

A Knowledge Based Decision Support System: 3D GIS Implementation for Indoor Visualisation and Routing Simulation

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ABSTRACT

In this study, a knowledge management based Decision Support System has been suggested. By collecting the data of people, event and properties of building, a 3D navigation system has been developed to support building management and users during the extraordinary circumstances. Most of the current navigation systems are still in the 2D environment and that is insufficient to visualize 3D objects and to obtain satisfactory solutions for the 3D environment. Therefore, there is currently still a lack of implementation of 3D network analysis and navigation for indoor spaces in respect to evacuation. 3D navigation within a 3D-GIS environment (Three Dimensional Geographical Information Systems) is increasingly getting more popular and spreading to various fields. In the last decade, especially after the 9/11 disaster, evacuating the complex and tall buildings of today in case of emergency has been an important research area for scientists. The objective of this paper is to implement 3D visualization and navigation techniques and solutions for indoor spaces within 3D-GIS. For realizing this, we have proposed a GIS implementation that is capable of carrying out 3D visualization of a building model stored in the CityGML format and perform analysis on a network model stored in Oracle Spatial. The proposed GUI also provides routing simulation on the calculated shortest paths with voice commands and visual instructions.

Keywords: *Intelligent Information System; Decision Support System; 3D-GIS; 3D Network Analysis; Indoor Navigation.*

I INTRODUCTION

In this study, a knowledge management based Decision Support System has been suggested. By collecting the data of people, event and properties of building, a 3D navigation system has been developed to support building management and users during the extraordinary circumstances.

Most of the navigation systems use 2D or 2.5D data (e.g. road layer) to find and simulate the shortest path which is lacking in the building environment (1). Therefore, there is a need for different approaches based on 3D which realize the 3D objects and eliminate the network analysis limitations on multilevel structures (2–5).

3D navigation within the 3D-GIS (Three Dimensional Geographical Information Systems) environment is increasingly getting more popular and spreading to various fields. Especially after the 9/11 disaster, evacuating buildings safely by the shortest path in extraordinary circumstances happening in complex and tall buildings has been one of the most important research areas, which is the subject of 3D network analysis applications for indoor spaces.

The objective of this paper is to investigate and implement 3D visualization and navigation techniques and solutions for indoor spaces within 3D-GIS. We explain how to perform 3D network analysis using Oracle Spatial within a Java based 3D-GIS implementation. As an initial step and for implementation, a GUI provides a 3D visualization of the building, and 3D network models based on CityGML data store spatial data in Oracle and then perform network analysis under different constraints, such as avoiding nodes or links in the network model. All experiments highlighted in this paper are performed on the 3D model of the Corporation Complex in Putrajaya, Malaysia. In following sections; first some examples of visualization of 3D building and network models from the CityGML format are given. Then, 3D network analysis tool and gives visualized results of 3D network analysis performed by our proposed 3D-GIS implementation are introduced. Besides, the routing engine integrated in the simulation module of the 3D-GIS implementation, and gives some visualization samples are elaborated.

II VISUALIZATION OF 3D MODELS IN CITYGML

Visualization of a 3D building model is performed by our own proposed Java based 3D-GIS implementation. The implementation uses *citygml4j* Java class library and API for facilitating work with the CityGML and JOGL Java bindings for the OpenGL graphic library to carry out visualization of 3D spatial objects.

The prepared implementation reads CityGML datasets from LOD0 to LOD2. 3D building models are represented in LOD2 described by polygons using the Building Module of CityGML (Figure 1). Network models are represented as linear networks in LOD0 using CityGML's Transportation Module (Figure 2).

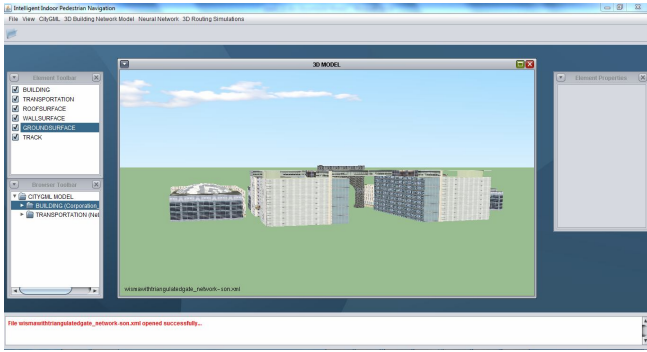


Figure 1. Building model (Textured viewing mode).

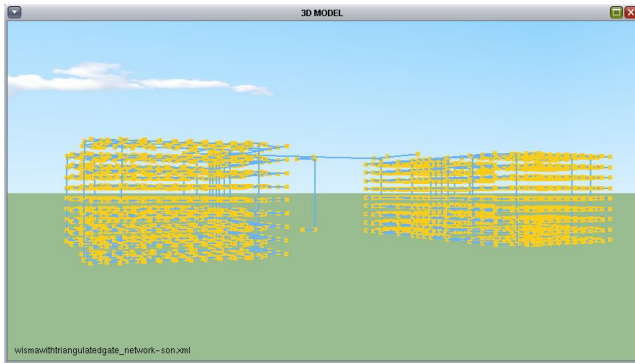


Figure 2. Network model.

