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WIRELESS FIRE DETECTION SYSTEM WITH GIS TECHNOLOGY FOR FIRE AND RESCUE APPLICATION

Muhammad Salihin Ahmad Azmil, Norsuzila Ya'acob, Khairul Nizam Tahar, Azita Laily Yusof and Mohamad Aiman Zainali

Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM), Shah Alam, Selangor, Malaysia

E-Mail: salihinazmil@gmail.com

ABSTRACT

The purpose of the Fire and Rescue Service is to protect human life, our property, and Earth natural resources from fire and other emergencies. With fluctuation in demands, the Fire and Rescue Service must equipped with the best techniques, training regime and equipment to meet public expectations. Mitigation, preparedness and risk management have taken on new benefit with challenges facing the fire service today. Fast response cannot be achieved without good planning and preparedness. As a result, three-Dimensional (3D) city and building models for Fire and Rescue Applications have become an important part of GIS network analysis. This technology can help Fire and Rescue service to work in complex and unfamiliar indoor environments.

Keywords: Geographical Information Systems (GIS), three-dimensional (3D) model, network analysis.

INTRODUCTION

Wireless Sensor Network is a collection of node distribution that capable on operating with the presence of minimal user whereby one user can monitor several nodes. Wireless Sensor Network can be the most useful way to collect various parameters and all the information needed by environments. The information gather by the sensor from the environment is able to be interpreted by Geographical Information Systems (GIS). GIS are used in many fields of study and application, including transportation network analysis. GIS allows users to manage, visualize, present and analyse spatial data. Navigation systems are the fast developing area of GIS. GIS map can also provide information of the latitude and longitude coordinates and heading directions for navigation. This positioning information can be used in a GIS to analyse the real world or create models.

The purpose of the Fire and Rescue Service is to protect human life, our property, and Earth natural resources from fire and other emergencies. With fluctuation in demands, the Fire and Rescue Service must equip with the best techniques, training regime and equipment to meet public expectations. Mitigation, preparedness and risk management have taken on new benefit with challenges facing the fire service today. Fast response cannot be achieved without good planning and preparedness. Many airports, office buildings and department stores have complex floor plans. In such environments, most of normal map is not sufficient and time consuming in helping the Fire Fighter to navigate during fire emergency. Therefore, 3D map will provide better view of the building plan as well as shortest route to required destination. Furthermore, not knowing the source of fire and its location can also delay the work of the fire fighter**.** Able to pinpoint the source of the fire will make the rescue operation smoother.

3D network analysis study will give the Fire and Rescue Department a new way on navigating in complex and confusing building plan. The old ways of using floor plan map is time consuming and time is very crucial when we are dealing in emergency cases. Effective response cannot be continually achieved without adequate planning and preparedness. A good way of navigation will lead to faster response and decision making of the Fire Fighter. A 3D view of the building and corridor will give the Fire and Rescue Department a better view of the emergency site. This study will also help in saving life and property during fire emergency.

LITERATURE REVIEW

3D Geographical Information Systems (GIS) and wireless fire detection system

3D Geographical Information Systems (GIS)

Geographical Information Systems (GIS) are used in many fields of study and application, including transportation network analysis. GIS allows users to manage, visualize, present and analyse spatial data. Navigation systems are the fast developing area of GIS. Global Positioning Systems (GPS) provide information of the latitude and longitude coordinates and heading directions for navigation. This positioning information can be used in a GIS to analyse the real world or create models.

In combination, these technologies provide sophisticated tools for emergency management. Emergency evacuation is an important issue for large buildings and facilities. The purpose of evacuation management is to evacuate people from danger zones through exits within in the shortest time. Examining the catastrophe of September 11th, (Erden and Coksun, 2001) argued that it is possible to reduce injuries and the loss of life with good planning and emergency preparedness.

