3D GEO-INFORMATION FOR LADDERL TRUCK FIRE-FIGHTING SIMULATION IN URBAN AREAS

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ABSTRACT: Fire departments use ladder trucks to achieve rescue, ventilation, access to upper floors and fire suppression on many fire scenes, especially in urban areas. In a fire scene, the most challenge of ladder trucks is the limitation of their aerial. Firefighters can pull more hose to reach the fire, but they cannot stretch more ladders to reach the fire building. Therefore, the first-in brigades need to evaluate the fire scene for optimal ladder trucks placement. However, positioning ladder trucks will be a challenge because of the tight competition for space at the fire scene. For example, the placement of ladder trucks may be complicated by the location of fire trucks, ambulances, police cars and hose line. The objective of this study is to simulate the operations of ladder trucks in a virtual 3D city environment. Before firefighters' arrival at a fire scene, the best position for ladder trucks can be determined, and other vehicles should move to other positions in order to avoid blocking the ladder trucks. Therefore, the ladder trucks can maximize their scrub area for any potential objective. This study can be used as a method to help firefighters quickly locate their ladder trucks, so as to reduce the response time after an incident.

1. INTRODUCTION

The fire-fighting operation of a public fire department provides important aids for the fire victims, which has a very close relationship with people's lives and property (Deng et al., 2001). Fire departments use ladder trucks (aerial apparatus) to achieve rescue, ventilation, access to upper floors and fire suppression on many fire scenes, especially in urban areas. In a fire scene, the most challenge of ladder trucks is the limitation of their aerial. Firefighters can pull more hose to reach the fire, but they cannot stretch more ladders to reach the fire building. Therefore, the first-in brigades need to evaluate the fire scene for optimal ladder trucks placement. In a fire scene, placing the ladder trucks near the fire building so that firefighters can use the aerial is vital. However, it will become a challenge because of the tight competition for space at the fire scene (Bernocco & Andrus, 2003). For example, the placement of ladder trucks may be complicated by the location of fire trucks, ambulances, police cars and hose line.

A virtual 3D city model can be used in different application areas such as disaster management (Over et al., 2010). Virtual reality (VR), which involves modeling, simulation, and visualization, is a powerful technology for users to interface and interact with virtual environments. Many advanced decision support systems for emergency management rely on geographic information systems (GIS) technology and virtual instrumentations (Beroggi et al., 1995). A virtual environment can provide a variety of fire-fighting scenarios for instruction and evaluation in a more realistic manner than verbal or written material and with less risk and expense than fighting with real fires.

The objective of this study is to simulate the operations of ladder trucks in a virtual 3D environment. Before firefighters' arrival at a fire scene, the best position for ladder trucks can be determined, and other vehicles should move to other positions in order to avoid blocking the ladder trucks, which is a priority. Therefore, the ladder trucks can maximize their reach area for any potential objective, and then they can offer unique capabilities for access, rescue and elevated master streams.

2. MATERIALS AND METHODS

In this study, the system architecture is shown in Figure 1. The system consists of a 3D viewer, a 3D building model, a 3D geometric network model (GNM) and virtual ladder trucks. Virtual ladder trucks allow the users to simulate the positioning and operations of aerial ladders. In addition, this study uses a particle system to simulate fire and quenching-water. The particle system is a method for modeling fuzzy objects such as fire, fumes, clouds, and water (Reeves, 1983). Table 1 provides a summary of the data used in this study as well as its sources, and the data types.

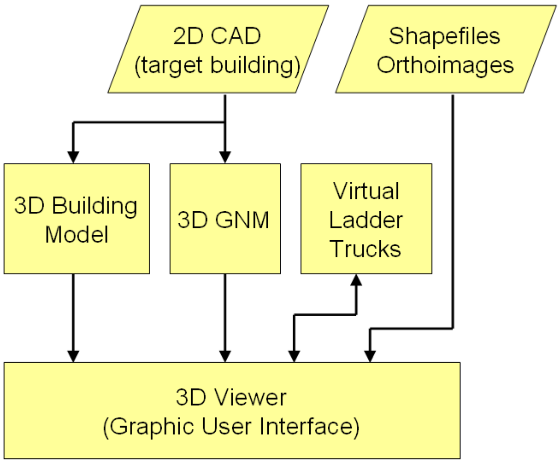

Figure 1. The system architecture.

Table 1 Summary of the Data Used in this Study

Data	Data type	Source
Buildings	Vector: shapefile	Taoyuan City Government
Roads	Vector: shapefile	Taoyuan City Government
Hydrants	Vector: shapefile	Taoyuan County Fire Bureau
Orthoimages	Raster	Taoyuan City Government
Target building (hotel)	Vector: CAD	Shanghai Fire Protection Engineering Co.

