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GEOGRAPHICAL INFORMATION SYSTEM (GIS) MAP FOR FIRE AND RESCUE APPLICATION

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Graphical abstract

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 be 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 faced by the fire service today. Fast response cannot be achieved without good planning and preparedness. This 3D network analysis model identifies the shortest path from the Fire and Rescue Service position to the source of emergency. The second objective was to design wireless fire detection systems to help fire-fighters to pinpoint the emergency call location, assess the potential consequences, and determine the most efficient strategy. The 3D model was built by Google Sketch Pro 8 and the 3D network analysis and it was mainly conducted in the ESRI's ArcGIS software. The 3D network analysis was based on distance measurements instead of GNSS coordinates. The distance of each path will be measured on the site personally for maximum accuracy. The fire detection systems prototype hardware will be equipped with smoke sensor, image sensor, a transmitter and a receiver.

Keywords: Geographical Information Systems (GIS), three-Dimensional (3D) model, Network analysis

1.0 INTRODUCTION

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. Geographical Information Systems (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 [1].

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 be 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 faced by 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 maps are 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 [2]. 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 continuously achieved without adequate planning and preparedness.

2.0 LITERATURE REVIEW

3D Geographic information systems (3D-GIS) are also needed in more and more fields. As argued, the increasing 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 [3].

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.

3.0 METHODOLOGY

3.1 Network analysis in 2 Dimensional (2D)

A transportation network is a flow network representing the movement of people, vehicles or goods. The approach is adopted almost universally to represent a transportation network by a set of nodes and a set of links [4]. The nodes represent points in space and also possibly in time, and the links tend to correspond to identifiable pieces of transport infrastructure (like a section of road or railway). Links may be either directed, in the case where they specify the direction of movement, or undirected. In graph theoretical terminology, a transportation network can be referred to as a valued graph, or alternatively a network [5]. Directed links are referred to as arcs while undirected links as edges.

Other useful terms with some intuitive interpretations are a path which is a sequence of distinct nodes connected in one direction by links; a cycle which is a path connected to itself at the ends; and a tree which is a network where every node is visited once and only once. The relationship between the nodes and the arcs is referred to as the network topology which can be specified by a node-arc incidence matrix: a table of binary or ternary variables stating the presence or absence of a relationship between network elements [6]. The node-arc incidence matrix specifies the network topology and is useful for network processing.

Dijkstra algorithm could be used in 3D environment and optimized the algorithm especially for 3D indoor navigation [7]. 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.

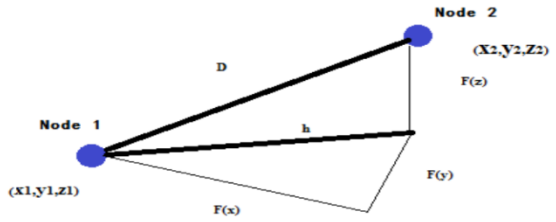
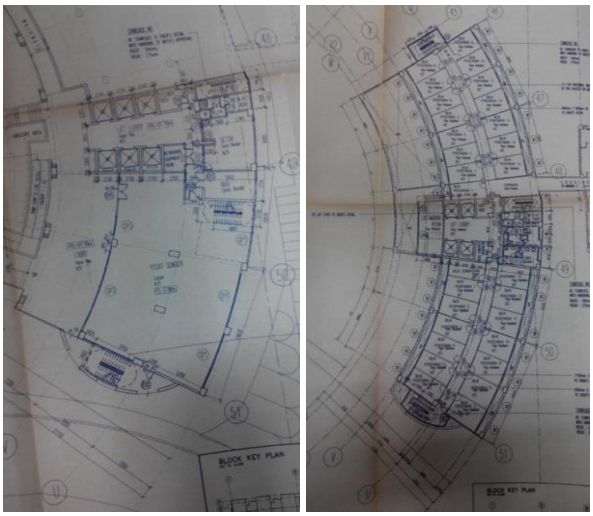


Figure 1 Basic elements needed to calculate the distance between two nodes in 3D

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.

3.2 Object Highlighting

As wireless broadband networks continue to expand, GIS support for a variety of operations becomes possible. Mobile PCs, computer tablets, and handheld devices with GPS and wireless advances allow all the findings in this research to be uploaded online and Fire Department can receive geographic information and incident updates in emergency locations. These GIS perimeters can be uploaded to a server called ArcGIS online. The perimeter polygons are combined with other GIS data on the server including imagery, corridor, and block group census data.



