A 3D MOBILE MAPPING AND NAVIGATION SYSTEM: AUTOMATIC 3D TOPOLOGICAL DATA EXTRACTION, NETWORK ANALYSES, SIMULATION AND INTERACTIVE HUMAN NAVIGATION

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ABSTRACT:

In this paper it is aimed to present a 3D mobile mapping and interactive human navigation system which consists of three components. The first component is used to extract the geometrical and 3D topological vector data automatically from architectural raster floor plan images. The second component is used for network analysis and simulations. It generates and presents the optimum path in a 3D modelled building, and provides 3D visualization and simulation. And the third and the last component is used to carry out the generation of the guiding expression and it also provides that information to the mobile devices such as PDA's, laptops etc via internet. That complete system was generated and tested on a complex building model using GPRS and also WIFI internet connections based on the web technologies. This paper discusses the results gained from the application.

1. INTRODUCTION

Emergency services, transportation, security, visitor guiding are some of common applications of 3D network analysis applications for indoor. Especially, the problem of evacuating the buildings safe via the shortest path, has become more important than ever in case of extraordinary circumstances (i.e. disastrous accidents, massive terrorist attacks) happening in complex and tall buildings of today's world.

The engineers are able to construct complex and state of the art buildings in order to gain more space in narrow cities and increase the life quality in those buildings. Thanks to high technology, high buildings such as skyscrapers provide comfortable life time. However more complex structures bring more complex problems to solve. One of those problems is evacuation of the building in short time in an emergency. Evacuation of the buildings has become more and more important issue especially after 11 September attacks. On September 11, 2001, an estimated 13,000-15,000 persons successfully evacuated the two World Trade Centre (WTC) towers (Gershon et al, 2004). Because full-scale evacuation plans of such buildings are rare, little is known about how readily and rapidly these buildings can be evacuated and what factors serve as facilitators or barriers to the process.

As far as the complexity of the state of the art structures concerned, engineers also should provide evacuation plans for the buildings. However those plans consist in complex algorithms from technological aspect. When we consider online navigation assisted evacuation systems it may need to solve complex topologies, network analyses, 3D modelling and so on.

Currently most of the building plans are represented in 2D with common attributes attached. Therefore, most of the available navigation systems use primarily 2D plans for visualization and communication. These programs have not been structured with respect to the functionality of the building, but largely with respect to the navigation / visualization routes. However, in the last few years, there has been an increasing interest in modelling based on functionality of interiors (Meijers et al, 2005).

In last decade number of studies have been carried out which may assist a building evacuation system. Lee, (2001) has developed a topological data model called the Node-Relation Structure (NRS). In this model, Straight Medial Axis Transformation technique was used in order to obtain the Network Model of a building.

Gillieron and Merminod (2003) have developed a personal navigation system for indoor usage. They have generated a topological model for navigation applications and implemented a route guidance and map matching algorithms.

Meijers et al. (2005) have reported a semantic model representing the 3D modelling of interiors of the buildings to be used for an intelligent computation of evacuation routes. And they have demonstrated and tested that model with an application.

Pu and Zlatanova (2005) have pointed out that automatically extracting geometry and logic models of a building was difficult, and the nodes and links have to be created manually or half-manually.

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In this study, in order to solve the evacuation of the complex buildings problem, a mapping, modelling and navigation system was developed by combination of different algorithms. The system consists of three components:

- Automatic geometry and topology extraction component,
- Network analyst and simulator component,
- Guiding expression generator (Navigation) engine component.

2. AUTOMATIC GEOMETRY AND TOPOLOGY EXTRACTION

Network analyses processes for indoors require 3D models of the buildings. The initial model is called "Building Model (BM)" which provides 3D visualization of the building. 3D BM is stored only for visualization and representation purposes, since it does not contain any topologic information. The main objective of BM is enabling user to see the geometry of the buildings on the screen (Figure 1a).

