TOWARD A 3D GIS FOR LOCAL GOVERNING: A WEB-ORIENTED APPROACH

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ABSTRACT

Municipalities are some of the institutions where the complexity and interrelations between different types of data (3D spatial and non-spatial), the problems and the requirements of the users vary to such large extent that current information systems have difficulty in handling and analysing them in their integrity. This status disturbs the process of urban planning and governing more frequently nowadays than a decade ago and seeks for new solutions. This paper discusses the range of data needed for a 3D GIS in a municipality and presents a web-oriented approach that aims at an improved service of users looking for municipal information.

MUNICIPALITIES AND GIS

A look at the information kept in a municipality reveals a complex mixture of spatial multidimensional and non-spatial data, kept and maintained by different information systems, organisations and companies (*Croswel et al 1994, Fuchs 1996*). Objects with spatial extent are commonly maintained by GIS and CAD systems, while objects lacking spatial extent (citizens, companies, deeds, etc.) are stored in DBMSs, spreadsheets, files or folders. More and more municipal tasks (i.e. urban planning, pollution monitoring) require analysis and visualisation in 3D space. The responsibilities for updating, exchanging and analysing data is spread over different departments and even external companies. Furthermore, the range of possible users varies from individuals asking for private information to different kinds of specialists involved in the decision-making process and responsible for the development of the town. These summarised observations reveal an urgent need for new ideas basically in three directions: data organisation ensuring appropriate functionality and efficiency, data visualisation providing rich 3D means to manipulate data and extended (preferably remote) access to the information system.

The software market is still not capable to respond to increased complexity of municipal problems. One of the major problems is the third dimension. The co-operation between vendors has resulted in various extensions of existing systems, merging functionality of CAD, GIS and DBMS (e.g. SDE, ArcCAD, Oracle Spatial) as well as standards for software development and data exchange (e.g. OpenGIS, OpenGL). With some exceptions (e.g. SDE) most of the solutions have conceptual insufficiencies to deal with 3D spatial objects. Spatial analysis in GIS and DBMS are currently restricted to 2D as only the visualisation is 3D. Despite improved capabilities for handling large urban data and some advances in analysing attribute information, CAD systems remain mostly the tools for visualising and navigating though 3D model.

Extensive research is conducted in GIS and computer graphics societies toward the third dimension. Recently, a new area of investigations, i.e. the remote query and visualisation of 3D spatial data over the Internet, is emerged (*Coors and Jung 1998, Zlatanova 1998*). The research, however, has tendencies to isolate problems of 3D spatial analysis from 3D visualisation, which is a basis for shortcoming in one or another aspect.

This paper discusses one approach for an integrated municipal organisation of data (spatial and non-spatial objects and parameters for 3D realistic visualisation) ensuring query and retrieval over the Internet. The paper is structured as follows: first the requirements to the data structuring are specified, second, the system architecture is presented and third, examples of graphics user interface for remote query are given. The benefits of such an approach for municipal users conclude the paper.

REQUIREMENTS TO THE CONTENT AND THE STRUCTURING

The generic question thinking of a municipal information system is the content and the structuring of the data. An extended functionality usually requires more data and better organisation. Several authors have already attempted to define requirements to a municipal system (*Bodum et al. 1998, Gruber et al 1997, Razinger and Gleixner 1995,Tempfli 1998, Zlatanova and Bandrova 1998*). Here we summarise several new requirements related to the mixed types of data (with complex interrelations) in urban areas and the new techniques for visualising and interacting with large 3D graphics data:

- The data has to be structured according to the rules of a common model in centralised or distributed databases. The current practice of having different models (CAD, GIS, etc) for different activities and services complicates the process of data management and involves a lot of manpower. A common model will facilitate the maintenance ensuring easy update, consistency, reliability, etc.
- The database has to accommodate spatial and non-spatial objects rather than geo-referenced objects and semantic information attached to them. This will allow a large number of different types of data (e.g. deeds, rights, properties, owners, users, etc.) to be organised in a more efficient way that will facilitate development of application software and will extend the functionality of the system (e.g. performance of analysis between spatial and non-spatial objects).
- The system has to be able to maintain 3D spatial objects and their spatial relationships (represented by 3D topology). The urban planning process often requires complex environmental analysis (e.g. estimation of the level of pollution, noise, etc.) that can be performed faster and easier by truly 3D GIS.
- The model has to accommodate a larger scope of characteristics (besides the traditional shape, size, position, etc.) about spatial objects, i.e. radiometric properties (e.g. colour and texture). The usual 2D visualisation techniques (relying on colouring) are insufficient for displaying 3D graphics. Many details (facades, ornaments, windows, doors) that are not of importance for 2D, has to be maintained and hence a solution for their representation has to be found. Since the complete geometric modelling and topological structuring is difficult and not necessary, a possible approach is the representation of the details as

textures attached to simpler geometric representations (compare Figure 1 and Figure 2). These textures have to be appropriately placed in the GIS model.

- The GIS model has to provide dynamic information such as “natural behaviour” of object, e.g. the door can be open, the elevator moves up and down. This will enlarge the possibilities for exploration and will enhance the perception of the information.
- A 3D spatial indexing (e.g. 3D R-trees) is highly desirable to speed up the traverse of the spatial records.
- Since the amounts of 3D data is often rather large and problematic for rendering, efficient methods for maintenance of different Levels of Detail (LOD) created on the fly or permanently stored for both geometry and texture has to be provided.