(a) (b)

Figure 2 Blueprint of Faculty of Electrical Enginering building (S&T).

This Web-based GIS application is accessible by authorized Los Angeles city personnel. The GIS application posts the perimeter data and automatically generates a population effects report. Personnel from various departments, such as Public Works, Parks and Recreation, and Emergency Operations, can observe where an incident is occurring; in to the imagery to visualize potential infrastructure damage and threats; understand how many people are affected, displaced, or injured; and determine possible evacuation requirements and officer needs in the rescue operation.

Three-dimensional (3-D) models are more useful rather than two-dimensional (2-D) maps because they provide more representation (such as colours and shapes) and thus a better resemblance of real world objects [8]. All the dimensions to sketch up the plan were referred from the actual blueprint of the building. Blueprint of the building are taken from *Pejabat Pembangunan UiTM Shah Alam* as shown in Figure 2 (a) and (b). The flow chart for Fire and Rescue System are as shown in Fig. 3. Both of the processes are conducted separately because of each of the subject background are different from each other meaning that the wireless Fire Detection Device are mainly designed using the knowledge of electronic engineering.

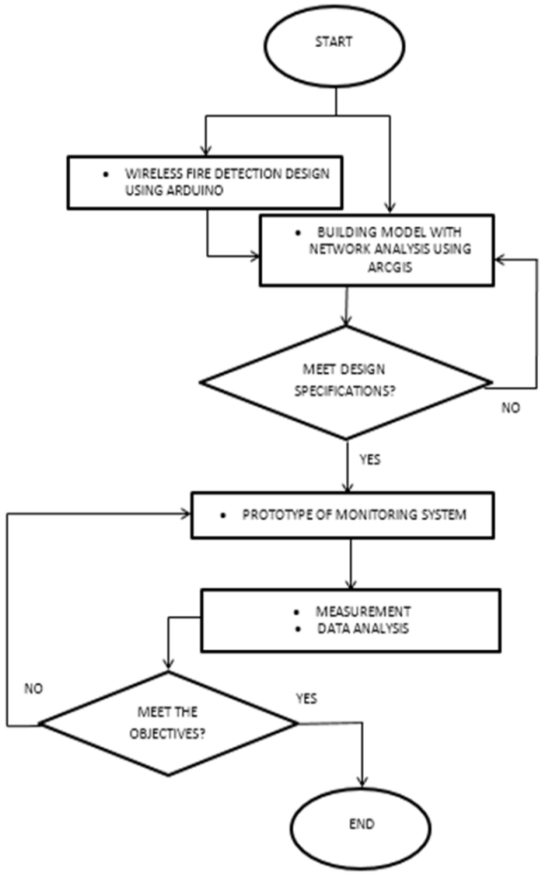


Figure 3 Flow chart in Fire and Rescue System

4.0 RESULT

4.1 3D Geographical Information Systems (GIS) Map

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. First the floor plan of the building will be digitized so that it will be easier to map. Google Sketch Up software has been used to digitize each of the floor plan.

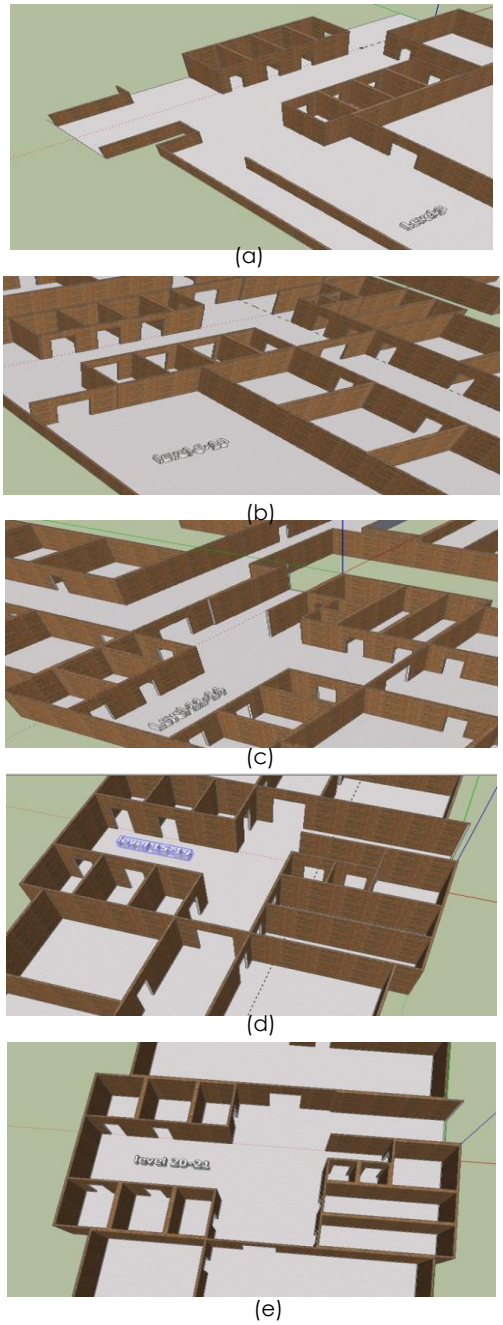
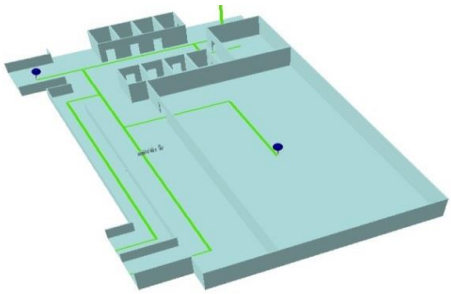