2.1 Simulation of Ladder Trucks

According to the NFPA 1901 standard, a ladder truck (aerial apparatus) is a vehicle equipped with an aerial ladder, elevating platform, aerial ladder platform, or water tower that is designed and equipped to support fire fighting and rescue operations (NFPA, 2003). Figure 2 shows main two types of ladder trucks used by Taoyuan County Fire Bureau, Taiwan. In general, a ladder truck contains: a driver’s cab and a chassis, a base support system, a turntable, telescopic booms, an articulated arm and a cage. Figure 3(a) shows the components of an aerial ladder platform. In this study, the ladder truck can be interpreted as a large scale robot with four rotary axes and one translational axis represented as follows: (1) raising-lowering (-10°-80°); (2) running in-running out (0-20 m); (3) rotating (not limited); (4) articulated arm flexing (0°-175°); and (5) cage rotating (-50°-50°). Figure 3(b) shows the rotation and translation of a ladder.

Figure 2. Two main types of ladder trucks: (a) turntable ladder and (b) aerial ladder platform.

Figure 3. (a) Components of a ladder truck and (b) rotation and translation of a ladder.

2.2 3D Building Models

2D floor data were derived from 2D building plans, which are CAD files and commonly used as digital blueprint of a building. Then 2D floor data (e.g. walls, columns) were extruded by their height values to create 3D floor structures. Finally, these structures were added to construct a 3D building model (Figure 4).

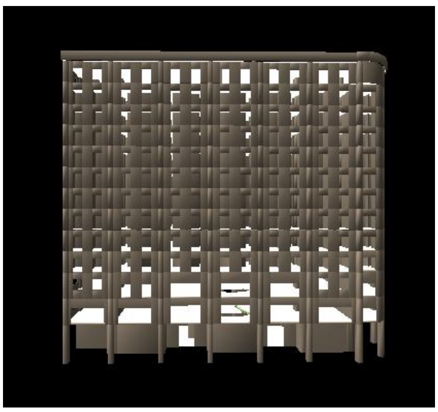

Figure 4. 3D building model.

2.3 3D Geometric Network Models (GNM)

In this study, we used the method proposed by Wu and Chen (2010) to generate 3D GNM from 2D building plan. Two-dimensional polygon layer data were derived from 2D floor data. These polygon layer data were divided into four parts: stairs, rooms, hallways and doors. For the rooms, doors and stairs, the location (x, y-coordinates) of the nodes was derived from the centroid of the polygons, and z-coordinate of the nodes was obtained from the CAD files. For the hallway, the medial axes were drawn to represent the routes (edges) of the hallways. Each node representing the rooms was connected with its doors. Then, each node representing the doors was projected and connected into the medial axis if there was a connectivity relation. In case of an emergency such as a fire, the usage of elevators or escalators inside the buildings is excluded by firefighters; therefore, vertical connectivity is defined only by the location of stairways. Finally, 3D GNM of the building was constructed by these nodes and edges (Figure 5). A node consists of an identifier, a position data in 3D (x, y, z -coordinates), a floor and a name. An edge contains an identifier, a start node, an end node, and a name. In this study, the Dijkstra (1959) algorithm is used to perform network-based analysis such as shortest path analysis.

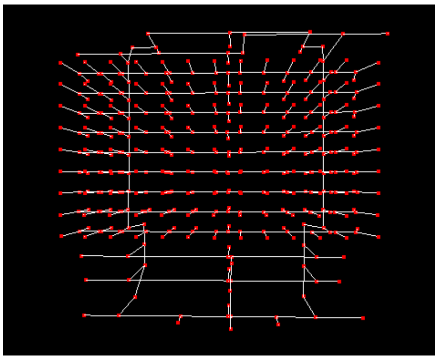

Figure 5. 3D geometric network model.

3. EXAMPLES AND TESTS

The system is established in a C++ and OpenGL™ environment. It consists of a 3D viewer module for simulating the positioning and operations of aerial ladders. When choosing the placement position for the aerial ladders, firefighters should consider the following: (1) whether immediate rescue is apparent, (2) where no immediate rescue effort is required, the size of the frontage of the building to be covered in case of future need, (3) smoke, heat or fire causing an exposure that would endanger a victim, a member or the ladder and (4) area or street conditions that might hamper optimum positioning (NYCFD, 1986). In this study, the target area is a hotel with 13 floors which is located in Taoyuan County, Taiwan. Two scenarios are provided below to illustrate the rescue route analysis and to represent the operations of ladder trucks in a virtual fire-fighting environment.

3.1 Fire Scenario I

Suppose that a fire occurs in Room 719 on the 6th floor of the building. The local fire brigade with a 32-m aerial ladder platform rushes to the scene in order to rescue the people and put out the fire. Firefighters with fire hoses decide to walk to the room from the ground level in order to extinguish the fire. The building's fire alarm system acquires a signal about the location of the fire through fire detectors. The name of the room is then input into the system and the results show the ID and the location of the room (Table 2). Figure 6 shows the shortest path (green line) from the entrance of the building to the disaster site. Once the rescue route is determined, it can be used as a navigation tool for firefighters in a virtual environment (Figure 7). In this case, the shortest path is 65 meters. This information provides firefighters a reference for preparation of hoses when they arrive at fire.

