Geovisualisation for Planning Support Systems*

Bin Jiang[1], Bo Huang[2] and Vit Vasek[3]

[1]Division of Geomatics, Institutionen för Teknik, University of Gävle, SE-801 76 Gävle, Sweden

[2]Department of Computer Science, Keele University, Staffordshire, ST5 5BG, UK

[3]Laboratory on Geoinformatics and Cartography, Masaryk University, Brno, Czech Republic

Abstract: *Planning support systems can be defined as spatial decision support systems, and they consist of three important components, namely: data, models, and geovisualisation (Klosterman 1999). In this chapter, we focus on geovisualisation in planning decision making, in which it has two roles to serve: collaboration and exploration, in particular when it is integrated with the other two components. We report several prototypes of geovisualisation for exploration and collaboration in the context of urban and environmental planning. These prototypes integrate recent developments in Internet GIS, geospatial virtual environments and multi-agent simulations. The techniques reported here have been used to develop a working planning support system based on the Internet.*

1. Introduction

Planning Support Systems (PSS) can be characterised as spatial decision making systems with particular application for planning, which involves a wide range of professionals with diverse backgrounds and the general public concerned. Current developments in GIS towards Group Decision Making Systems and Public Participation GIS (PPGIS) seem to have the same target. Due to the diverse nature of people involved in the planning process, specialist software and platforms certainly do not meet the various requirements from different people. However, all professionals and the general public as human beings are used to visual approaches, just as planners use maps and sketches to communicate and exchange ideas about planning scenarios. We concentrate on geovisualisation, which provides efficient and effective visual methods and tools for understanding complex geographic phenomena in planning decision making activities.

Researchers in urban planning are among those who use geovisualisation extensively to promote their professional activities. Various experiments have also been conducted towards exploratory visual tools for urban planning, mainly using

---

* In: Geertman S. and Stillwell J. (eds. 2003), *Planning Support Systems in Practice*, Springer: Berlin, pp. 177 - 191

multimedia integrated with geospatial databases in GIS (e.g. Shiffer 1995, Batty et al. 2000, Gouveia and Camara 1999, Laurini 2001). Several studies have been made towards using maps and visual tools for collaboration. Florence et al. (1996) proposed the metaphor of the wallboard for group decision support systems. Rinner (1999) adopted an argumentation map in a web-based planning support system. More recently MacEachren (2000, 2001) has presented a comprehensive overview towards collaborative geovisualisation, focusing on using maps and GIS as a mediator for collaboration. Thanks to recent developments in VRML and various other 3D standards, nowadays large-scale geographic databases can be easily visualised and disseminated over the web. GeoVRML, as a new extension of VRML97, implements some more nodes which are particularly for geographic applications, and overcomes some limitations of VRML97 (Reddy et al. 1999).

The research reported in this chapter is oriented towards two important functions of geovisualisation in planning processes: exploration and collaboration. There are various ways of doing visual exploration through interactive techniques such as dynamic geographic representation and multimedia with nonlinear hyperstructure. The exploratory geovisualisation we are going to elaborate here adopts different techniques. The first technique is the adoption of geospatial virtual environments, through which its counter-part real world environment can be explored extensively, and planning scenarios can be previewed with different levels of details. The second technique is to integrate analytical models for visual interrogation. Thus modelling processes can be explored visually and intuitively. To the best of our knowledge, this kind of exploratory visualisation has not yet received much attention, with a few exceptions (e.g. Bishop and Karadaglis 1996). Furthermore, these two kinds of exploratory geovisualisations can be realised through the Internet for collaboration in planning processes. To illustrate, this chapter introduces several experimental prototypes in the context of urban and environmental planning.

The remainder of this chapter is organised as follows. Section 2 focuses on two important functions of geovisualisation in planning, namely exploration and collaboration. Section 3 presents several geospatial virtual environments (GeoVE), which can be used for exploration of real-world environments. Section 4 introduces exploratory analysis environments for conducting what-if experiments. Section 5 deals with geovisualisation servers on the Internet for planning tasks. Finally in section 7 we draw some conclusions.

2. Geovisualisation for exploration and collaboration in planning

Geovisualisation in this context is simply referred to as geographic or cartographic visualisation. But it integrates knowledge and expertise from modern cartography, GIS, scientific visualisation (McCormick et al. 1987), information visualisation and virtual environments (Chen 1999). Highly interactive and dynamic exploratory tools can facilitate planning decision making. Through these tools, end users can thoroughly explore real-world environments, and new design scenarios can be previewed through well constructed virtual environments. More importantly, such effective and efficient geovisualisations can be implemented in a decentralised context, which supports collaborative decision making. While geovisualisation is integrated with analysis and simulation models, what-if modelling can be carried out for planning tasks.