Figure 4 3D model of Faculty of Electrical Engineering building (S&T) using Google SketchUp, (a) Level 3, (b) Level 6-10, (c) Level 11-14, (d) Level 15-19, (e) Level 20-21

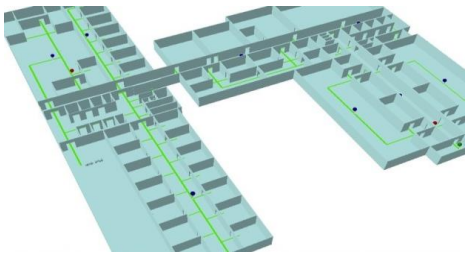
Then each level in this building were then grouped into the same design labels as level 3, level 6-10, level 11-14, level 15-19 and level 20 -21. The results of 3D digitizing for each group were designed using Google SketchUp as shown in Figure 4 (a), (b), (c), (d) and (e).

The complete 3D model sample from the SketchUp will then be imported into ArcGis sotware for network analysis process to take place [9]. A network is referred to as a pure network only if its topology and connectivity are considered. If a network is characterised by its topology and flow characteristics (such as capacity constraints, path choice and link cost functions), it is referred to as a flow network. The old way of using floor plan map is time consuming and time is very crucial when we are dealing in emergency cases. Effective responses cannot be continuously 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. 3D network analysis study shown in Figure 5 (a), (b), (c), (d) and (e) will give the Fire and Rescue Department a new way of navigating in complex and confusing building plan.



(a)



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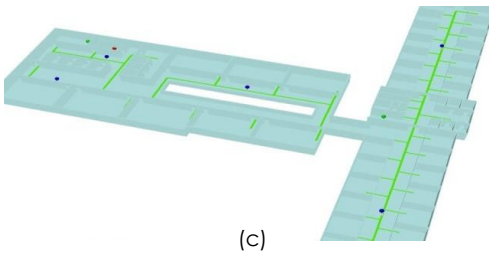

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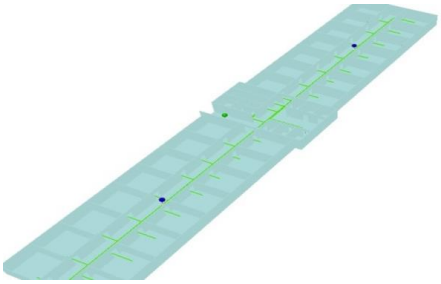
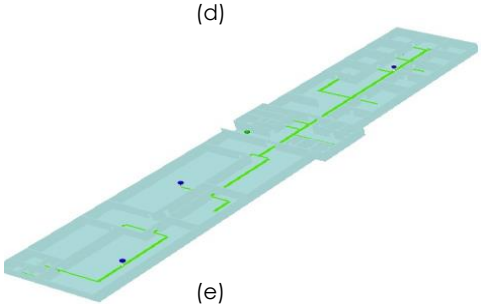


(d)



(e)

Figure 5 Network Analysis of Faculty of Electrical Engineering building (S&T) using ArcGIS software.