The collapse of the World Trade Centre (WTC) and serious structured damage to the Pentagon on that day restricted access spots and influenced the evacuation

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speeds significantly. The implementation and support of network-constrained navigation systems could help address these evacuation problems. Network analysis can help identify the fastest route to an exit and assess how factors such as crowding and walking speed affect evacuation.

3D Geographical Information Systems (GIS) and indoor environments

3D Geographic information systems (3D-GIS) are also needed in more and more fields. As argued that with the increasingly population in amount and density, 3D land use and development had attracted more and more attention from governments. The requirements for 3D GIS have risen rapidly. The functionalities of 3D GIS models have been tested in many scenarios. The determination of shortest routes and simulations of complicated phenomena, such as cyber cities or digital cities are examples. Cyber cities require sophisticated visualization models and the comprehensive information and integrated layouts of features in the real world.

Skyscrapers and other kinds of huge buildings were built during the 20th century all over the world in order to save land space of the cities. These constructions may have very complex indoor environments: multiple levels, labyrinth floor plans, dense populations, and elaborate flow patterns. All of those complicated situations make indoor navigation more difficult in times of emergency. GPS can be difficult to use in many indoor environments. Many GIS applications have been developed for indoor applications, such as integrated GIS, 3D navigation, and mobile with 3G capabilities for GPS. Nevertheless, all of those technologies were initially designed for outdoor application. GPS information can be transferred fluently in the open areas argue (Li and He, 2011), nevertheless the signal will be interfered by walls when used in the circumstances inside the buildings. The use of GIS applications in indoor environments is also limited by the 3G capabilities of mobile devices and by computing power needed for analysing complex systems (Coors and Kray, 2011). Individual networks must be built to reduce these limitations from the start.

METHODOLOGY

Network analysis

Network analysis usage in GIS is in 2 dimensional (2D) environment. It uses 2D or 2.5D data (e.g. road layer) to locate and result the shortest path route. In some other situation, road networks layer were overlaid with Triangular Irregular Networks (TIN) for best visualization scene, but the shortest path results are still using 2D horizontal plane for the distance calculation. Shortest path algorithm such as Dijkstra is the most common algorithm used in finding shortest path which has a lower computational complexity (Zhan and Noon, 1998). For the past years, lot of study (Demetrescu and Italiano, 2005), (King, 1999), (Ramalingam and Reps, 1996) have focus on developed and tune the current Dijkstra algorithm for a lot of benefit (e.g. static and dynamic shortest path problems) which it is still under fundamental algorithmic method that are the kernel of shortest paths. GIS software creator used these algorithms (mainly static shortest path algorithm) for their 2D network analysis engine. The focus still uses 2D data model and the data manipulated into the routing algorithm is limited and therefore it impossible be used in 3D network analysis practice, thus it cannot to do navigation in 3D-GIS environment.

There are a few study done (Coors, Flick and Köninger, 1998), (Bartel and Zlatanova, 2000) related towards 3D GIS for web-based and urban development, but these researchers' only devoted on concepts, establishing framework and its application from a bigger scope of view. While in (Altmaier and Kolbe, 2013), (Kolbe, Gröger and Kolbe, 2005), (Döllner, 2006), (Döllner and Hagedorn, 2007) were making pretty much on the improvement of virtual 3D city model using different technique (such as CityGML) and its usage for managing and manipulate urban data, and visualizing and navigating (in 2D) the city models. Since data management and visualization is the focus, there is a need for a real 3D routing from the research idea which it can be extended towards 3D navigation for 3D-GIS.

Dijkstra algorithm

Dijkstra algorithm could be used in 3D environment and optimized the algorithm especially for 3D indoor navigation. Figure-1 shows the basic elements needed to calculate the distance between two nodes in 3D space. x1, y1, z1, and x2, y2, z2 are coordinates from node 1 and node 2.

