GIS-based Routing System for UTM Campus

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Abstract – Universiti Teknologi Malaysia (UTM) has always been to spend a lot of effort in order to enhance the reputation towards a world-class centre of academic and technological excellence (WCU 2010). In this regard, the authorities began to recruit foreign students who come from various countries such as China, Libya and Oman. In order for foreign students are familiar with the environment here as soon as possible, development of a GIS-based routing system is strongly recommended. This system able to assist foreign students adapt to the UTM environment easier. For instance, students can recognize the cultural background of Sultan Ismail Mosque according to one of the buttons there. In addition, this routing system also provides the information pertain location of faculties, residential colleges as well as the bus services information which stored in the database. This system enables users to do query on the bus route in order to extract the information about bus journey time and distance from one place to another. This function helps bus passengers to plan their journey wisely within UTM campus. On the other hand, this routing system also acts as a guidance tool for off-line car navigation. It will reveal the best and the shortest route together with the approximate distance and time. As the procedure, ESRI ArvView version 3.3 software together with the extension which is ArcView Network Analyst is utilized to develop the routing system. In conclusion, users will easier integrate into the UTM environment by using this routing system in text, photos and videos help.

Keyword: GIS, Database, Routing system

I. Introduction

In March 14, 1972, Malaysia’s Supreme Ruler, DYMM Seri Paduka Baaginda Yang Dipertuan Agong officially proclaimed the formation of Institut Teknologi Kebangsaan (ITK) under section 6(1) of the University and University College Act 1971. After that, on April 1, 1975 it was officially declared as Universiti Teknologi Malaysia (UTM). Today, UTM have 20867 local students, 882 international students, 1877 academic staff, and 27 international academic staff [1].

UTM Skudai is the main campus and located about 18 kilometers from the Sultan Ismail Airport of Johore Bahru, Malaysia, which is equipped with complete infrastructures, variety of teaching and learning stuff and graceful education environment in order to support the daily activities of staffs and students. In an effort to introduce the UTM campus to all the new local students and international students, developing an efficient database is required.

The database require a large amount of data for processing, analysis and storage for effectively disseminate information to users. There are some of the example data are collected for instance, information about buildings, road network and bus station. As thus, a geographical information system (GIS) is used to allow large data to be effectively processed, stored, analyzed, logically associated, and graphical displayed.

On the other hand, UTM campus consists of 16 residential colleges, 12 faculties and schools, sports and recreations facilities, student unions, eatery places and a health centre. Moving within the UTM campus is a confusing and frustrating thing without a proper instruction that clearly shows the direction from certain places to destination respectively. Furthermore, some of the roads in UTM are restricted to one-way road, so it will endanger other road user and cause traffic congestion if the drivers mistake the roads.

With the GIS-based routing system, it able to provides a convenient and powerful tool for storage and graphical representation of information, which can be useful to users. Furthermore, by availing the powerful GIS functionalities, a user can conceive a problem and allow the appropriate software to assist
him in the decision-making process regarding optimum route selection and trip planning.

II. GIS and ITS

Geographic Information Systems (GIS) is a management system to data entry, data display, data management, information retrieval and analysis [2]. These systems are implemented with computer hardware and software functions. Some of the existing functions are as follow [3]:

1) Acquisition and verification
2) Compilation
3) Storage
4) Updating and changing
5) Management and exchange
6) Manipulation
7) Retrieval and presentation
8) Analysis and combination

A GIS, simply put, is a spatial database [4]. Geographic locations are stored as sets of mathematical coordinates. Information about the locations is stored in tables that are linked to the locations. Different spatial information is stored in different files, or layers. These layers can be viewed simultaneously. The system can also be queried to extract information from these layers. Hence, GIS is an adequate system to establish comprehensive database in order to suit the user requirement.

Recently, GIS has been incorporated into the emerging area of intelligent transportation systems (ITS), where traditional base maps are updated in real time with information on lane closures and traffic levels, which is then provided to traffic operations, enforcement, and emergency response teams [4]. GIS can be effectively implemented in ITS to improve the efficiency and safety of the transportation infrastructure.

GIS is the type of integrated information system that consists of an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information. GIS can be used effectively for route guidance, en route driver information, and identification of an incident location [5].

With GIS playing a larger role in the transportation industry, state and local governments, as well as public transit operators, have a wider variety of instruments and tools for collecting and processing data. Some of the examples instruments and tools that can be incorporated with geographic information system are as follows [4]:

1) In-pavement sensors, red-light cameras, and closed-caption television (CCTV)
2) Global Positioning Systems (GPS)

In brief, GIS-based ITS applications acquire real-time traffic data from global positioning system (GPS) units, video cameras, and road-monitoring units for en route traffic information dissemination.

III. GIS-based Routing System Development

A. Methodology

Developing routing system under the ArcView GIS environment was the objective of current project. In this system, GIS-enabled modules for the shortest path, closest facility, and campus bus routes have been included. Besides these features bus stations and city bus route are also included. Methodology involved in the development of the system is described in later sections.

