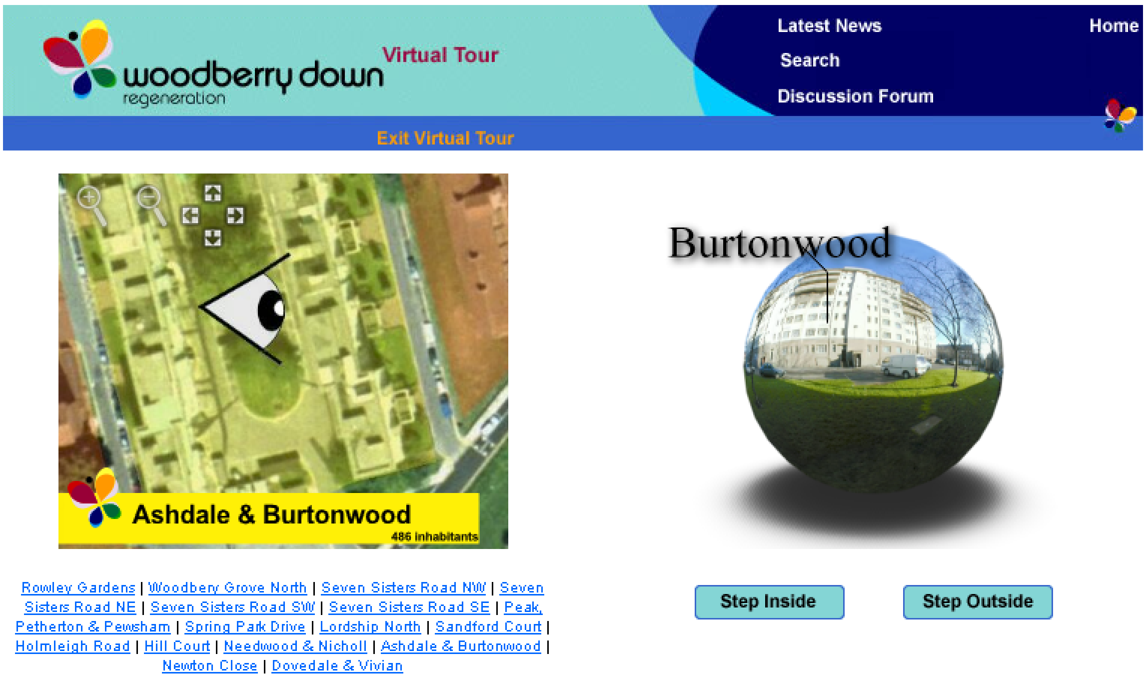

Figure 5. Coupling GIS and panoramic visualisation. The image on the left is the interactive map with the 'eye' icon representing the location the panorama was generated from. The image to the right shows the interactive

panorama of the Burtonwood block of flats. The block is labeled within the panorama and the 'Step Inside' button can be used to view the panorama 'immersively'.

For the production of full three-dimensional models of the existing built environment there are three critical factors - building footprints, roof morphology and height data. It is the combination of these factors that allows the creation of realistic models. Building footprints are widely available in the UK, most commonly in the form of landline data from the Ordnance Survey. The data is however expensive and licences prohibit extensive use over the Internet.

Average height data can be purchased 'off the shelf' from mapping companies such as the GeoInformation Group. This data provides the average height according to building footprints, but this data is too generalised to provide a convincing three-dimensional model of a detailed city.

Another approach is to generate data using photogrammetric techniques. The resulting x, y and z data can be used to generate a wire frame model within a CAD package or a GIS. This approach is illustrated in figure 2 where a detailed model of part of New York City was generated as a by-product from the generation of a highly detailed orthophoto of the city. This model, although fully integrated with other GIS data (such as sewage pipes as shown in figure 2) is designed to function on a high end system and as yet cannot be accessed via the Internet. The relatively high costs of developing a photogrammetric model of a detailed urban area is also a limiting factor to adopting this technique.