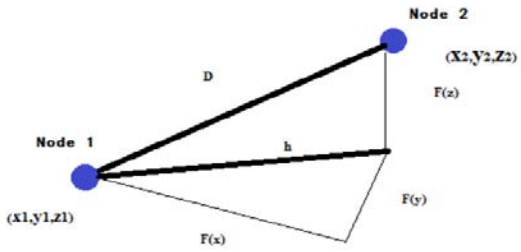

Figure-1. Basic elements needed to calculate the distance between two nodes in 3D (Li and He, 2011).

Node 1's extended line and the Node 2's vertical line intersects. The letter "h" is the distance between Node 1 and the cross point O. Then the distance (D) between node 1 and node 2 can be calculated as these two equations in Equation (1).

$$D = \sqrt{[\Delta x]^2 + [\Delta y]^2 + [\Delta z]^2} \quad (1)$$

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D = distance,
x = x-plane,
y = y-plane,
z = z-plane

Wireless Sensor Network (WSN)

Wireless Sensor Network is a collection of node distribution that capable on operating with the presence of minimal user whereby one user can monitor several nodes. WSN was built from many numbers, in which each point is connected to one or many sensor. For example, one point is attached to many sensors such as temperature sensor, pressure sensor and gas sensor.

Wireless Sensor Network can be the most effective method to collect a lot of data and all the information needed by environments such as in industrial, shipboard, home, building, utilities and transportation system automation. But the sensor is resources constrained which include the battery life, communication bandwidth, CPU storage and capacity. The main function of wireless sensor network is to determine the environmental conditions that are monitored by sensing some physical event. Sensor network consists basically of a large number of sensor nodes deployed in a large physical area to monitor and track the activities of real-time environment. This sensor nodes works together to collect data such as temperature, humidity, and acceleration from the environment.

In each of sensor network node consist of several parts which are the radio transceiver with an inside or outside connection to an antenna, a microcontroller which are the electronic circuit for connecting with the sensors and power supply, usually a battery.

Smoke alarm detector

The contribution in development of smoke detector was from research made by Walter Jaeger in 1930. In the early 1940's, the first smoke detector was developed by (Meili and Jaeger, 1940) that required high voltage power input. Then (Duane D. Persall, 1965) created the first affordable home smoke detector that using individual battery powered that can be replace and install easily by the users. then invented the first automatic fire alarm in 1890 (Francis Robbins Upton, 1890) that give great contribution to today smoke alarm detector.

Smoke alarm, both ionization and photoelectric type using a piezoelectric horn to inform the consumer that the smoke alarm has been activated. Piezoelectric horn sound source is a piezoelectric diaphragm. Diaphragm consists of a piezoelectric ceramic plate, which has electrodes on both sides, and metal plates are usually made of brass or stainless steel.

When voltage DC is used for piezoelectric diaphragm electrode, it causes a mechanical distortion of the piezoelectric element. A piezoelectric element either expands or contracts depending on the polarity of the applied voltage to the piezoelectric elements. Metal plate that was attached to a piezoelectric element do not expanding. It wills alternately repeated expansion and contraction when the voltage AC is used for electrodes producing sound waves in air.

The unit that most commonly used to measure the sound intensity is in decibel (dB). Decibel scale is a logarithmic scale, an increase of 10 dB in sound intensity represents 10-fold increase in sound power and 100-fold increase in sound pressure since the noise power is directly proportional to the square of sound pressure. Whereby the sound pressure is measured with a meter sound-stage.

RESULTS AND DISCUSSIONS

Wireless fire detection system

Wireless Fire Detection System prototype design consists of both smoke sensor and Camera (image sensor). Figure-2 shows the Arduino Wireless Fire Detector hardware.

