3D Navigation for 3D-GIS – Initial Requirements

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Abstract

The needs for three-dimensional (3D) visualization and navigation within 3D-GIS environment are growing and expanding rapidly in a variety of fields. In a steady shift from traditional two-dimensional (2D) GIS toward 3D-GIS, a great amount of accurate 3D data sets (e.g. city models) have become necessary to be produced in a short period of time and provided widely on the market. This requires a number of specific issues to be investigated, e.g. 3D routing accuracy, appropriate means to visualize 3D spatial analysis, tools to effortlessly explore and navigate through large models in real time, with the correct texture and geometry. There had been a lot of study on 3D landscapes, urban and city models. The rapid advancement in science and technology had opened wide options for a change and development of current methods and concepts. Virtual Reality (VR) is one of those developments, which gives the sense of feel in virtual environment. It enables users to visualize, make query and exploring 3D data. Such system can, not only help laymen, who often have trouble in understanding or interpreting complex data, but they also can help experts in decision making. The objective of this paper is to discuss some initial requirements of the proposed solution towards 3D-GIS. Eventually, this paper will serve as a starting point for a more challenging research idea. The focus of this research is to investigate and implementing 3D navigation techniques and solutions for 3D-GIS. Investigation on the support of navigation in real world environment will be carried out. This will include a research on the benefits of using 3D network model (non-planar graph) compared to 2D, how to use visual landmarks in route descriptions and using 3D geometry to get more accurate routing (in buildings, or in narrow street, etc). And as for implementation, a GUI provides the users with means (e.g. fill-out forms) to specify SQL queries interact and visualize 3D outcomes in virtual reality environment. This has opened up the ability to distribute and navigate accurately in 3D virtual worlds. The initial study on Klang Valley will go through data conversion processes from different formats like Laser, VRML, CAD and Shape 3D in a first person view environment using a developed system using VRML, JAVA and .Net compiler. The dataset structure will be in the form of various 2D, 2.5D and 3D array of height fields.

KEY WORDS: 3D-GIS, Navigation, Visualization, Virtual Reality.

1. INTRODUCTION

The needs for three-dimensional (3D) visualization and navigation within 3D-GIS environment are growing and expanding rapidly in a variety of fields. This requires a number of specific issues to be investigated, e.g. 3D routing accuracy, appropriate means to visualize 3D spatial analysis, tools to effortlessly explore and navigate through large models in real time, with the correct texture and geometry.

There had been a lot of study on 3D landscapes, urban and city models but it focuses on typical three-dimensional visualization of geo-data. No further functionality, e.g. topological relations between the objects or object identities, are attached or maintained to these visualization elements. Therefore, the current 3D-GIS are widely recognized as so called "pretty model" of a landscape of a city. In fact, in some map navigation situations, due to the limitation of the viewing device, having a large data set and improper data management issues, it is hardly to visualize, generalize and even maintained landmarks on the map. To overcome this problem, a description for each possible route and point of interest on the map is created. Currently, mainly geometry is used to generate description like "turn left in 50m" and present it to the user either in voice mode or in text appearance. Again, GPS that attached to the viewing device has certain drawbacks. It needs of course direct contact to the satellites and it gives no idea of the landmark's whereabouts. If the signal is lost or multipath occurred, this point of interest or route description is no longer valid, thus giving a wrong information or direction to the user. But then, if visual landmarks are present in route description, it could give better understanding. With visual support it could be "turn left at the red building on the right side".

There are many promising applications in reach, if we can take advantage of the "knowledge" of third dimension in the applications. For example, in 3D navigation, one can have an accurate point-to-point network routing based on 3D network model compared to 2D if an accurate data set is present. Besides that, it can also used to determine the position and the orientation of a human within an urban environment, for instance (Jasnoch et al, 2000). A virtual tourist can use this information to get from one place of interest to another with an accurate and efficient route and retrieve detailed information of that particular place, thus taking advantage in travel planning.

The overall aim of the study is to investigate on the support of navigation in real world environment. This will include; firstly, a research on the benefits of using 3D network model (non-planar graph) compared to 2D which will not limited to buildings but also at street level. Secondly, emphasis on how to use and generate visual landmarks for route descriptions. For implementation stage, a GUI will be developed which provides the users with means (e.g. fill-out forms) to specify SQL queries, interact and visualize 3D outcomes in near-virtual reality environment (PC based).