Geovisualisation, or visualisation in a more general sense, sounds like an interface to geospatial database, or a means to show modelling results. However it has several different roles in data management and scientific activities. Inspired by exploratory data analysis, DiBiase (1990) identifies four roles in two distinct domains for geovisualisation. The first is the private domain, in which professionals, like scientists or engineers, use geovisualisation for visual thinking. Two relevant roles are exploration and confirmation. Then what is discovered through visual thinking is synthesised and presented to the lay professionals or the general public in the public domain - the second domain. This geovisualisation conception has been extended by adding one more interactivity dimension by MacEachren (1994). Obviously planning activities involve both professionals and the general public, therefore in this context, we focus on two important roles of geovisualisation in planning processes, i.e. exploration and collaboration. It can be used for exploring planning sites, previewing and communicating planning scenarios.

Conventional maps provide fewer capabilities for exploration, as they are static. The map reading process can be thought of as *reactive,* i.e. maps are passive and readers have to make an effort to understand the map symbols and what they represent. This is very similar to the way human beings react in the real world. Another reason why conventional maps have fewer exploratory capabilities is that they serve as geographic databases. In other words, visual representations and geographic information are not separate. This situation has changed rapidly since the advent of interactive graphic techniques. Particularly in the GIS environment, maps no longer serve as databases. Maps displayed on the computer screen are supposed to be *interactive,* although maps are still considered to be static to some extent. Such interactivity can occur in various ways, such as map display layer by layer, clickable map, and graphic manipulation like zoom and pan, or alternatively changing colours or symbols of maps. In this context, visual displays or geovisualisations in a more general sense are considered to be visual interactive tools to facilitate planning processes, rather than as geographic databases as discussed for instance in Craig and Elwood (1998).

The advent of multimedia has brought far more opportunities for the exploration of geospatial data, as an important complement to maps. The technology has been further pushed forward by the Internet, WWW in particular, which integrates all kinds of multimedia formats. With respect to the limitation of interactive graphics in that the interaction between system and user is constrained by a limited number of commands pre-defined by system developers, Buttenfield (1991) proposed the notion of *proactive graphics,* to refer to these exploratory capabilities not expected by system designers. She argues that with proactive graphics like multimedia with nonlinear hyperstructure, data should be explored in a manner consistent with the associative power of the human intellect. She and her colleague implemented a working prototype, focusing on spatial query in a form of visual exploration of biogeographical data (Buttenfield and Weber 1994).

The second role of geovisualisation in planning is collaboration, which has much to do with visual communication. Collaboration occurs between various groups at different stages of planning, for example, between various professionals and between professionals and lay professionals or the general public. On the one hand, various professionals have to understand each other (professionals likely to be involved include planners, cartographers, environmentalists, politicians and investors). On the other hand, the general public should be consulted about environmental issues. In this case, it seems more appropriate to refer to collaboration as participation. Geovisualisation facilitates collaboration through providing interactive and dynamic visual tools. For instance, 3D photorealistic representations are used to show urban redevelopment; dynamic computer simulations are used to show possible pollution diffusion over the next few years, to mention a few examples. These various techniques can dramatically increase the degree of understandability of PPGIS, should they be implemented (Kingston et al. 2000).

Collaborative planning can be conducted in both centralised and decentralised manner. Centralised collaboration usually takes place in committee rooms, or computer facilities room. GIS can be adopted for such tasks, but it needs redevelopment towards group decision support systems (Armstrong 1994). As far as public participation is concerned, collaboration has to be done in a decentralised manner. Both centralised and decentralised collaborations can occur at the same time or at different times. Thus it leads to four different scenarios of collaboration: same time-same place, same time-different place, different timesame place, and different time-different place. Corresponding to these scenarios, various new technologies have been discussed as to how they facilitate public participation in an urban planning context (Shiffer 1998). The rapid development of the Internet technology provides a good platform to realise all these scenarios. The Internet integrates various interactive and proactive techniques which can be used for planning processes. Participants can be involved in discussion and exchange of ideas through Internetworked GeoVE. More importantly, the Internet can overcome time constraint, which leads to asynchronous and long time span debate for some controversial planning tasks.

3. Exploratory geospatial virtual environments

Following the line of proactive graphics, geospatial virtual environments (GeoVE) opens far more possibilities for proactive exploration. Firstly VE provide realistic or photorealistic representations, which are hard to achieve with both conventional maps and multimedia. Bill Jepson, a pioneer in urban simulation, once posed an interesting question – "if a picture is worth one thousand words, what's a 3D model worth?"(Potel 2000). This question presents a great challenge for planning professionals and developers of PSS. Secondly, the interactivity of VE is very high. Using a head-coupled viewing device like a Head Mounted Disply (HMD), participants can be fully immersed in VE with the highest sense of presence and it allows thorough exploration of complex data-sets or phenomena. Most often low cost VE is non-immersive one based on desktop PC through the Internet browser, but it can be implemented in a more distributed manner. Our experiments are more targeted to the later non-immersive platform.