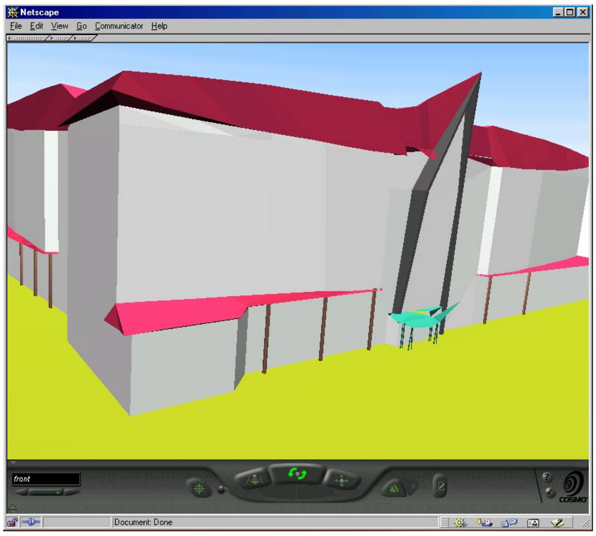

Figure 1: Low-resolution geometry

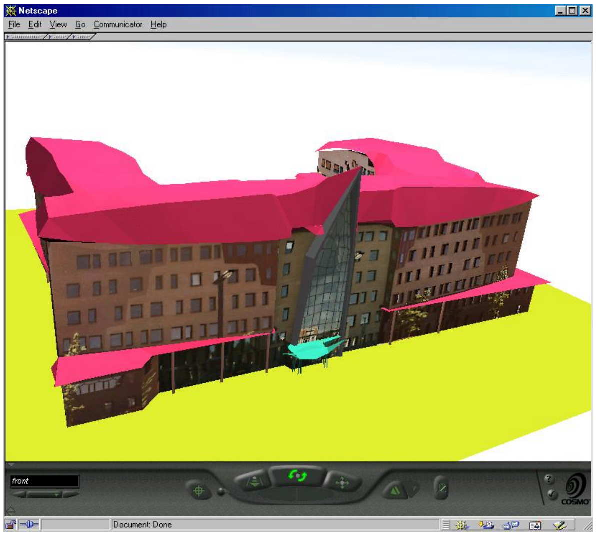

Figure 2: High-resolution obtained by texturing with real photo images

A WEB-ORIENTED APPROACH TO ACCESS, QUERY AND VISUALISE

The next issue is the system architecture for accessing, retrieving and analysing data. Commonly, the municipal data are stored in stand-alone or Intranet systems to which the user does to have a direct access. Officers that are responsible for receiving queries and delivering requested information administrate the different systems. This type of service involves considerable man effort and time. A possible alternative, which may shorten this process, is the enabling of an Internet access to the data. Selling information over the Web, considered as a revolutionary step by many authors (*Bichler et al 1998, Doyle et al 1998*), is already a well-established practice in a number of businesses, e.g. shopping, tourism. The supply of GIS data on the Internet market is not so successful. One of the main reasons is the spatial aspect that requires appropriate visualisation expressions and tools for browsing and exploring the data. Until recently, the most often used approach for displaying spatial data is the creation of an image in a format supported by the Web (e.g. *ATM locator*, http://www.visa.com). This approach, indeed, cannot be applied for visualisation of 3D data, which forced many vendors (e.g. Autodesk, ESRI) to develop their own software (plug-ins) for visualisation and interaction with 3D data. The disadvantage in this case is that the plug-ins are dependent on and limited to a particular GIS (CAD). In this respect, the agreement on a web standard, i.e. the Virtual Reality Modelling Language (VRML), opens a wide range of new possibilities for visualisation of 3D graphics. VRML is a language for describing 3D geometry, lights, colours, texture, views and dynamics. Coupled with Java and ECMA scripts, the potential for displaying and interaction increases almost unlimited. Moreover, VRML enables basic virtual reality techniques, which are considered very appropriate for exploring urban areas (see *Coomans and Timmermans 1997, Dodge et al 1998, Koller et al 1995, van Maren and Germs 1999*). A lot of information about VRML can be found in the VR repository (http://www.web3d.org/vrml/vrml.htm). Although VRML gains more and more popularity for visualising virtual cities on the Web (see *Arena 2000 project, IGG-University of Rostock 1999, Wizard Solutions 2000*), its utilisation as a front-end visualisation engine is still limited. Some disadvantages of the transfer of the VRML worlds over the Web such as large files, lack of compression, are the most frequently discussed. However, our deep understanding is that VRML provides the needed means to accomplish 3D realistic visualisation on the Web. Therefore the system architecture discussed below employs VRML in very large extends.

Bearing in mind the type of municipal work and the potential of the Web, we have proposed a client-server system architecture that consists of four key components: DBMS, Web server, Web browser, VR browser and communication software (CGI scripts). The user can access data on the server with the help of Graphics User Interface (GUI) built on combinations of HTML forms and 3D VRML worlds. The HTML documents are used for specifying queries and visualising text, images, movies, etc., i.e. information supported by Web browser (e.g. Netscape). VRML worlds are extensively used for 3D graphics. The GUI allows either pointing graphically objects in the VRML model, or typing SQL queries, or selecting data from pull-down menus. Some examples illustrating this type of GUI are discussed in detail later. The query of municipal information is thus possible from any computer with Internet connection.

The components utilised have a number of advantages. The employment of RDBMS to maintain data allows the last achievement of the database industry to be exploited, i.e. standard languages, binary and spatial indexing techniques, optimisations in maintenance and control of data. The utilisation of Web browsers and VR browsers to specify queries and visualise results ensures propagation of basic Web design criteria over the 3D GIS: functionality (support of a variety of file formats), portability (independence from software and hardware availability), scalability (visualisation of arbitrary large documents), extensibility (provide new capabilities, which do not exist in the minimal configurations), low cost solutions on the client site (most of the browsers are free available on the Web), etc. The utilisation of VR browsers for visualisation reduces the task of the software developer to only the creation of the VRML document and lives the rendering algorithms to the developers of VR browsers (see *Nadeau 1997*). Finally, the utilisation of CGI scripting makes use of HTTP protocol, scripts and HTML forms commonly implemented on the Web.