Comprehensive height data can be obtained, en masse, from range imaging methods, the most widely used being Light Detection and Ranging (LiDAR). LiDAR provides a high-resolution three-dimensional surface, which can be imported into a GIS and draped with an aerial photograph and the effect can be quite convincing, (see figure 6).

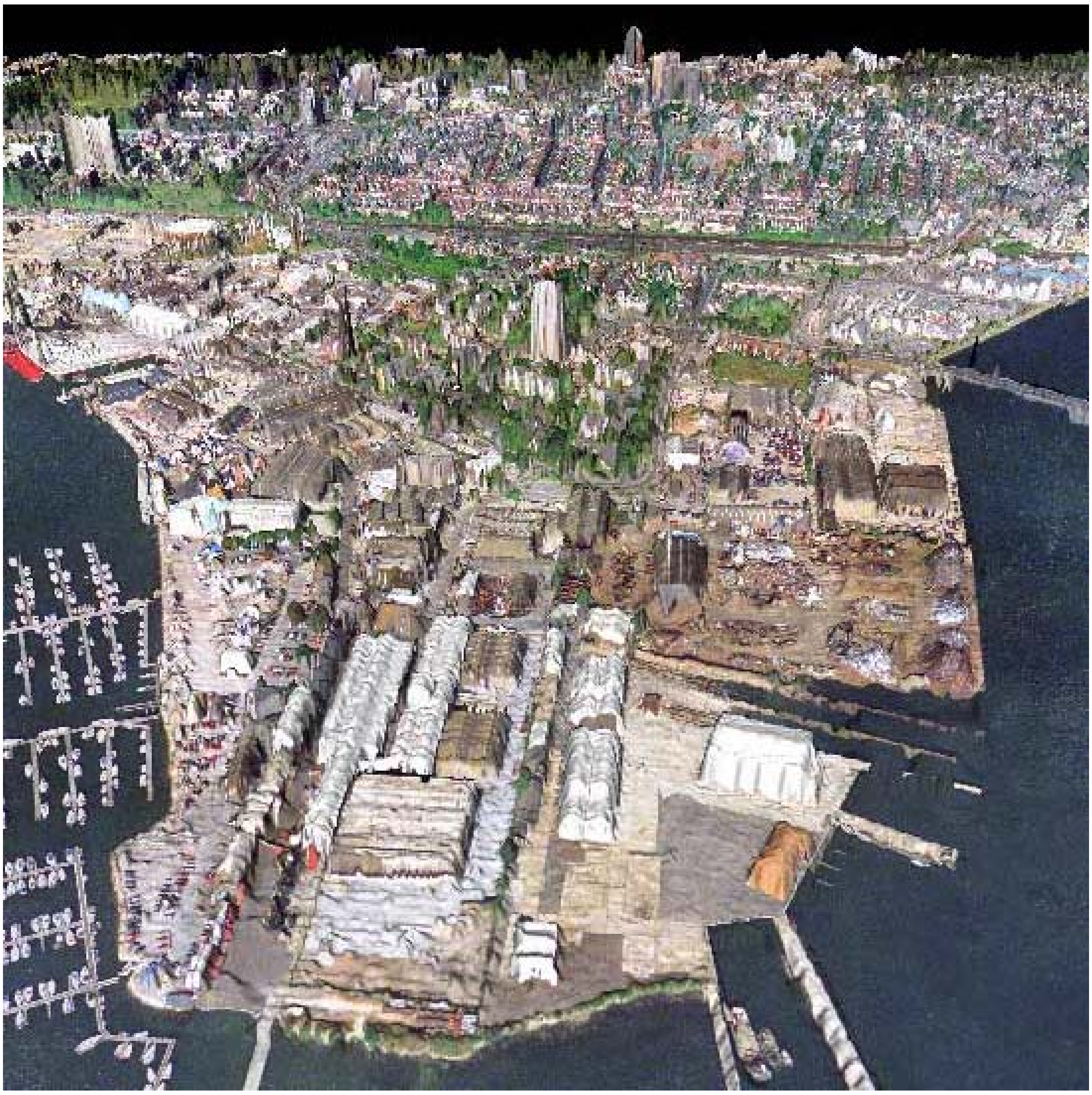

Image © Environment Agency 2001

Figure 6. LiDAR-Based City model (courtesy of Ordnance Survey © Crown copyright 2001)