Realistic geovisualisation can be important tools for communicating with lay professionals and the general public in PSS. Assuming in an urban planning task, one sketches a 2D plan and converts it automatically into a 3D scene. With the 3D scene, planning scenarios can be investigated in various exploratory ways, such as zoom, pan, fly over, walking though, rotate, change perceptive etc.. Should the 3D scene be published over the Internet, it could attract wide public debate and participation. Several years ago, in a small town in California, it took several months to paint a historical building to meet the needs of community stakeholders (Potel 2000). However, such tasks can be done in a virtual environment within a few weeks. Equally, to locate mobile phone transmitters in a city, a 3D scene can help to examine the best sites in terms of the largest coverage. It will dramatically improve the original planning proposals.

We have developed various visual representations of real-world environments using affordable cutting-edge technologies such as internet GIS and virtual reality. GIS is used because these representations are supposed to be georeferenced and maps can be used as texture for 3D representations. These representations can be disseminated through the Internet and viewed through the Internet browser with an appropriate plugin. In order to introduce these representations, we herewith propose a classification scheme which involves two axes, as shown in table 1. The first axis shows dimension ranging from 2D to 3D, while the second axis shows the material these representations are based on. As these representations are in contrast to the real world, they can be said to be virtual or semi-virtual, corresponding to screen-based and material-based respectively.

Table 1: A classification of geovisualisation

	2D	2.5D[1]	3D
Screen-based (/virtual)	Maps, plans, orthogonal photos	Perspective photos, sketches	3D models (CAD, or VRML)
Material-based (/semi-virtual)	Printed maps, plans, orthogonal photos	Printed perspective photos and sketches	Printed 3D Polyester models

Although we focus on 3D representation, this type has a close link to 2D and 2.5D representations. The 3D representation is derived from the 2.5D representation using appropriate tools with 2D maps and photos for textures. The VRML models are interactive and dynamic which allow users to fly over or walk through, also with hotlinks to other hyperlinked information or scenes. More interestingly, the 3D representation can be printed out using durable polyester through 3D printers. There are various kinds of 3D printers on the market, and they are basically used in mechanical engineering for output CAD model. The size of hardcopy is scalable, so the hard copy is also portable and rather convenient for dissemination. Despite the increasing spread of the Internet, there is still a certain percentage of people who have difficulty getting access to the 3D virtual environments on the Internet, not to mention the people with visual impediments. Thanks to the affordable cost, the hard copy of 3D representations provides an excellent complement to the virtual environments in the computer.

Our first set of examples is at building scale[2]. The examples were built in a reasonable size, so it is easy to navigate and explore through any Internet browser. The models were derived from perspective photos of the built environment. Several editions of the models were created. Figure 1 demonstrates a campus model shown in Cosmo player through Netscape communicator (left), and a hardcopy version with polyester material (right, where a pen gives a sense of size scale). These two versions of the model are in bird's-eye view. In contrast, figure 2 presents another photorealistic version of the campus model, assuming one is "immersed" in the virtual environment. Please note that the trees in the model were planted virtually and do not exist in reality. This shows some potential for previewing planning scenarios.

1 2.5D meanly refers to perspective photos and sketches, but it is sometimes very confusing. For example, screen shots shown in figure 1 and 3 are 2.5D, but they are initially 3D representation using VRML. In this situation, we still refer them to as 3D representation rather than 2.5D.

2 for a live demo, please refer to site http://www.hig.se/t-inst/virtualrc/virtual campus/

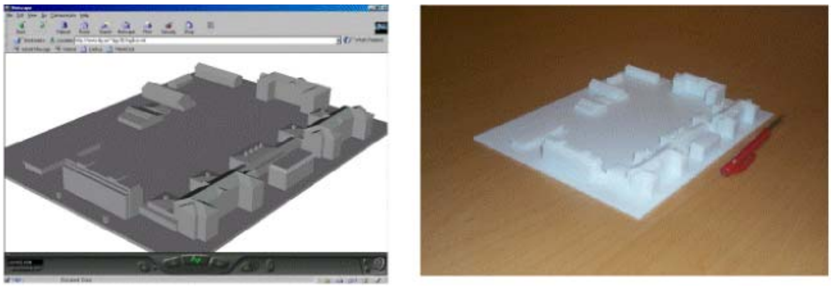

Figure 1: A campus model shown in browser (left) and in hardcopy (right) – bird's-eye view