Table 2 Results of the Attribute Query (Room 719)

ID	X (cm)	Y (cm)	Z (cm)	Floor	Name
139	4204	331	2140	6F	R719

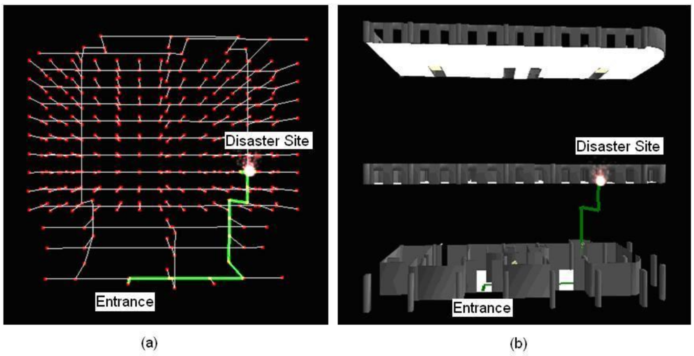

Figure 6. Shortest path analysis: (a) 3D GNM and (b) 3D floor structure.

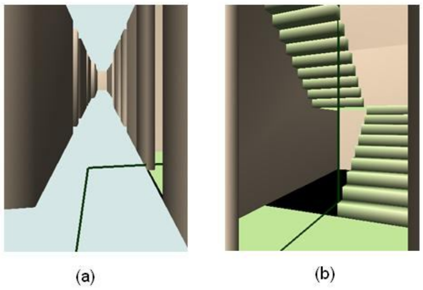

Figure 7. Rescue route navigation: (a) in a hallway and (b) in a stairwell.

3.2 Fire Scenario II

Suppose that Room 719 on the 6th floor is still on fire. Smoke spreads rapidly and fills the corridor. Some people are trapped by the smoke in Room 721 on the same floor. People who are trapped at the room call the emergency number (119) and tell the firefighters where they are by cell phone. The name of the room is input into the system and the result shows the ID and location of the room (Table 3). Since the room is accessible by the 32-m ladder truck, firefighters decide to immediately rescue the people using the ladder. According to the system, the building is next to a two lane road (width: 19 meters) which is wide enough for the placement of the ladder. The best position for the ladder truck is (280571.2, 2767340.1) in Taiwan Datum 1997 (TWD97) coordinate system. Figure 8(a) shows the location of the ladder truck, and Figure 8(b) shows the entrance of the Room 721.

Table 3 Results of the Attribute Query (Room 721)

ID	X (cm)	Y (cm)	Z (cm)	Floor	Name
136	5140	429	2140	6F	R721

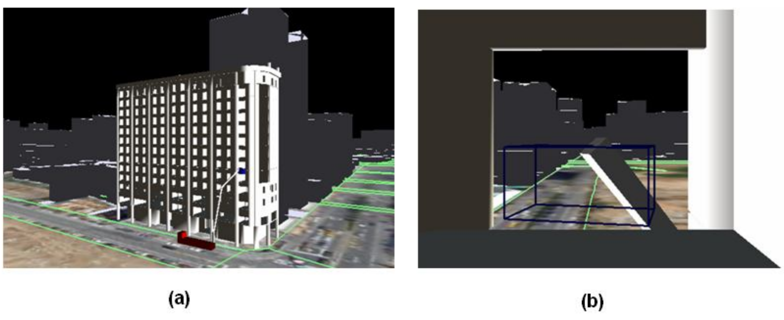

Figure 8. (a) Location of the ladder truck and (b) entrance of Room 721.

4. CONCLUSIONS

This study provides a virtual fire-fighting environment for firefighters to simulate the positioning and operations of ladder trucks. Before firefighters' arrival at a fire scene, the best position for a ladder truck can be determined, and other vehicles (e.g., fire trucks and ambulances) should move to other positions in order to avoid blocking the ladder truck. Therefore, the ladder trucks can maximize their reach area for any potential objective. In addition, because conducting fire drills in modern buildings under realistic fire conditions may be difficult, this study can also provide a virtual fire drill environment for a local fire department to simulate fire-fighting operations.

There are some limitations for further research. First, obstacles such as trees, power lines and signboards may influence the operation of ladder trucks in a real fire scene. Therefore, this system might be integrated with a 3D city model, and more realistic scenarios should be considered. Second, 3D building models used in this study are not state-of-the-art. Another source for acquiring 3D building data could be the building information model (BIM). The most important characteristics of BIMs are 3D information and semantic information. Thus, the applicability of BIMs in geospatial environment may provide a 3D visualization environment with sufficient geometric and semantic information about buildings (Isikdag et al., 2008).

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