III 3D NETWORK IN GEO-DATA BASE MANAGEMENT SYSTEMS

Geo-database management systems (geo-DBMS) are developed for facilitating and organizing works with spatial data. Using geo-DBMS in 3D modelling and spatial analysis has a lot of advantages. Besides the standard advantages of DBMS with respect to centralized control, data independence, data redundancy, data consistency, sharing data, data integrity, and improved security, geo-DBMS brings efficient management of large spatial data sets. The management of a 3D network requires usage of a graph model in DBMS. While CityGML is used to store and visualize 3D spatial objects, the graph model is used to perform network analysis. Oracle Spatial is one of the most powerful geo-DBMS, which offers a combination of geometry models and graph models.

A network is a type of mathematical graph that captures relationships between objects using connectivity. A network consists of nodes and links. Oracle Spatial maintains a combination of geometry and graph models within the Network Data Model. Network elements (links and nodes) may have geometric information associated with them. A logical network contains connectivity information but no geometric information. A spatial network contains both connectivity information and geometric information. In a spatial network, the nodes and links are SDO_GEOMETRY objects representing points and lines, respectively. A spatial network can also use other kinds of geometry representations. One variant lets you use linear referenced geometries. Another lets you use topology objects (6).

In this study, as we define a spatial network containing both connectivity and geometric information, we use SDO_GEOMETRY for representing points and lines.

IV PERFORMING NETWORK ANALYSES FOR DECISION SUPPORT

Our implementation performs network analysis with its network analysis tool based on a Java API provided by the Network Data Model of Oracle Spatial (7).

Our network analysis tool allows doing most common 3D network analyses supported by Oracle Spatial (Figure 3). Some of these analyses are; Shortest path, Travelling salesman, Given number of nearest neighbours, All possible shortest paths between given nodes, All nodes within given distance, etc.

With this network analysis tool it is also possible to perform common 3D network analysis with full functionality including constraints and to see the results on a 3D graphical screen.

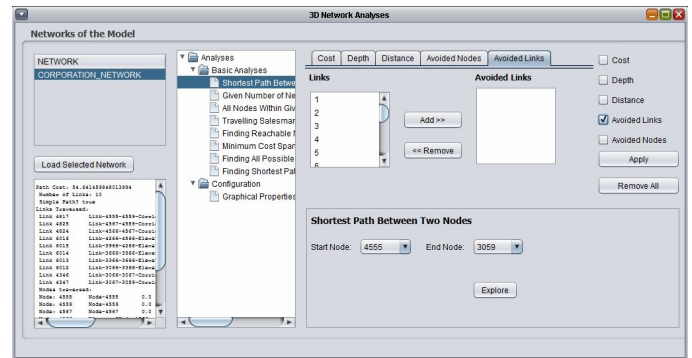


Figure 3. 3D network analysis tool.

Among these analyses, shortest path network analysis is mentioned here. Figure 4 shows a shortest path analysis result without any constraints. To find the shortest path between two nodes, we use the *shortestPath()* method provided by the Java API.

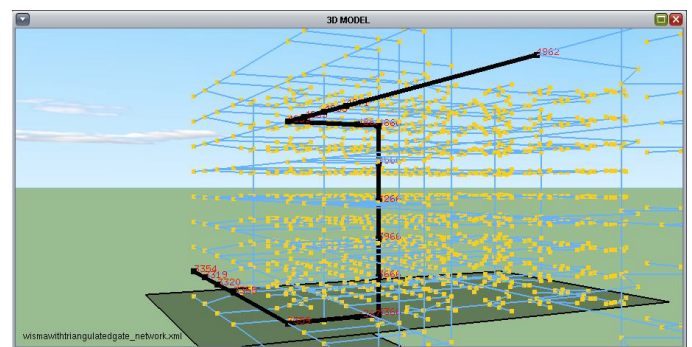


Figure 4. Shortest path between two nodes without any constraint.

V DESIGNING OF ROUTING INSTRUCTION ENGINE

One of the most important components of an ideal evacuation system is an instruction engine which should produce real time instructions for the users to assist them in the routing process until they arrive at their destination. Our implementation has such an instruction engine which is integrated into the simulation module to produce voice

commands and visual instructions for assisting users dynamically on the way to their destination. This instruction engine is intended to be the infrastructure of a voice enabled mobile navigation system for indoor spaces in our future work (Figure 5).