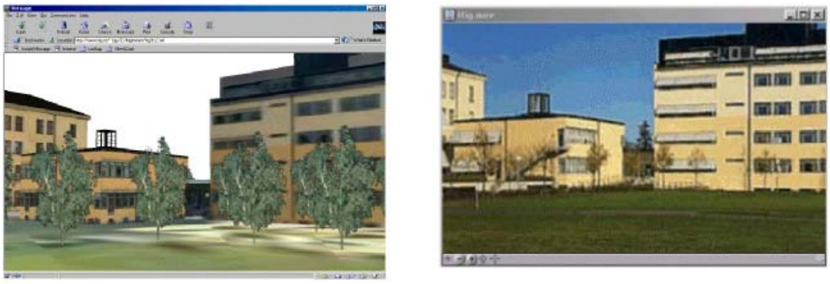

Figure 2: An exploratory version in browser (left) and in quicktime player (right)

Our second set of examples is at a larger urban scale, and they were built with ArcView 3D analyst. Figure 3 illustrates a city model of Gävle, a small town located north of Stockholm. For a more meaningful visualisation, different colours can be used to show different building functions; for example, red colour for residential houses, black for industrial, and grey for public buildings. Not only physical environment, but also socio-economic phenomena can be visualised in 3D. It is particularly of interest for the general public to comprehend and perceive social aspects of their environments. In this connection, figure 4 demonstrates population density both in 2D and 3D formats.

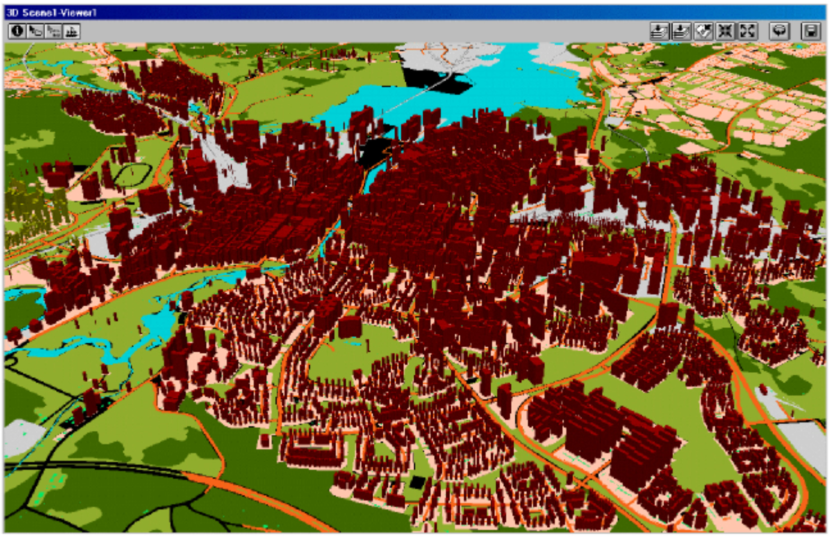

Figure 3: A virtual city model of Gävle

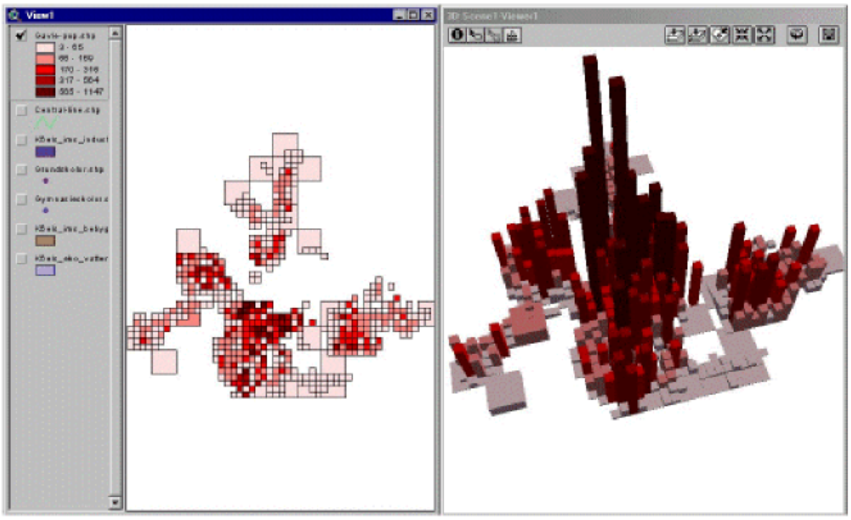

Figure 4: demographic distribution of Gävle in 2D and 3D representations

For the example shown in figure 4, the 2D representation to the left is supposed to be for professionals while the 3D representation to the right is for the general public. Let's mention an interesting observation. One day we showed the 2D representation of population density to one of our friends, who has lived in the town for two decades. She first seemed puzzled about the meaning of the different colours. However, as she was shown the 3D scene, she immediately realised that the height of the rectanglular pillars represented some value. When we had explained to her how the two scenes showed the local population distribution, she showed preference for the 3D representation, which is more intuitive and understandable.