However, the LiDAR data poses exactly the opposite problem compared to average building height, since it represents point heights for every few centimetres. Without extensive post processing of the data, it can result in very 'spiky' models that can sometimes bear little resemblance to the building they represent (see figure 7). The data can also carry a certain amount of noise since it will record all objects in the area it passes over, including trees, scaffolding and buses. The model generated is in fact a 'continuous surface' and hence individual objects such as buildings cannot be queried and moved interactively (unless a great deal of further processing is carried out on the data). Three-dimensional models generated this way also tend to have a very large 'polygon count' which can prove difficult to optimise. As such they are not suitable for use by home users who download data using a telephone line since they would take far to long to download and the model would be slow to navigate around.

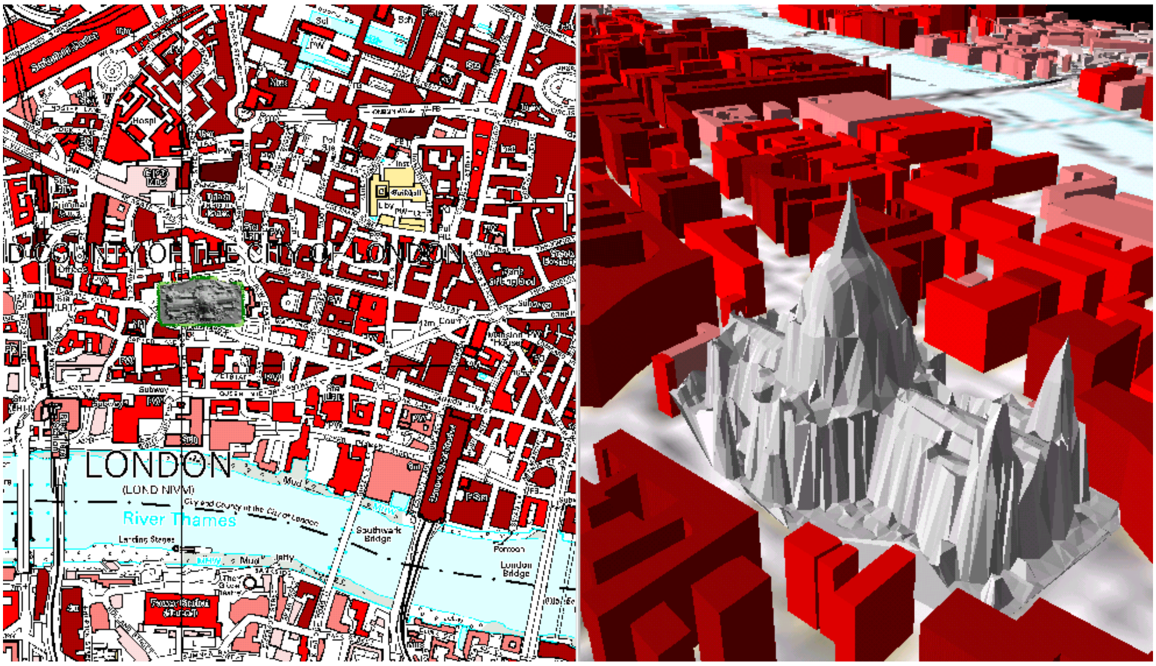

Figure 7. St. Pauls cathedral modeled using LiDAR data

In light of experiments and experience using all of the modelling techniques outlined above, researchers at CASA have adopted a different approach to the problem. We have tried to integrate some of the techniques applied by the computer gaming market using a combination of different software packages. The result has been that we can derive building shape (including roof shape), with a relatively low polygon count and these ‘low bandwidth friendly’ models can be streamed across the Internet to a home user with a 56K modem. The models we have generated are photorealistic since we ‘recycle’ the photos that we use to derive the geometry, and then use them to ‘texture’ the model. The model can be divided up into individual objects that can match building footprints or even smaller objects. Information can be tagged to individual blocks or objects and this can be coupled back to a related database. The individual objects can be made to be non-fixed if the user wishes and hence we can rapidly create moveable chunks of a city (as shown in figure 8). This way, different scenarios can be viewed, for example what a region would look like if one building were moved out and another one took its place. One of the benefits of exploiting technology aimed primarily at the computer games market is that we can generate applications that can be navigated interactively using standard home based computers. This can be fun, informative and can even be developed as a multi-user environment, where the user is represented as an ‘Avatar’ roaming the streets and meeting other ‘Avatars’.