4.2 3D Navigation and Estimated Time of Arrival (ETA)

The network analysis routing will give up the shortest travel route to the desired locate on [10]. Figure 6 shows the 3D result of route analysis.

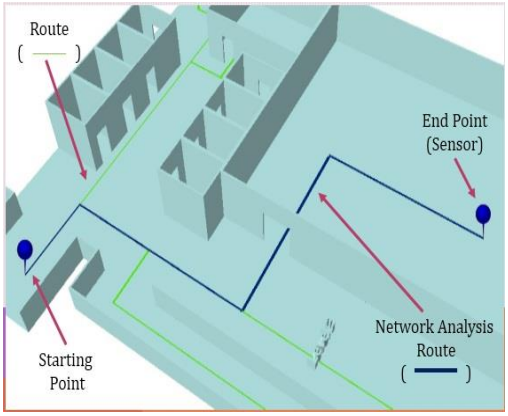


Figure 6 3D result of route analysis

Meanwhile, Figure 7 shows the estimated time of arrival (ETA).

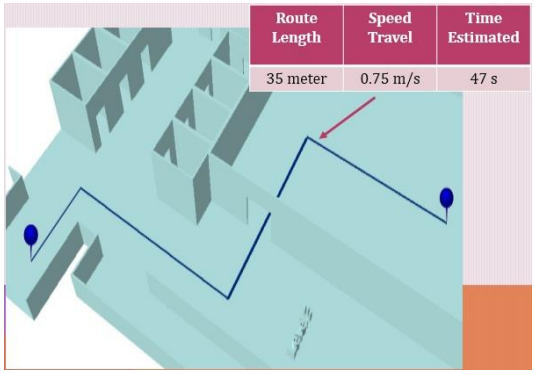


Figure 7 Estimated time of arrival (ETA).

Marker shown in the figure 7 above is the starting and the end point where the end point refers to the location of the sensor. The route network analysis result which is represented in blue line shown in both Figure 6 and 7 will then be examined in Acrscence 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 Firefighter Recruitment Physical Fitness Test. Through speed and distance data, we can get the ETA data using speed = distance/time formula. Another location such as the nearest exit from the sensor and fire hose was also added to the map to assist them (firefighter).

4.3 ArcGIS Mobile and ArcGIS Online

As we know, being a Firefighter requires a lot of searching and movement or might be call as freedom of movement while completing their mission. Therefore, all of the data which are analyzed using ArcGIS of the map will be imported into a mobile device such as smartphone or tablet [11]. This is possible by using ArcGIS Mobile and ArcGIS Online in our device. ArcGIS online will act as a storage device that enable us to keep all the findings online while ArcGIS Mobile will give us permission to access the data via our mobile device. Due to hardware and software limitation of our device, not all interface can be displayed. However, a simplify version will also be helpful to assist the firefighter. The overall map of the building, location, length of route travel, the ETA and even the picture of location will be displayed in the application. Figure 8 (a) anb (b) show the examples of interface of the map using ArcGIS Mobile.

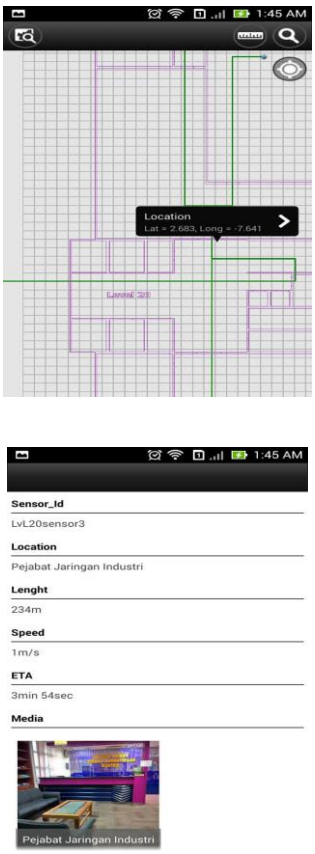


Figure 8 Example interface of the map using ArcGIS Mobile, (a)

4.0 CONCLUSION

This study suggests that a monitoring system for Fire and Rescue Application using Geographical Information Systems knowledge is design. As for the novelty, this 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 purpose of the Fire and Rescue Service is to protect human life, our property, and Earth natural resources from fire and other emergencies. Fast response cannot be achieved without good planning and preparedness. The fire fighter also will also will be given a lot freedom of movement as they can access the map using mobile app via smartphone or tablet. 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.

Acknowledgement

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