4. Exploratory analysis environments

Instead of data display, geovisalisation can be useful tools for data analysis, that is, using geovisualisation as an interface for exploratory data analysis or for modelling experiments. Such highly dynamic and interactive environments can be thought of as a virtual laboratory, with which planners can post questions to conduct what-if modelling. To illustrate, let's mention a prototype for street accessibility analysis based on space syntax (Hillier and Hanson 1984). According to how each street segment (which is the longest visibility line) links to all the other segments, it derives a range of parameters to show the level of street accessibility. These parameters can be used to predict pedestrian or vehicle flows in urban systems based on well established empirical studies. With the tool, planners can foresee how pedestrian flows move around in a proposed street network. Thus it provides a nice model for analysing people movement. Obviously intuitive geovisualisation provides not only an interface to show the analysis result, but also an exploratory environment for conducting what-if modelling. For example, how does traffic flow change if a street is built up across street A and B? Using central Gävle as an example, figure 5 shows a typical interface from our prototype implemented as a plugin to ArcView GIS (Jiang, Claramunt and Batty 1999). The environment consists of several visual components such as 2D visibility lines, 3D accessibility scene, an attribute table and a statistical chart. These components are interconnected, thus facilitating exploratory data analysis. In both 2D and 3D graphic windows, the degree of street accessibility is represented by a spectrum colour legend, i.e. red represents the most accessible street, and blue represents the most inaccessible street, and other colours represent some between the two extremes. These are actually pedestrian flow distribution if we adopt one of these parameters – so called local integration. Within the environment, we can easily add one assumed street across streets A and B, re-calculate these parameters, one can observe the changes of distribution of street accessibility.

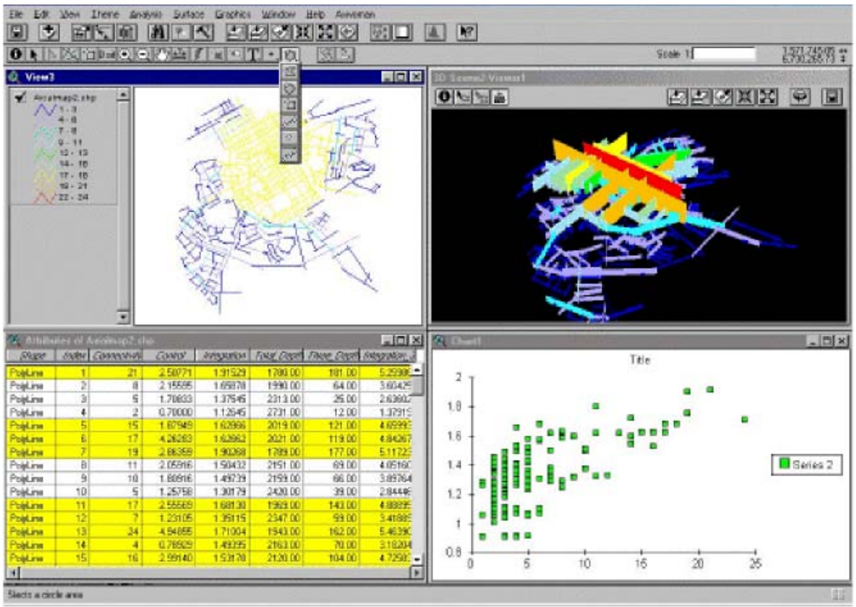

Figure 5: An example of exploratory analysis environments

To have an analytical model implemented with user-friendly geovisualisation environments is not a straightforward task, as it needs high efficient algorithms for analysis purpose. If a question is posed, a system should have an instant response to the question; a long time delay is not allowed for interactive visual thinking. In this connection, the parallel processing method provides a good technique for such tasks. Computation of isovist – a visual field from a standing point of view in an urban environment, has been a difficult task in conventional computational geometry, as it involves the calculation of line of sight. Instead we adopt a multiagent approach for the task and the algorithm is described as follows. Fill in space with agents, and let them explore space freely. Basically agents move in every direction to explore how far they can go, and the explored results are stored as the property of each location of space (Jiang 2000). Based on the computation, isovists can be explored dynamically, i.e. whenever mouse pointer passes, it shows the pattern of the visual field (figure 6-left). Such an exploratory capability can stimulate planning scenarios. For example, one can observe how visual fields will change by positioning a new building (represented as a polygon) in an area. In the same line, we implemented an exploratory environment based on viewshed analysis for Digital Elevation Models (DEM). Depending on the resolution of TIN structure from DEM, we extract a large set of discrete points, and calculate viewsheds from individual points. With interactive technique, all these viewsheds can be explored dynamically by clicking individual points (figure 6-right).