3D Network model is called "Network Model (NM)" which represents the network in the building based on a graph representation. NM contains the paths between the entities in a building. Each entity is defined as a node, and the links between the nodes are also stored in this model. Therefore, NM is a topological model, since it contains connectivity information (Figure 1b). Besides, it contains geometric information such as coordinates of the nodes and the link lengths for providing visualization and the cost (the shortest/optimum path) computation. The model, which is represented both geometrically and topologically, is called "Geometric Network Model" by Lee (2001) (Figure 1c).

The first component of the system is for automatically generation of BM and NM from architectural plan. By using the method developed in this study, it is possible to generate 3D BM and NM based on the floor plans of the building.

Architectural plans of the buildings are generally either drawn on a paper as blueprints or stored in vector format. Blueprints can be stored in raster formats after scanning process. Whether the floor plan information is in raster or vector format, or even drawn on a form by a user, this method can be applied in any case. The key point is that the images of the floor plan should be represented as image on the GUI. Then the models are generated automatically by analysing and processing those images. Therefore, the method is basically an image processing method and it is named as MUSCLE (Multidirectional Scanning for Line Extraction) Model.

The method, actually, depends on generating middle points of the lines. The algorithm of the method implements the line thinning and the simple neighbourhood methods to perform generation. BM and NM are generated and stored in a geo-database after a series of processes including generating and vectorizing the lines and optimisation.
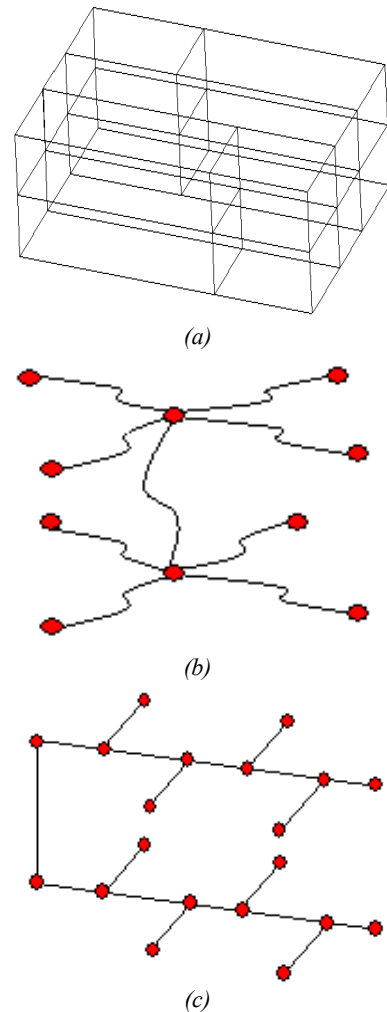

(a)

(b)

(c)

Figure 1. (a) 3D Building Model (b) Topologic Model (No geometry) (c) Network Model (Topology + Geometry)

By using this method, BM is generated at the first stage. As shown in Figure 2, first, lines are determined. Then lines and points, both generate the floor plan, are obtained by determination of intersection points using optimisation process (Figure 2b). Based on user defined data such as floor numbers and heights, 3D BM is generated after designing each floor automatically by assigning different elevation values to floor plan (Figure 2c-d).

In NM, corridor is the main backbone in the floor plan since it connects the rooms with all other entities in a building. Therefore, determining and modelling the corridor is very important. Once the corridor was provided by the user, the algorithm deletes the all other entities from the image except the corridor, and then, determines the middle lines of it. After number of processes on selected middle lines, topological model and coordinates of the corridor are found as seen in Figure 3.
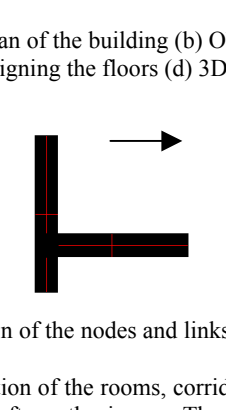
(a)