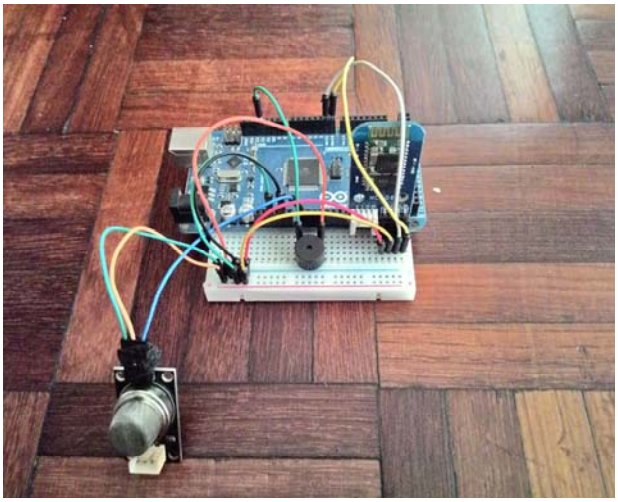

Figure-2. Arduino wireless fire detector hardware.

The Wireless Fire Detection sensors in Figure-2 are compute by Arduino Mega microcontroller. Then the Wireless Fire Detection prototype will send all the sensor data to the monitoring system wirelessly by using the wireless module.

This devise will warn the user if fire emergency in the building happen. It also informs the user the location of emergency. This will give great help to fire-fighters in their rescue operation. Arduino Fire Detector also help in giving inside view of the emergency site due to image sensor installed.

The capability and sensitivity of the sensor use as well as the range of coverage by the wireless module use in the device will be crucial factor in the limitation of the device.

3D Geographical Information Systems (GIS) map

Three-dimensional (3-D) models are more useful rather than two-dimensional (2-D) maps because they

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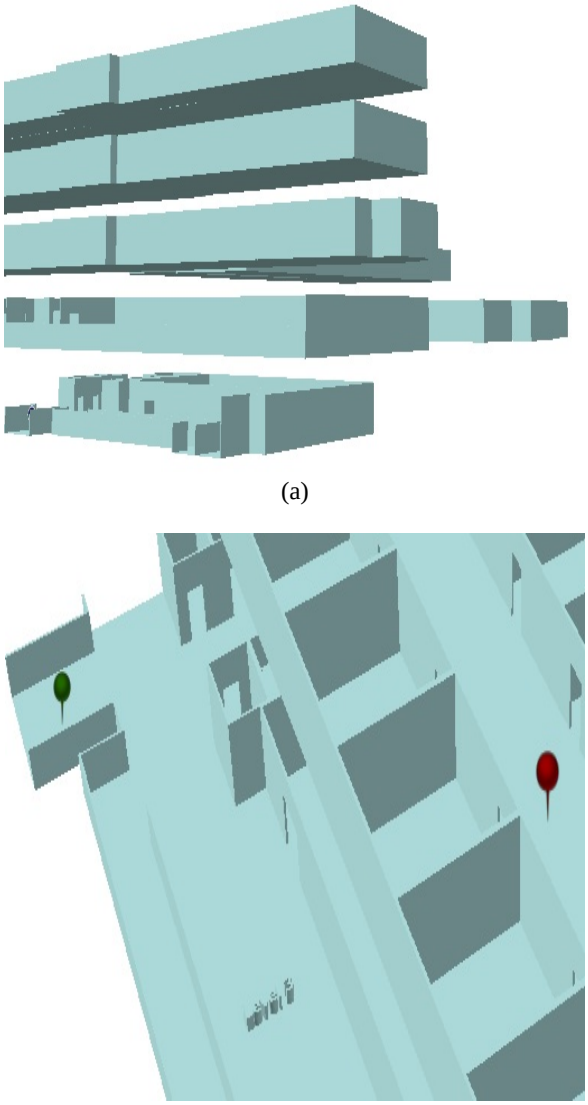
provide more representation (such as colours and shapes) and thus a better resemblance of real world objects (Skarkawi et al., 2011).

3D network analysis of a building for Fire and Rescue Applications, which was based on a 3D model of Faculty of Electrical Engineering building (S &T) in MARA University of Technology (UiTM), Shah Alam as shown in Figure-3 (a) and (b).



(a)

(b)

Figure-3. 3D model of Faculty of Electrical Engineering building (S&T).