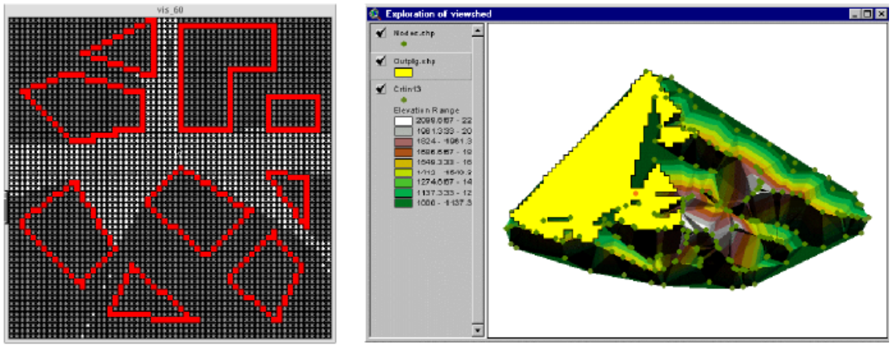

Figure 6: Snapshots of dynamically exploring isovists and viewsheds

The two examples in this section illustrate how analytical models can be integrated with geovisualisation for exploratory purpose. It should be noted that for planning tasks, the models should be well established and validated. Otherwise, the exploratory results do not make sense. We can remark that these tools are very intuitive and can be used by the general public for planning tasks.

5. Towards a geovisualisation server

The examples discussed so far are still considered for centralised environments, although they can be converted into VRML files, disseminated across the Internet and viewed on the web. However, for a practical planning support system, its three components (data, analysis model and geovisualisation) need to be considered coherently to support decentralised collaborative planning. One of the important challenges in this direction is a well designed server-client architecture to meet the requirements of geovisualisation for dynamic and interactive exploration and collaboration over the Internet. The notion of geovisualisation server we have used here refers to this special kind of server. Such a server overcomes the disadvantages of current client-server architecture, and has special capability in dealing with data transferring, analysis, and interactive display in order to meet real-time geovisualisation purposes (Huang, Jiang and Lin 2001).

Using the server-client architecture of the Internet technique, existing GIS and geovisualisation software can be mounted over the Internet, which provides an interoperated environment for distributed planning processes. Databases, GIS analysis models (or modelling tools) and 3D representations can be made available for remote clients for collaborative planning purposes. It provides a fast and economical solution to developing practical PSS using existing software resources.

We have implemented a geovisualisation server using ArcView GIS and its extensions. The prototype is based on an architecture which consists of three parts: a Java–based client, a web server, and a geovisualisation server (figure 7). The Java-based client resides with the Web server like Apache. This serves also an interface in which end users interact with the system by sending requests and receiving results. The Web server is integrated with an Internet Mapping Server (IMS). Existing GIS and geovisualisation software together constitute the geovisualisation server. For this implementation we have used ArcView IMS combined with Web server, ArcView and its extension 3D analyst stay at the geovisualisation server. Therefore the prototype is an interoperated environment with a range of interactive visualisation and analysis functions.

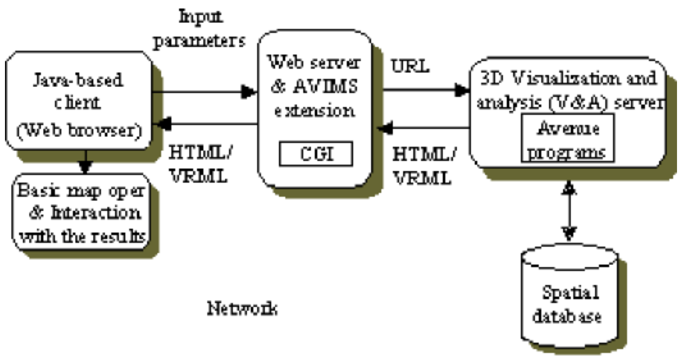

Figure 7: A geovisualisation server built with Internet server-client architecture