(b)
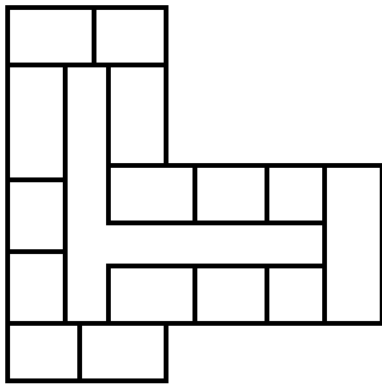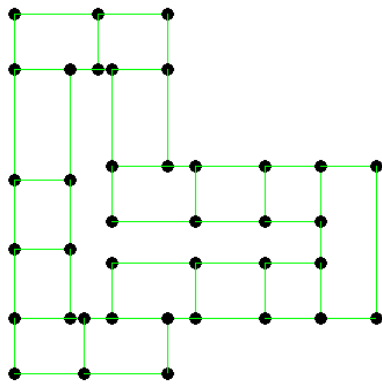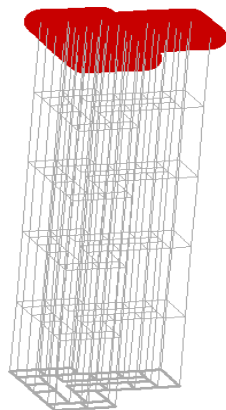
(d)

Figure 2. (a) Floor plan of the building (b) Obtaining the points and the lines (c) Designing the floors (d) 3D Building Model.
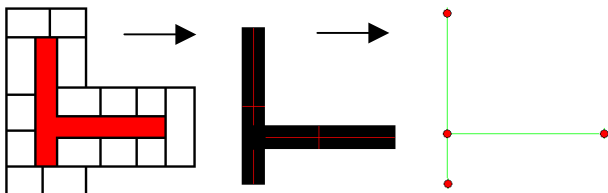

Figure 3. Generation of the nodes and links of the corridor.

During the determination of the rooms, corridor is excluded and only the rooms are left on the image. Then, by applying the method, middle points of the rooms are determined and defined as the nodes which represent the each room (Figure 4).
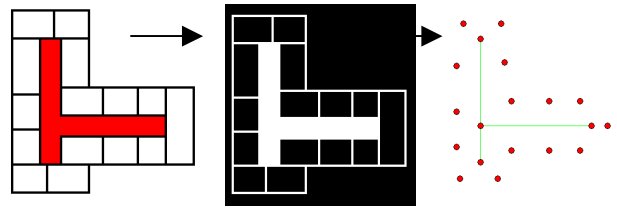

Figure 4. Generation of the Room Nodes.

After locating the nodes that indicate corridor and rooms, user interactively points out which room nodes connect with which corridor nodes, and finally geometric network of the 2D floor plan is generated (Figure 5a). After indicating the stairs (or elevator) nodes, the network is automatically designed by assigning different elevation values for each floor based on various data such as floor number and floor height, and then, 3D NM is generated as seen in Figure 5b.
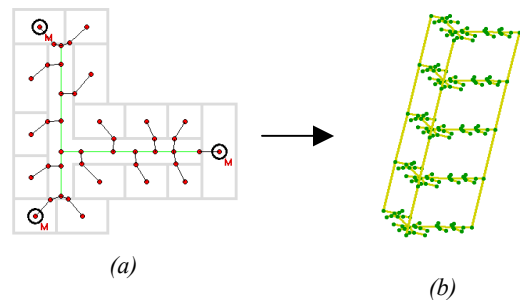

(a)

(b)

Figure 5. Generation of the Network Model.

After the obtaining of BM and NM, that geometric data is stored in a geodatabase. In the next stage, all of the nodes located over NM are processed according to the shortest path algorithm developed by Dijkstra (Dijkstra,1959). This process calculates the distances between all of the nodes in each other, and finally that data is transferred and stored in a geodatabase.