RESULTS

We developed a prototype system to demonstrate the feasibility of the approach. The components of the prototype system were selected under two major criteria, i.e. availability of software and possibility for low-cost solutions. Employment of existing software modules and standards eases and speeds up the implementation process. A working system utilising low-cost (or freeware) components premises a successful realisation with commercial modules. The prototype system is built using MySQL and Apache server (running under Linux). The communication software is written in Perl. The data are organised according to an extended 3D GIS model (*Zlatanova and Tempfli 2000*), which maintains a large number of parameters with respect to the requirements specified above. Experimental GUI demonstrates some capabilities of the system. The developed GUI does not pretend to be fully operational, it gives an idea of organising the communication between the municipal server and the client computer. Assuming that the initial identification steps (e.g. connection to the server, identification with user name and password) are completed, we have developed four groups of GUI. They aim to cover the most of the queries that may be needed in a municipal system: obtaining information for a particular object, specifying SQL queries, change and update, and complex queries.

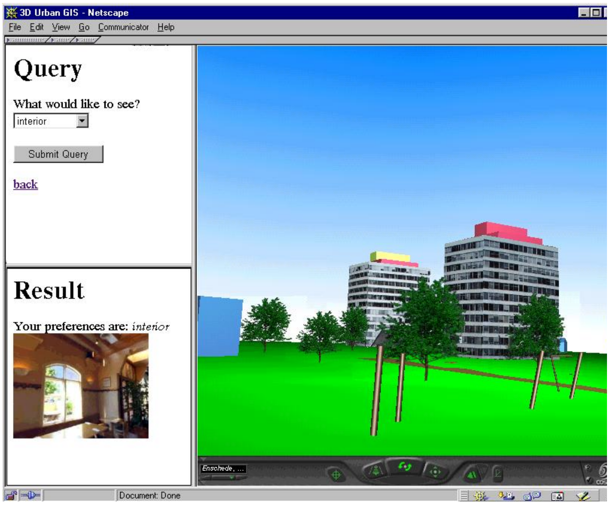

Figure 3: Query of object properties

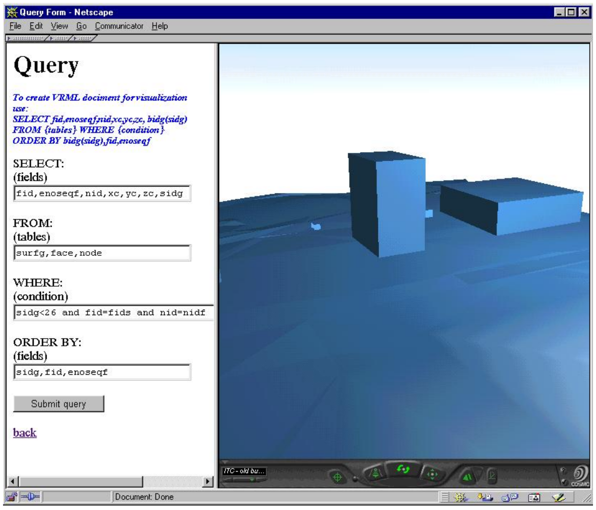

Figure 4: SQL query of spatial information

Information about a particular object (geometric or semantic)

The first example focus queries such as “what are the co-ordinate of this building”, “what the interior of the building looks like?”, “what kind of information is available for this building”, etc. The GUI allows the user to point the object of interest in an initial VRML world. The pointing activates a CGI script that extracts from the database the types of data available for the object. They are offered in an additional section in the Web Browser (see Figure 3) where further specifications can be made. The snapshot in the figure shows the interior of the selected building. The interior is stored in the database as a panoramic movie, that can be activated by an appropriate plug-in for “walk-trough” and “look around”.

Thematic, spatial or mixed queries defined in SQL statements

The second group of GUI offers a flexible way of obtaining information by specifying SQL queries. The snapshot in Figure 4 presents an HTML form for the SELECT statement. The user has to fill in the HTML form in the left section and after the processing, the requested information is visualised in the right section. Depending on the type of the information (text, graphics), different documents are delivered (HTML, VRML).