The communication between server and client is bi-directional, and it is achieved through various web and GIS programming such as Java, HTML and AVENUE. For example, the client side of the system provides several pages embedded with Java applets, which allow users to select operations, define properties of 3D scenes or input parameters for 3D analysis. End users then submit the request in the form of Unique Resource Locator (URL) to the geovisualisation server via a CGI program within ArcView IMS running on the Web server, or conduct some operations (e.g. 2D map browsing) locally. The correctness of parameters is also examined by the Java-based client before a command is submitted. The main mechanism for Java-based clients to communicate with the geovisualisation server is through the encoding of parameters in URL. After receiving a URL request from the Java-based client, the geovisualisation server extracts all the necessary parameters, processes them, and then delivers the results in the HTML-compatible format to the client for display. The results could be a 2D map or a 3D VRML model. In both cases, end users can still interact with them via zooming, panning, and querying on the client side.

To illustrate, let’s introduce two screenshots of the prototype. Figure 8 (left) shows an interface of 3D scene parameter setting in order to create 3D perspective displays by extruding spatial features in 2D maps. Attributes of spatial features (e.g. stories of buildings) are usually taken for height information (Z-value). Such an extrusion changes the form of a feature: points into vertical lines, lines into vertical walls, and polygons into 3D blocks. After parameter inputs, clicking the "Create 3D-VRML" button will generate a 3D scene and its VRML model on the fly (figure 8-right). In addition, a range of 3D analysis can be conducted such as viewshed analysis, and profile graph creation. It should be stressed that all these geovisualisations and analyses are conducted in a decentralised manner, that is, users send requests in normal web pages which go through different servers and finally receive the results in their screen. We can remark that these parameters are still too technical to be understood by the general public, so it is more oriented to professional users.

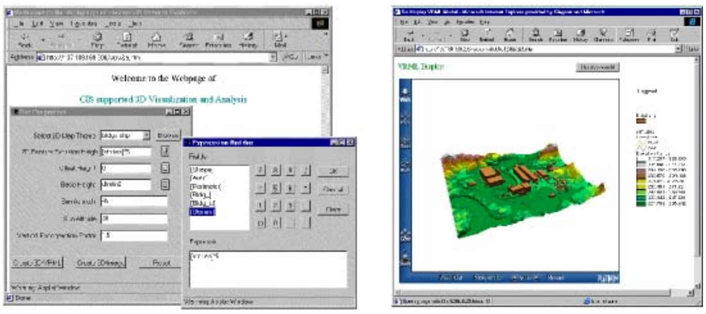

Figure 8. Parameters input (left) for creating a 3D scene in VRML (right)

6. Conclusions

New technologies have provided a powerful platform to develop noval geovisualisation methods and tools for conducting planning tasks in the information era. These technologies include multimeda, interactive and proactive computer graphics, virtual reality, and web techniques. In this chapter, we focus on the two roles of geovisualisation for the planning process, namely exploration and collaboration, and provide several prototypes in each respect. They illustrate how geovisualisation can facilitate the planning process, particuarly when it is combined with data sets and analytical models. To conclude the chapter, let’s make a summary of these protoypes towards a web-based planning support system.

Planning activities involve a large amount of data, which covers topographical, socio-economical and demographic data etc.. So massive data geovisualisation in realistic ways like VRML is a pre-requisite for a successful PSS. Due to the continuous development of computer performance, massive photorealistic geovisualisation can be made possible in desktop environment through the Internet. What-if modelling is rather important for planning tasks, as it helps to explore planning scenarios. For more ambitious and difficult implementation, it would be to develop specialist models with real time calculation. This kind of modelling may not be applicable for the general public, as these models are intended for planning specialists. But there is a way to simplify parameter inputs for the general public. Thus it presents more challenge for research work. From a practical point of view, the prototypes introduced here need to be coherently organised as a PSS for planning purpose. In this connection, interface design is an important challenging issue among others. Multimode communication for collaboration is likely to be one of the requirements. All these have implications for our future work.

Acknowledgements

This paper presents part of our Virtual Planning Studio project, supported by the Swedish Research Council For Environment, Agricultural Sciences and Spatial Planning, and GIS Institute in Gävle. Vit Vasek's work is supported by the Swedish Institue through the Guest Scholarship. We would like to thank Prof. Bengt Rystedt, Prof. David Douglas and Cecilia Ljunggren for their advice and comments on an early version of this paper.

References:

Armstrong M. P. (1994), Requirements for the development of GIS-based group decision-support systems, Journal of the American Society for Information Science, 1(1), pp. 669 – 677.

Batty M., Dodge M., Jiang B. and Smith A. (1999) Geographical information systems and urban design, in: J. Stillwell, S. Geertman and S. Openshaw (editors), Geographical Information and Planning, Springer, Heidelberg, Germany, pp. 43 – 65.