3D network analysis study shown in Figure-3 (a) and (b) will give the Fire and Rescue Department a new way on navigating in complex and confusing building plan.

The old ways of using floor plan map is time consuming and time is very crucial when we are dealing in emergency cases. Effective response cannot be continually achieved without adequate planning and preparedness. A good way of navigation will lead to faster response and decision making of the Fire Fighter. A 3D view of the building and corridor will give the Fire and Rescue Department a better view of the emergency site.

The major scope of the project is to develop and investigate a GIS network analysis, which was based on a 3D model of Faculty of Electrical Engineering building. Other building cannot be used in this system.

Geographical Information Systems (GIS) Network Analysis.

Route finding has been always utilize by ordinary people in navigating from one destination (of origin) to another (destination). And lot of the route are in two dimensional routing or network. Figure-4 shows network analysis routing process on ArcMap.

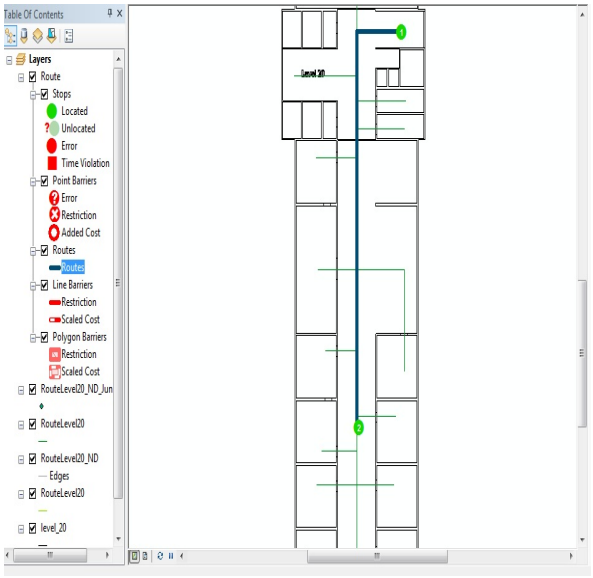


Figure-4. Network analysis routing process on ArcMap.

In orthogonal perspective, 2D or 3D routing uses planar or non-planar graph and spatial extension, where the third dimension is used to formularize the weights for the data in the graph (Ivin et al., 2007). Usually way finding is done in a planar graph embedded in 2D space like shown in Figure-4. Sometimes it is extended to non-planar graphs to model building, etc. but still picture in 2D space. For sample, if the network model type is planar (directed) graph, where the point as 0D coordinate (x, y) in 2D space, therefore objects such as building, skyscraper, etc. cannot be modelled.

As for non-planar (directed) graph, where point as 0D coordinate (x, y) in 2D space, objects such as

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building, skyscraper, etc. can be modeled but road length cannot be derived from the model (directly). And as for 3D space (which is the target of this study), objects such as building, skyscraper, etc. can be modeled in a non-planar (directed) graph, with point as 0D coordinate (x, y, z). Street length can only be derived from the model, if curve are close to original road geometry, which is no need for routing. For way finding, a point is need at each point etc. A slope street with no junction still can be modeled with two point and one curve for way finding purposes even if it is far away and has many serpentines as usual in the hills but this is the geometry part of the network.

3D Navigation and estimated time of arrival (ETA)

The network analysis routing will give up the shortest route travel to the desire location. . Figure-5 shows the 3D result of route analysis.

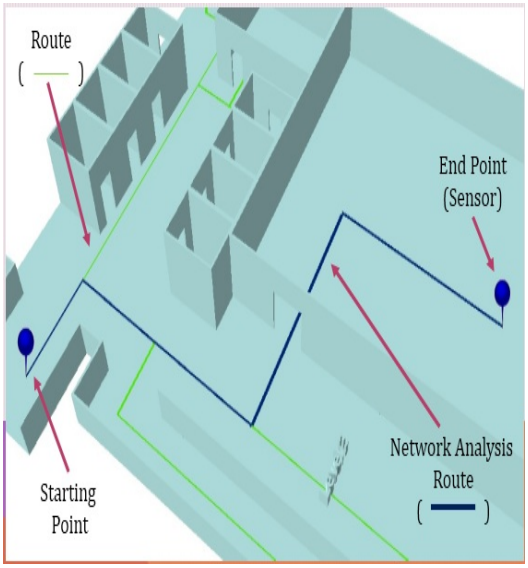

Figure-5. 3D result of route analysis

While Figure 6 show the estimated time of arrival (ETA).