3. 3D NETWORK ANALYSES AND SIMULATION

Applying the network analyses can be possible over the data obtained regarding to the previous chapter. In the analyses stage, it is possible to view the 3D building model and complete network on the screen (Figure 6). When users select two entities, optimum path between them and cost is calculated and represented (Figure 7). Afterwards, user can continue to next stage called simulation stage. In the simulation stage, a floating cursor moves over the path in order to simulate a walking person respect to the given orders. For that, first, the turns, descending and ascending ways are calculated between nodes and floors, and instructions are defined respect to the calculations. Then, according to the path and calculations, moving person is simulated on the screen by a floating cursor over the path line step by step, and also direction instructions are spoken by computer by using the text speech algorithms, and written on the screen (Figure 8).
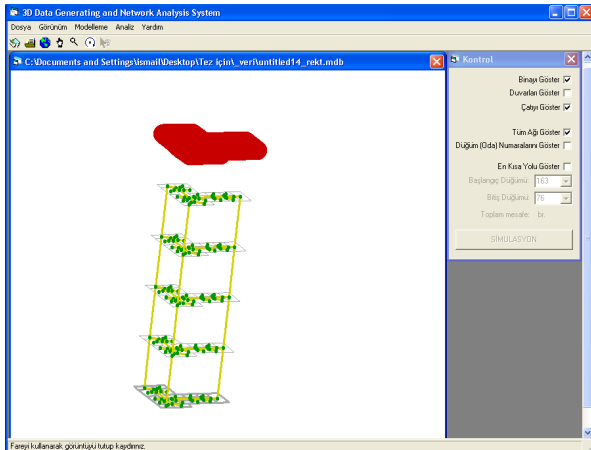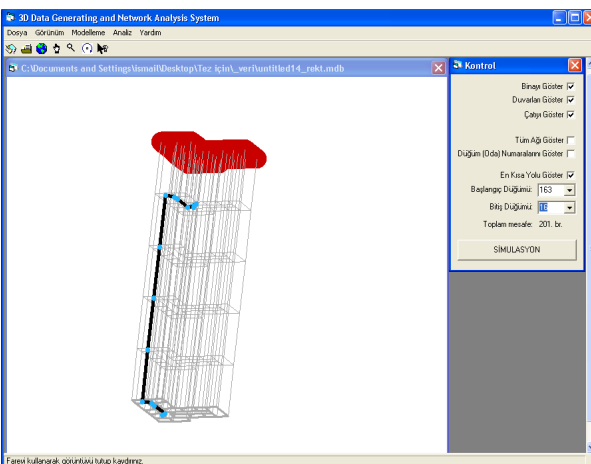
Figure 6. 3D Building and Network Models.

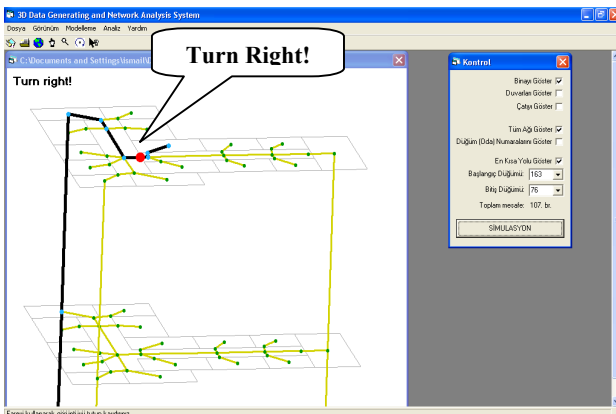Figure 7. Optimum path between two entities.

Figure 8. Audible and Visual Simulation.

4. NAVIGATION

The last component of the system is navigation component which provides online and real-time navigation to the user via internet. Navigation component is a server side component and it is developed with ASP, VBScript technologies. This component also contains a database application. When the complete model generated regarding to the previous sections, data can be used for online navigation.