Bishop, I. D., and C. Karadaglis, 1996, Combining GIS based environmental modeling and visualisation: another window on the modeling process. Proceedings Third International Conference on Integrating GIS and Environmental Modeling, Santa Barbara: National Center for Geographic Information and Analysis, Santa Fe, WWW and CD.

Buttenfield, B. P. (1993). Proactive graphics and GIS: prototype tools for query, modelling and display. Proceedings of Auto Carto 11. ACSM/ASPRS, Minneapolis, pp. 377-385.

Buttenfield, B.P. and Weber, C.R. (1994), Proactive graphics for exploratory visualization of biogeographical data, Cartographic Perspectives, Vol. 19(3): pp. 8-18.

Chen C. (1999), Information Visualisation and Virtual Environments, Springer, Berlin.

Craig W. J. and Elwood S. A. (1998), How and why community groups use maps and geographic information, Cartography and Geographic Information Systems, Vol. 25, No. 2, pp. 95 - 104.

DiBiase, D. (1990), Visualization in the earth sciences. Earth and Mineral Sciences, Bulletin of the College of Earth and Mineral Sciences, Penn State University, 59(2): pp. 13-18.

Florence J., Hornsby K and Egenhofer M. J. (1996), The GIS wallboard: interaction with spatial information on large-scale displays, in: M. J. Kraak and M. Molenaar (eds.) Advances in GIS Research II, Taylor & Francis, pp. 8A.1 – 18.

Gouveia C. and Camara A. (1999), Multimedia and urban planning, in: Geertman, S., S. Openshaw, and J. Stillwell (eds), Geographical Information and Planning: European Perspectives. Springer-Verlag, pp. 391 - 402.

Hillier B. and Hanson J. (1984), The Social Logic of Space, Cambridge University Press.

Huang B. Jiang B. and Lin H. (2001), An integration of GIS, internet and virtual reality for the visualisation, analysis, and exploration of spatial data, International Journal of Geographical Information Science, Vol. 15, pp. 439-456.

Jiang B., Claramunt C. and Batty M. (1999), Geometric accessibility and geographic information: extending desktop GIS to space syntax, Computers Environment and Urban Systems, Vol. 23, pp. 127 – 146.

Jiang B. (2000), Agent-based approach to modelling urban and environmental systems within GIS, in Forer P., Yeh A. And He J. (eds.) Proceedings of the 9th International Symposium on Spatial Data Handling, Beijing, 10-12, August, 2000, pp. 3b.17 – 3b.29.

Kingston R., Carver S., Evans A. and Turton I. (2000), Web-based public participation geographical information systems: an aid to local environmental decision-making, Computers, Environments and Urban Systems, 24, pp. 109 – 125.

Klosterman R. E. (1999), New perspective on planning support systems, guest editorial, Environment and Planning B: Planning and Design, Vol. 26, pp. 317 – 320.

Laurini R. (2001), Information Systems for Urban Planning: A Hypermedia Co-operative Approach, Taylor & Francis: London.

MacEachren A. M. (1994), Visualization in modern cartography: setting the agenda, in: A. M. MacEachren and D. R. F. Taylor, editors, Visualization in Modern Cartography, Pergamon, pp. 1 – 12.

MacEachren, A. M. 2000. Cartography and GIS: facilitating collaboration. Progress in Human Geography 24(3): pp. 445-456.

MacEachren, A. M. 2001. Cartography and GIS: extending collaborative tools to support virtual teams. Progress in Human Geography, also available at: http://www.geovista.psu.edu/publications/amm/ammP00.pdf.

McCormick B. H., DeFanti T. A. And Brown M. D. (1987), Visualization in scientific computing, Computer Graphics, Vol. 21, No. 6.

Potel M. J. (2000), Visualisation in urban planning: they did not build LA in a day, IEEE Computer Graphics and Applications, May/June 2000, pp. 10 – 16.

Reddy M., Leclerc Y., Iverson L and Bletter N. (1999), TerraVision II: visualizing maasive terrain databases in VRML, IEEE Computer Graphics and Applications, March/April, pp. 30 – 38.

Rinner C. (1999), Argumaps for spatial planning, Proceedings of TeleGeo99, First International Workshop on Telegeoprocessing, Lyon, France, May 6-7, pp. 95 – 102, also available at: http://set.gmd.de/~crinner/pub/telegeo.pdf.

Shiffer M. (1995), Interactive multimedia planning support: moving from standalone systems to the World Wide Web, Environment and Planning B, 22: pp. 649 – 664.

Shiffer M. J. (1998), Multimedia GIS for planning support and public discourse, Cartography and Geographic Information Systems, Vol. 25, No. 2, pp. 89 – 94.