This paper describes the possible research for 3D navigation development as one of 3D-GIS application. Firstly, a simple concept on 3D navigation for 3D-GIS is briefly presented. Several research questions have been point out here as well. Secondly, it concentrates on the methodology for the development of a simple viewing prototype of the 3D navigation solution. A short description for the experiment is described. Final remarks and further works summarize and conclude the research on 3D navigation for 3D-GIS.

2. 3D-GIS

In comparison to the advancements in 3D visualization, relatively little has been accomplished in the realization of practical 3D-GIS. The obvious reason remains: the transition to 3D means an even greater diversity of object types and spatial relationships as well as very large data volumes. In a 2D GIS, a feature or phenomenon is represented as an area of grid cells or as an area within a polygon boundary. A 3D GIS, on the other hand, deals with volumes. Consider a cube. Instead of looking at just its faces, there must also be information about what lies inside the cube. 3D GIS require this information to be complete and continuous.

2.1 3D Navigation

Van Driel (1989) recognized that the advantage of 3D lies in the way we see the information. It is estimated that 50 percent of the brain's neurons are involved in vision. What's more, it is believed that 3D displays stimulate more neurons: involving a larger portion of the brain in the problem solving process. With 2D contour maps, for example, the mind must first build a conceptual model of the relief before any analysis can be made. Considering the cartographic complexity of some terrain, this can be a difficult task for even the most dexterous mind. 3D display, however, simulates spatial reality, thus allowing the viewer to more quickly recognize and understand changes in elevation and texture.

The concept applies to 3D navigation as well. When a user route him/herself to an unknown destination (point), it is good to have a system that can visualize map in a way that will make the user understand better and assist him/her to the destination in a most efficient route. Currently, most navigation systems tend to display the map by changing the map's horizon perspective (to look like a 3D scene). This is just somehow a nice map presentation to user and it doesn't mean anything without any help such as landmarks on the map. 3D navigation system on the other hand, should be able to show 3D surrounding objects along the path to the place of destination. These 3D objects are also known as visual landmarks. The visual landmark has more likely the same shape as the real-world object with generalized details. And of course, navigating through 3D dataset will make sense when it comes to accuracy since data that are involved will be an accurate one. Application such 3D network analysis could be applied here, and therefore, user may have alternative solutions for a minimal distance or cost for each route to destination. For example, in exploring a 3D city, one can query where his/her current location is and then choose where to go next, either to a known point/location of interest or by a certain radius interval (e.g. 1 km from a point). Options like fastest route, shortest route or minimum cost can be choose from here on. From the derived results, it is possible to know which route should to be taken with an option of desire (e.g. with shortest and minimal cost route). The route is not limited to road (line features) networks, but also able to show routes that across terrain (if overlaid with DSM data), but then navigation rules need to be applied here, e.g. whether allowing search to cross boundary of line networks or not. While navigating along the chosen route, detail information (attributes) for 3D objects surrounding can be viewed as well, where they are cross-referenced with another database.

2.2 The Research Questions

In order to be able to start investigating 3D navigation techniques and solutions for 3D-GIS, the present system (techniques and solutions) had first to be thoroughly examined and described. In this research, although with the support of visual landmarks in navigation, several research ideas and possible methods still remain as gaps that need to be addressed, where the following research questions raised:

- How to generate visual landmarks descriptions as a solution for 3D navigation? How do visual landmarks influence a 3D visualization as navigation support?
- What is the most suitable or appropriate spatial modeling for 3D navigation 3D-GIS environment? Will mobile augmented or mixed-reality visualization make a big benefit towards 3D navigation?

  For data accuracy wise, to have an accurate routing (in buildings, or in narrow street, etc), 3D geometry and surface obtained from Laser and any related data will be used. Emphasis is put on how OGC standards could be implemented in such system, especially uncertainties about their integration between several data formats and systems that will be handled in 3D navigation solution. Possible methods of 3D-GIS database regeneration and integration by reconstructing 3D buildings will, as mentioned above, be one of the main issues to be discussed in this study. Here, focus will be on processes rather than on technical device.

- Does generalizing roof top in large-scale maps will affect the accuracy of the generated 3D-GIS database?