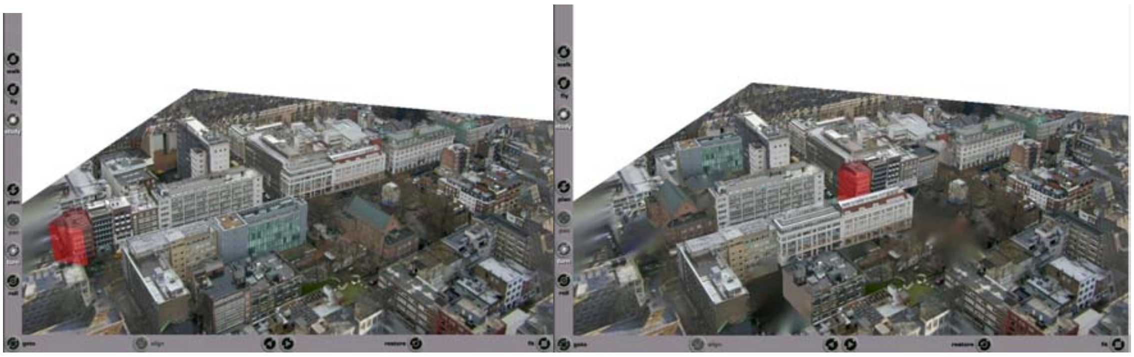

Figure 8. An interactive model of the Tottenham Court Road region of London. The building highlighted in red can be moved from one location to another.

However, one of the major disadvantages is that this approach can often be seen as being too much like a computer 'game' to be considered as an application with a business focus, despite its obvious applications within the planning process. A downside with the approach we adopt to generating the model in the first place is that although it is rapid, it is a manual process, and thus prone to operator error. It also means that developing models of large cities is time consuming and hence our approach has been limited to areas of approximately 2km x 2km.

3. Woodberry Down Regeneration

An opportunity arose to develop a fully functioning system when CASA won a contract to develop a website for Hackney Council. The website needed to provide detailed information to the local residents within a small sub-region of Hackney, called Woodberry Down. This region, which borders Finsbury Park in northeast London is approximately 2 km by 1km, and is one of the most deprived areas in London. The building stock in the area is in a poor state and in urgent need to structural overhaul or even complete demolition and renewal. The area will see the demolition of 2500 homes with the re-housing of 6000 residents, to be accomplished over the next 10 to 15 years using funds from a Single Regeneration Budget and from a Private Finance Initiative. The local residents are fully involved in the process with elected representatives for each of the 30 or so blocks that cover the area. They have provided input in the website development process and from the outset expressed an interest in a system that could enable the local community to learn about their local environment and to participate in the redevelopment process. On top of this they needed to be able to view, comment on and vote on various architects plans and drawings in an easy to understand format. Due to the large amount of redevelopment work planned, the approach also needed to provide a 'historical representation' of the area as a by-product for future generations.

Our approach at CASA has been to develop a range of software that enables the local residents to examine planning information in three-dimensions and to comment on the various options via the website. Aside from the 3d-information system, the website provides a wealth of information about the redevelopment process itself. This includes 'jargon busting' pages which attempt to explain any complex terminology, information about scheduled community meetings to discuss the future plans, historical information about the region and an outline of the planning process. There is also an online discussion forum or chat board. This is an area where users can leave comments, ask questions and suggest solutions. This is particularly important since it makes the website a two-way system that not only provides information but also receives information.