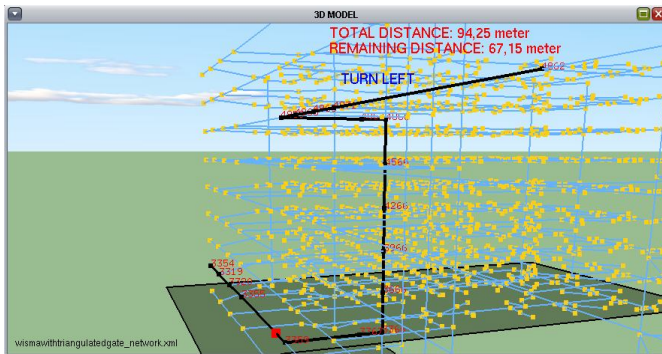


Figure 5. Routing simulation process of the instruction engine (The red point (■) is the user).

The most significant job for producing routing instructions is to determine the direction that users should follow. For generating instruction commands, a method developed by Karas (8) has been used. According to the direction determined by this method, “Go upstairs, Go downstairs, Go on the floor, Turn left, Turn right, Keep going” commands are generated and vocalized while the user approaches each node.

When the red point (the user) passes through a node in the simulation, firstly, the difference of elevations between the first next node and the second next node that the user will visit is compared. If the second next node is at a higher elevation than the first one, the instruction engine generates a “Go Upstairs” command (Figure 6a). If it is lower, a “Go Downstairs” command is generated (Figure 6b).

Apart from these, the user needs to walk on the floor after descending or ascending by using an elevator or stairs. In other words, if the elevation of the first next node and the second next node are equal, but the current node is different, a “Go on the Floor” command is generated.

If the elevations of the three nodes are equal then the instruction engine decides to go straight or turn right or left. To make this decision, perpendicular distance calculations should be performed. By using perpendicular distance calculations of surveying computations, it can be determined if a node is on the right side or on the left side of a line segment. Accordingly this calculation, for a line segment which starts with node A and ends with B, if a node C is on the right side of this line segment then the sign of the perpendicular distance of C is obtained as positive (+), otherwise negative (-) (9). Assuming A is the node that the user passes through, B is the first subsequent node and C is the second subsequent node that the user will visit, if the length of the perpendicular distance of node C to the line segment AB is calculated, the instruction to the user can be determined by checking the sign of the distance. If it is positive (+), the command should be “Turn Right” (Figure 6c), if negative the command is “Turn Left” (Figure 6d). If the calculated

distance is zero the instruction engine produces a “Keep going” command (Figure 6e).

After all these processes, the generated command is vocalized by the simulation while the red point step by step approaches to the first subsequent node. The explanations of the terms of equation in Figure 6 are as follows.

- A: The node that the user is currently passing through.
- B: The first next node that the user will visit
- C: The second next node that the user will visit
- D: The perpendicular distance of the C node to the AB line
- E: The elevation of the nodes
- (AB): Bearing of the AB direction.

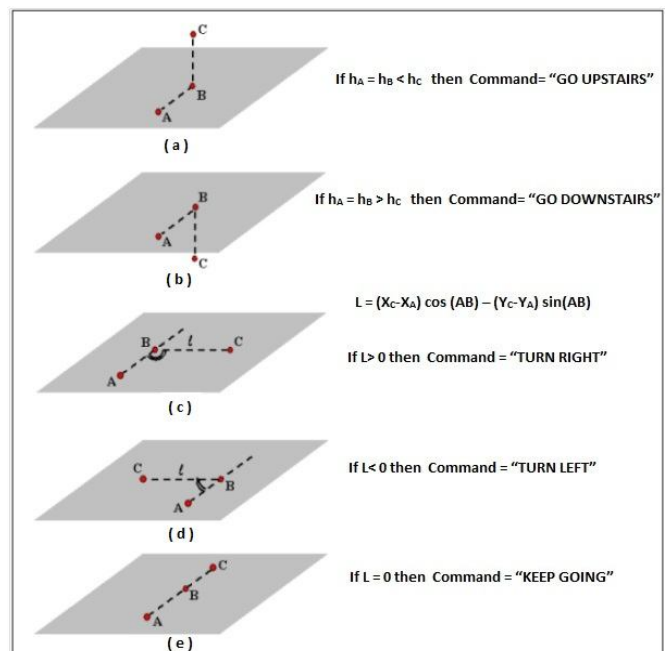


Figure 6. Generating instructions based on side direction calculation for routing.

VI CONCLUSIONS

In this study, a knowledge management based Decision Support System has been suggested. By collecting the data of people, event and properties of building, a 3D navigation system has been developed to support building management and users during the extraordinary circumstances.

This paper presents 3D-GIS implementation which can visualize 3D building and network models based on the CityGML format, automate a 3D network definition in Oracle Spatial's Network Data Model and perform network analysis. We showed examples of performing 3D network analysis with both graph based and geometric constraints applied. We also elaborated a method for generating voice commands and visual instructions for assisting people dynamically on the way to their destination, which is intended to be the routing engine

infrastructure of our intelligent evacuation system work in progress. Our experiments successfully showed that our 3D-GIS implementation could be improved to design an ideal navigation system for evacuation purposes.

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