Change and update

The VR browser used to visualise VRML document does not maintain means for editing of the VRML world. Two approaches are possible to perform editing operations. Firstly, the VRML document can be enhanced with Java applets or ECMA scripts, which will allow interactivity on the client station. Secondly, the changes can be performed directly at a database level and a newly generated VRML or HTML document will present the changes. Figure 5 shows an example of changing the image file used for texturing of one of the buildings. This operation is expected to facilitate the design or renovation of facades. Following this approach at least two connections to the database are needed. If the user is allowed to change large portions of data (e.g. discussing new urban projects or buildings), this process might become very time consuming. Java applets instead of direct connection to the database are the better solution for such cases.

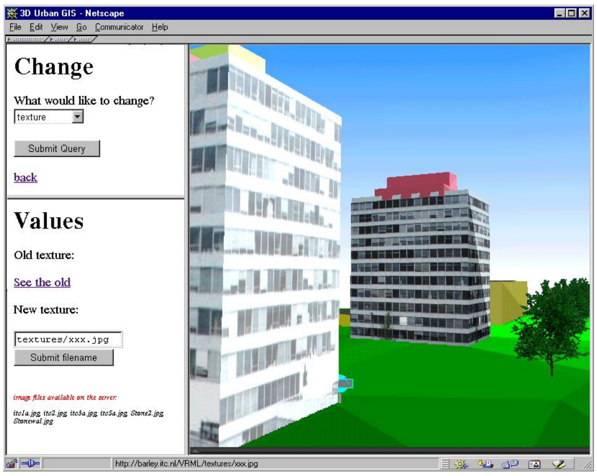

Figure 5: Change of values

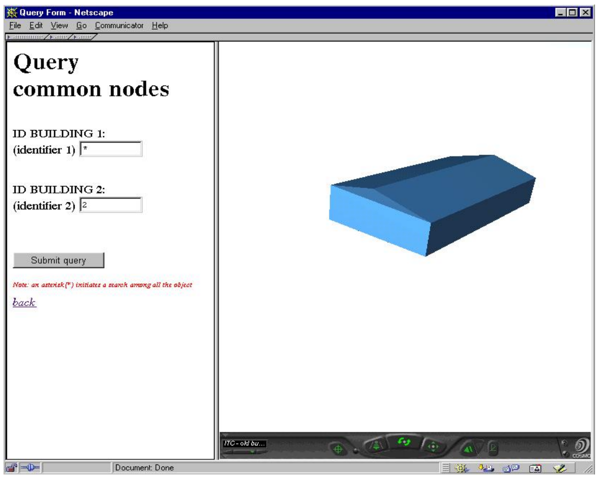

Figure 6: Complex queries

Complex queries

Finally, to perform complex queries that cannot be specified in any of the forms presented above, e.g. "find all the common points of two objects", the queries have to be organised either in a specialised form (Figure 6) or in series of HTML forms.
The prototype system and the examples are available at http://barley.itc.nl

CONCLUSIONS

We briefly presented an approach for a web-oriented 3D GIS for a municipal system. The tests performed on different data sets have show positive performance results (*Zlatanova 1999*). The system was tested more for appropriate database organisation rather then for global performance of the selected components. Therefore, our expectations are for improved performance on better hardware and software platform. We consider our results a successful step toward a better organisation of municipal data toward extended functionality of the system and more efficient services of clients. Compare to the existing services, municipality clients are likely to benefit of our approach in several aspects:

- The scope of analysis can be enlarged with 3D spatial and mixed (between spatial and non-spatial objects) analysis.
- The user is able to query graphically 3D objects in a virtual environment.
- The results of 3D spatial queries are visualised in an environment that allows virtual reality navigation and exploration.
- The outcomes of the queries can be visualised in a variety of different file formats, e.g. movies, images, text, 3D graphics.
- The user interface can be adapted to the different qualifications of the users.

- The access to the information is possible from any office via the Internet.
- The software running on the user's computer is freeware available on the Web (VR and Web browsers).

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