By accessing the 'Virtual Tour' section of the website, the user can explore the region interactively. An interactive map allows the user to zoom into and 'swoop' over the region. They can also locate a particular block of flats or group of buildings and retrieve relevant information about them. This includes what is planned for the next 12 months for that area, who their local representative is and a selection of suggestions about how to improve the area. Panoramic images have been captured for much of the area and these can be viewed alongside the interactive map as shown in figure 5. Individual regions also have three-dimensional models of the buildings, placed upon an orthophoto of that area. These download in small 'streamed' data chunks and allow the user to view selected regions (see figure 9). A series of option buttons allow the user to view the area as it is now, and how it would look with a range of different buildings replacing those that currently exist. Clicking on these option buttons results in any buildings that are due for demolition being removed and any of the new buildings proposed for the site moving in. The model can then be viewed interactively once more. Currently, any comments about the different options have to be posted via the online discussion forum, although we intend to implement a 'ballot box' that allows the user to vote on the option that they prefer the most. It will also be possible to leave comments that are specific to each option displayed. Currently the 'swapping' of buildings is a fixed process that we have 'animated' for the purposes required. However, we are currently developing a version that allows the user to pick up individual buildings and 'drag' them into a preferred location. This will allow the user to interact fully with the model and to generate a preferred layout of buildings. Further developments will make it possible for an architect or a developer to 'upload' a CAD model to the site and view what their design might look like in the context of the surrounding urban landscape.