Marker shown in the Figure-5 above is the starting and the end point where the end point will refer to the location of the sensor. The route network analysis result which is represent in blue line shown in Figure-5 and 6 will then be exam in Excrescence so that a 3D view can be made. Network analysis also can be manipulated to predict the time of arrival. The speed assumption for the fire fighter to travel is based on the Fire fighter Recruitment Physical Fitness Test.

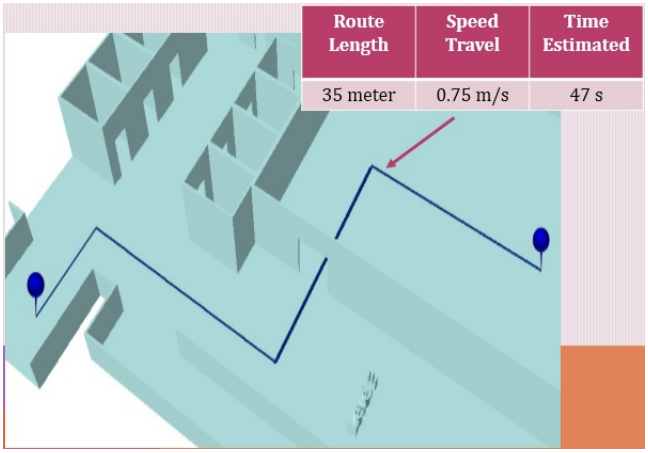

Figure-6. Estimated time of arrival (ETA).

Add on location

Another location such as the nearest exit from the sensor and fire hose also been added to the map as shown in Figure-7.

Figure-7. Nearest exit from the sensor and fire hose location.

The red dot marker in Figure-7 shows the location of the fire hose in the building, while the green marker shows the nearest exit.

CONCLUSIONS

This study suggests that a monitoring system for Fire and Rescue Application using both Electronic engineering and Geographical Information Systems knowledge is design. 3D map from GIS will help the fire fighter in their navigation in complex and confuse building plan. Information on Geographical feature for example route length and estimate time of arrival provide in the map will be beneficial in emergency operation. The fire fighter also will get the inside visual and the location of

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emergency area due to image and smoke sensor installed in the wireless fire detection device. Although this study is only focusing on Faculty of Electrical Engineering UiTM, another building plan, map and etc. can be forwarded as future study and development.

NOVELTY

When fire emergency happen in a big building, it is hard for the fire brigade to react to the situation as they are not familiar with their surroundings. Most of the fire brigade used an old 2D floor plan of the building in order to navigate them self and planning for the rescue mission. By using the new 3D map, it is easier for the fire brigade to navigate themselves and also increase their response in planning for rescue mission. All the navigation routes in the map are result from GIS network analysis, where the shortest distance to the required destination is display. Other data such as estimated time of arrival to the location and the route length are hoped to help the fire and rescue team. The GIS 3D map will also be equipped with a wireless fire detector. When the fire emergency happens, we don't want the sensor device disconnect from the monitoring system and by connecting the sensor wirelessly will solve the problem. The wireless fire detection device will warn when fire emergency happen by trigger the buzzer and send its position to the monitoring system. The advantage tin pinpoint the source of fire will give a great advantage for the fire-fighter to execute their mission. In conclusion, Fire and Rescue Service must utilize the best tools and it is believe the crossover between two knowledge which is electronic engineering and geometric knowledge will serve them well in their rescue mission.

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