  Generalization of 3D objects plays a major role in 3D navigation. It is possible to use either Level-of-Details (LoD) or some compression (e.g. Edgebreaker, Delphi, etc.) or even multi-resolution modeling approach to improve data storage and retrieval in order to avoid the time-consuming data rendering and query results.

- Will the implementation of data compression to the generated 3D-GIS database improve data retrieval or the use of LoD would be better? How about tiled-based method (Zhu et al., 2002)? Or trying to implement using multi-resolution modeling (Coors & Flick, 1998)?

  Nowadays, multi-resolution models are only used in raster images and in highfields. Guéziec has introduced an algorithm using multi-resolution model in VRML (Guéziec, A. et al., 1998). However, none of these multi-resolution modeling approaches is focused on redundancy free transmission of different LoD on demand in a web-based application.

- How to implement multi-resolution modeling in 3D navigation solution without having transmission redundancy of different LoD?

3. METHODOLOGY

The exploration of the 3D worlds in the near-VR systems ensures a certain level of virtual reality techniques. Existing VRML, X3D, JAVA, GML, SVG and other Web standards and software modules allow the development of GUI with limited effort, relying on some operations provided by browsers or viewers. Therefore VRML and JAVA will be employed as a front-end engine to the 3D-GIS model.

As for a start, a simple viewing prototype has been developed. The prototype tries to render and visualize the 3D city model of Putrajaya and try to connect the objects in the 3D scene with their attributes in the land registry dataset. Laser data of Putrajaya area obtained from the National survey department is used. The true distance for accurate routing will be based on surface model from Laser data. The motivation was to give the user the ability to interact with the 3D scene not only by moving around, but also to have access to the attributes information by clicking on the objects or 'intelligently' display the information on the screen. The given 3D dataset only consists of geometry information so that an algorithm had to be invented, which connects the geometry with the attributes.

This section is considered to be the designing and developing a simple viewing prototype of 3D navigation solution. The simple application prototype is just an initial progress of the full development to show how 3D navigation for 3D-GIS can be done. Although the test application is a desktop application, it is possible to realize the concept on a website as well. The VRML viewer can be added in web pages and the application part could be realized as a Java Applet, which interacts with the viewer.

3.1 Tools

The development environment is VB.Net and for VRML visualization, the Cortona Viewer by Parallel Graphics. Parallel Graphics supports developers by the Cortona SDK (User guide), which allow the Cortona VRML

Viewer be added into the .Net projects as an ActiveX component. There are also some event handler classes to handle mouse events and other interface functions so you can completely interact with the viewer.

3.2 Visualization

The 3D geometry dataset will consists of several ASCII files (temporary) dumped or connected directly form databases, which will consist of point tables. Besides the x, y, z-coordinates each point has got the attributes houseindex, wallindex, kindofwall (roof, wall, floor). With the help of these attributes it is possible to create an IndexedFaceSet-Node (IFS). The used fields are shown in Figure 1. This VRML-Node seems to be the best solution to describe the building geometry, because it can describe complex objects, which consist of several areas, very easily.

```
IndexedFaceSet{
exposedField  SFNode color NULL
exposedField  SFNode coord NULL
field    MFInt32 coordIndex
field    MFInt32 colorIndex
}
```

Fig. 1. Part of VRML Specification '97

Converting the ASCII information (temporary) into VRML syntax will go through the ASCII table first, read the coordinates and the attributes and then decide when to create a new building (IFS-Node), a new area or when to change the color of the created area to color roof and walls differently based on the attribute selected.

To be able to identify the objects, which are essential for the connection, each IFS-Node has to be given a unique identifier. In VRML it is possible to give a Node a name called DEF-Name. In the ASCII file the index for the buildings starts always with one, so if this index is used and the 3D scene consists of more than one temporary ASCII file there is no unique identifier for the buildings. Therefore a combination of filename and index is used to form a kind of primary key for each building, which is also used for the connection later on.

3.3 Connection to attribute data

The connection is done by a geometrical test, similar to point-in-polygon concept. Each building of the temporary ASCII file has got a representative point inside its geometry. The location of this point in the 2D land registry is checked and if the point lies inside of a land registry building's outline, the dataset connected to this outline is considered to be connected to the 3D building. This connection (Abdul Mannan, 2004) is saved in a text file (see Table.1), to avoid doing this test each time a model is loaded.