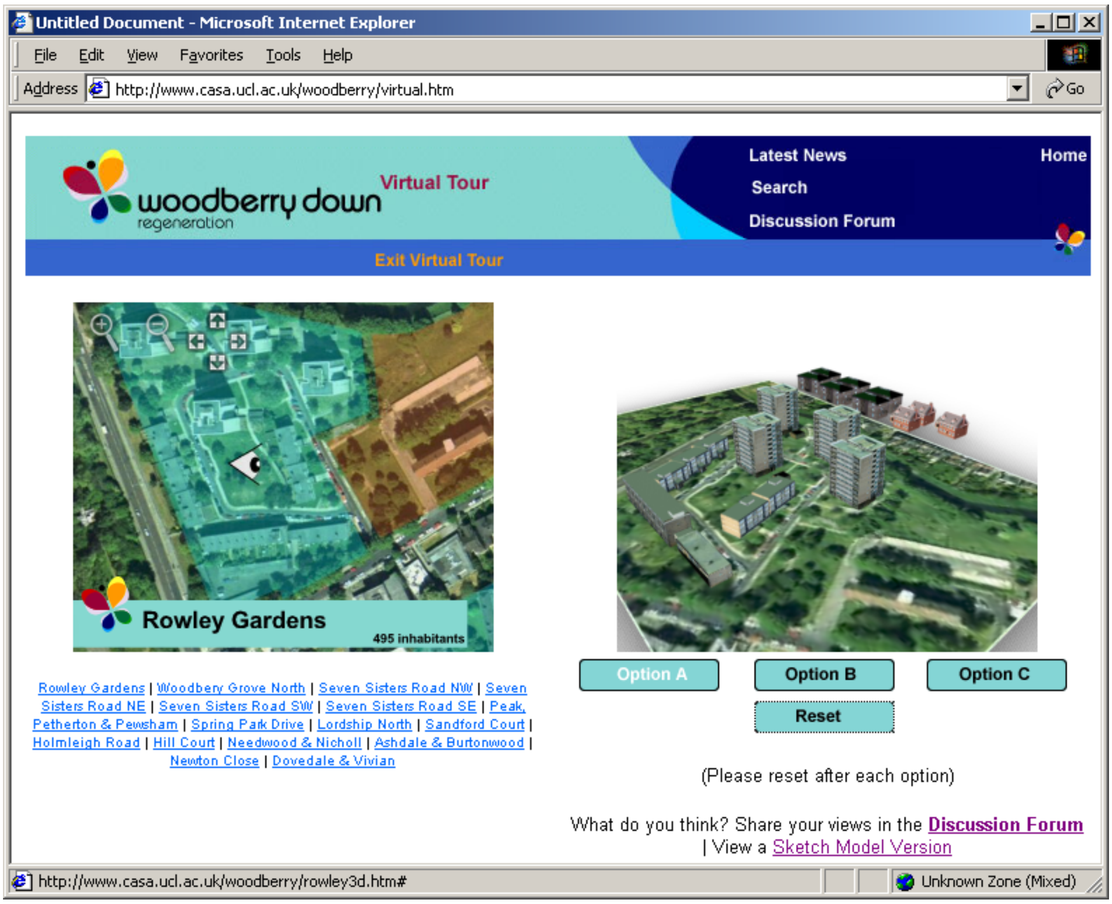

Figure 9. The Virtual tour with the 3-dimensional model of Rowley Gardens shown in the right hand side of the frame.

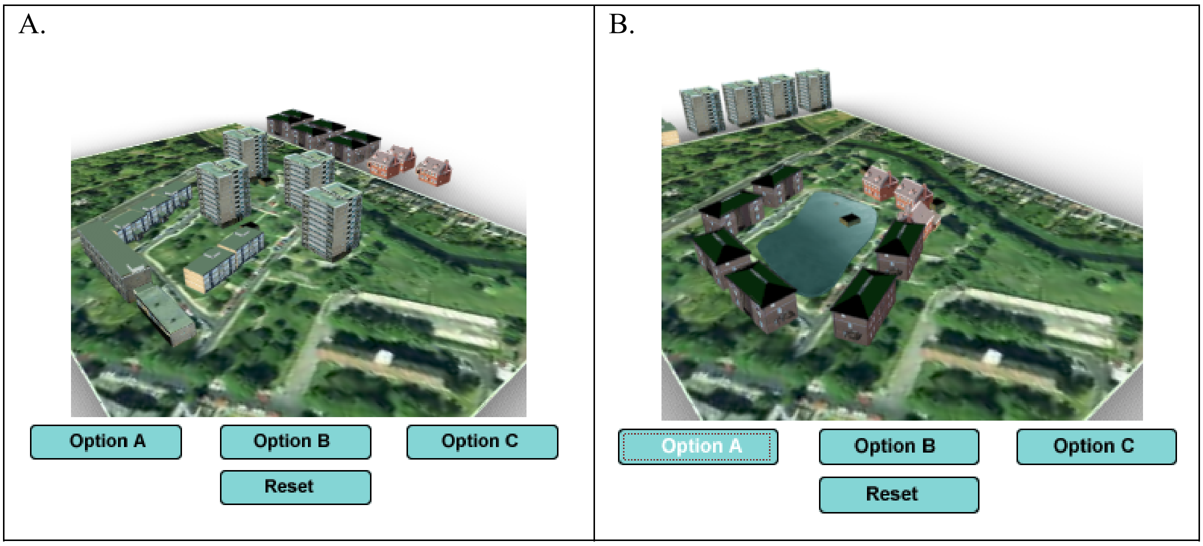

Figure 10. A. Shows the Rowley gardens as it currently is. B. shows option A with the blocks of flats removed and the new buildings in place

Finally, it is also feasible to run the Woodberry Down project on hand held devices, such as Palm Pilots, while maintaining the required level of interaction. GIS, in the form of ArcPad, can be linked with both panoramic images and 3d models optimised to run on either Windows CE or Palm operating systems, leading the way to portable on-site visualisation and communication.

Conclusions

We are living in an increasingly information rich society. GIS and spatial data related to urban regions will increasingly need to represent these complex environments using three-dimensional visualisations. We consider that within a generation, the singly largest use of 'new information technology' in planning will no longer be in an exclusively professional context such as in preparing development plans or in development control. It will be in educating the wider community in planning matters and in engaging the community through planning information and participation in the design process. There are a number of different techniques that can be used to model urban environments, but these may not all achieve the desired end result. Special consideration must be given to presenting these models over the Internet under the current bandwidth limitations. We have developed a website for Hackney Council which attempts to address many of these issues. Currently the uptake of the website and the techniques we have applied has been limited to a few select users therefore it is too early to draw any significant conclusions regarding the ease of use of the website. However, the response we have had so far has been very promising…

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