The component was designed to be used by people in a building over internet. Since the people evacuating the building are mobile, it was considered to be online system over internet. In order to supply software independency, system was designed and developer web based; so, the only prerequisite component for users is a web browser enabled mobile devices and internet connection. While the network analyses and guiding engines are deployed on the server side, users can revoke web services via internet (Figure 9).
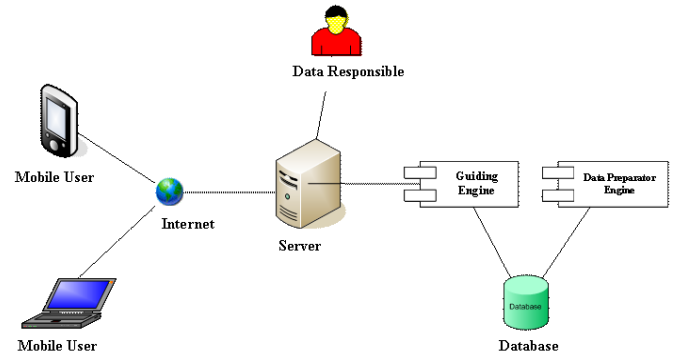

Figure 9. System Architecture of Navigation Module

In this stage user may have a mobile device such as a PDA or a laptop computer. The only prerequisite is to have a HTPP protocol enabled web browser and internet connection via either WIFI or GPRS. When there is an available internet connection, user can open the web page which is designed for navigation process. This page, first, need variables which define "node to go" and "from node" parameters. User selects the "from node" which indicates the current location of the person. Then, as a second parameter user selects node to go as "node to go" which indicate the target location (Figure 10a). When the parameter selection completed, server side listener activates the processes in order to store the parameters in the database. The listener application checks the database periodically, when the data entry process occurs, it defines the shortest path and stores it step by step. Any modification on the database triggers processes and returns the direction information to the user via ASP web pages.

When user gets the direction instructions, then system needs information that indicates the user arrived or completed the task. In that case user approves the received task from web page and sends that information to the server (Figure 10b). Since locating the user is not possible without special indoor instruments, system works with user interaction. When user approves all the task send by server, target destination is reached (Figure 10c).
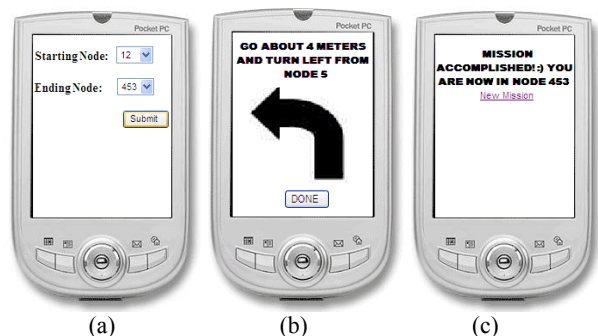

(a)   (b)   (c)
Figure 10. Human navigation by using mobile devices.

The test of the system was done in 2 building blocs of Yildiz Technical University successfully (Figure 11). In that test, a windows mobile 5 based handheld device and wireless connection were used.
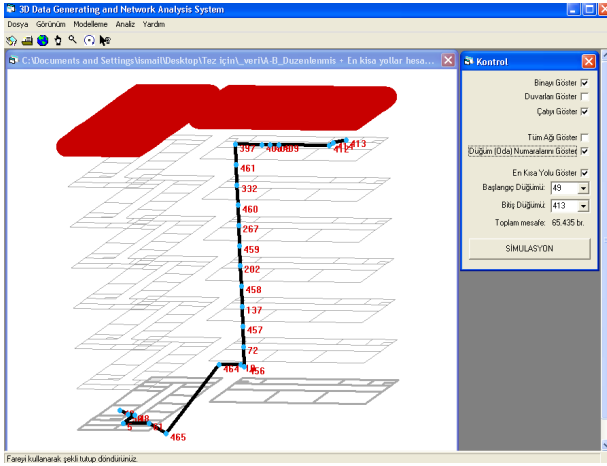

Figure 11. Testing the navigation system in 2 building blocks of Yildiz Technical University.

5. CONCLUSIONS

In this paper, a 3D mobile mapping system that is developed for multi storey and complex buildings is presented. It is also exposed that the MUSCLE model which is developed in this study, is able to use the data extracted from the floor plans of the buildings automatically for 3D network analyses. And after the tests of the system, it was revealed that the navigation application of the system can direct people successfully in tall and complex buildings, online and real- time.

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