Table 1. Connection Table

DEF-Name	DBF-Index	Representative3D

In this table ("connection table") the DEF-Name of the 3D object and the corresponding dbf index of the land registry dataset are saved. The representative coordinates are saved in addition for query or analyzing matters.

The concept of the test is fairly simple but there are some more difficult points in programming. To test if the representative is inside of the polygonal outline, it has to be connected with a very far point by a line. Now the intersection points of this line with the outline are counted. Even number of intersection means the point is outside, an odd number of points means point is inside. This test works also if the geometry has got void areas inside (Finley, 1998).

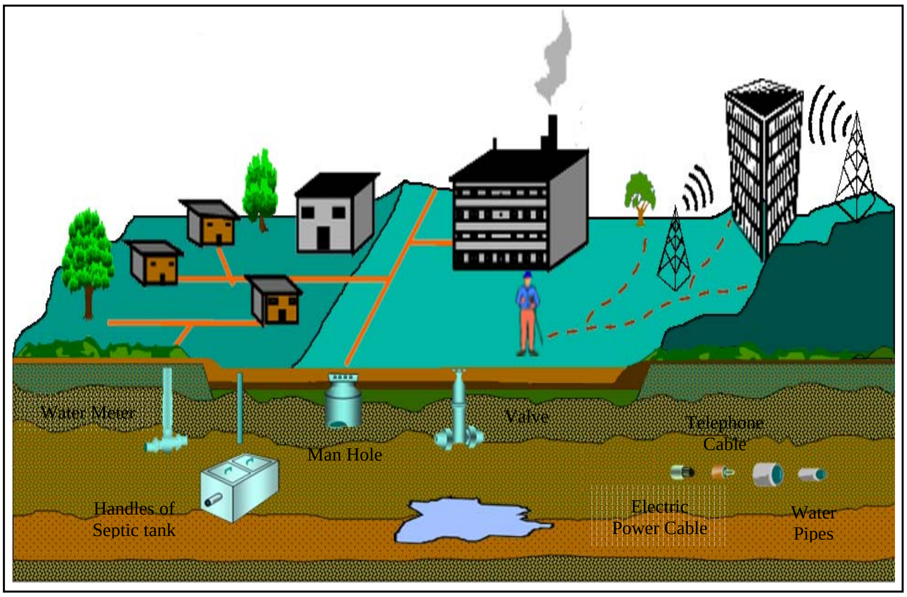

Fig. 2. The anticipated view for 3D Navigation for 3D-GIS.

4. FINAL REMARKS AND FURTHER WORKS

This paper has discussed a few problem arise in implementing 3D navigation for 3D-GIS. An investigation on the support of navigation in real world environment will be carried out to find techniques and solutions for 3D navigation. Several research ideas and some initial requirements of 3D navigation solution towards 3D-GIS also been discussed. To make it more understandable, a simple viewing prototype has been developed as an initial stage of implementation. Eventually, this paper will serve as a starting point for a more challenging research effort and the will be part of on going research program on 3D-GIS.

Currently, map navigation solution in the market doesn't support fully 3D features and functions. In fact, it can only be found as street navigation system in autos and a few only as web-based applications. One major drawback in such system is the support of navigation in real world environment. The system only support for 2D environment. Only basic network analysis can be done. Map landmarks are not emphasized in presentation. For example, maps that served in car navigation system does not help much in visualizing objects e.g. buildings, landscapes, landmarks, etc.

thus making it hard for user to recognized it. The map display buildings or any place of interest as a point feature or as a square box. User interaction with map is not possible, thus information (attributes) for each map features is not shown completely.

Although, there are a few of works devoted to 3D navigation, the research is concentrated around a few basic research ideas. Integration of 3D navigation with current direction and technology for 3D-GIS raises research topics at a database level toward standard object descriptors and operations. It is expected that the outcome of this research could help laymen who often have trouble in understanding or interpreting complex data, but also can help experts in decision making. It is hope further works could focus on data regeneration and management for 3D-GIS. Still 3D-GIS functionality needs to be addressed: 3D buffering, 3D shortest route, 3D intervisibilities are some of the most appealing for research for integrating with 3D navigation system.

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