1) Route Planning: Route planning is a process that helps vehicle drivers to plan a route prior to or during a journey. In the shortest-path scheme for route planning, the objective is to select and implement vehicle routing algorithms for intra campus route planning while addressing the following issues [6]:

1) Shortest distance
2) Quickest route
3) Vehicle traffic restrictions
4) Drivers travel preferences

Currently, route planning is carried out by using a graphical user interface of the system. For the shortest path computation, length and speed limits of the road segments on that road are stored in a digital database and the travel time was calculated (distance/speed limit). The calculated travel time is used as travel cost in the performance of path optimization. The travel cost represents the cost of traveling over the link and depends on many factors, such as distance, travel time, travel speed, and number of turns. Path optimization
has been carried out using ArcView Network Analyst (AVNA).

2) Closest Facility: In the closest facility problem, route length and travel time (drive time) are considered as travel costs. Different facilities, such as bus stations have been taken as themes in the project. The closest facility algorithm calculates all the routes from the selected origin to facilities based on travel cost. It compares travel costs of these routes and gives one optimal route as output.

3) Campus Bus Routes: Campus buses with their numbers are stored in a database in a compressed format because there will be more than one bus on one road segment. A search algorithm is used to find bus service number from a selected origin and destination. According to the bus number, road segments on the map were selected and highlighted with different color.

B. Source Program

The source program for this system has been written in the avenue programming language. Avenue is an object-oriented scripting language for ArcView GIS in order to automate tasks, add new capabilities, and build applications [8]. The source code is divided into many scripts and each is used for a particular purpose.

C. Work Plan

The following systematic steps are followed for the development of the routing system:

Step 1) collection of digital maps
Step 2) collecting spatial data and attribute data
Step 3) georeferencing of all data sources
Step 4) database creation
Step 5) software development in ArcView GIS

D. Input Data

Routing system development is carried out for the whole UTM campus. The total area of the region is around 1222 hectare. The following data was collected and used in the development of routing system:

- Time tables of campus bus
- Location of bus stops
- Speed limits on roads
- Road names
- Information of one-way road segments

E. Themes and Database

For the current routing system, all the important geographical details of UTM campus are categorized as separate features as depicted as follows:

- Road networks
- Faculties
- Lecture halls
- Residential colleges
- Bus stations
- Administration buildings

For the current routing system, these features are spatially represented as themes. Each theme has discrete characteristics known as attributes that emphatically separate it from other themes. For example, attributes of a street might include its name, type, length. Features and their attributes are linked to each other. Therefore, a user can access or locate any feature from its attributes. All the important information associated with each feature was entered into its theme’s attribute table in order to analyze it. This was accomplished by adding the required number of fields (columns) to the table and entering the data for all the features in their corresponding records (rows). Table I gives the details of fields.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Field</th>
<th>Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration Building</td>
<td>ID</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td>Name</td>
<td>String (35)</td>
</tr>
<tr>
<td></td>
<td>Block_No</td>
<td>String (10)</td>
</tr>
<tr>
<td>Faculties</td>
<td>ID</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td>Name</td>
<td>String (50)</td>
</tr>
<tr>
<td></td>
<td>Block_No</td>
<td>String (10)</td>
</tr>
<tr>
<td>Lecture Hall</td>
<td>ID</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>String (10)</td>
</tr>
<tr>
<td>Library</td>
<td>ID</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td>Name</td>
<td>String (50)</td>
</tr>
<tr>
<td></td>
<td>Others Name</td>
<td>String (10)</td>
</tr>
<tr>
<td>Mosque</td>
<td>ID</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td>Full Name</td>
<td>String (50)</td>
</tr>
<tr>
<td></td>
<td>Others Name</td>
<td>String (10)</td>
</tr>
<tr>
<td>Residential College</td>
<td>ID</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td>Name</td>
<td>String (50)</td>
</tr>
<tr>
<td></td>
<td>Block No</td>
<td>String (10)</td>
</tr>
<tr>
<td></td>
<td>Others Name</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td>Name</td>
<td>String (10)</td>
</tr>
<tr>
<td></td>
<td>Qty Room 1</td>
<td>String (10)</td>
</tr>
<tr>
<td></td>
<td>Qty Room 2</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td>Principal Name</td>
<td>String (35)</td>
</tr>
<tr>
<td></td>
<td>College office</td>
<td>String (20)</td>
</tr>
</tbody>
</table>
Roads in the campus were not classified as various types of roads. This is due to the road type of UTM campus are almost similar. Roads that have names were identified and that data was stored in this database. More than one bus will travel on one road. Storing all bus numbers traveling on each road segment is an intricate task and this increases the size of the database. Hence, all bus numbers in one road segment were stored in one field in a compressed format. In addition, some field for one-way road segment length, speed limit, and drive time was created.

The bus stations database was created in order to identify the location of each bus stop. An ID has been given to each bus stop according to their nearest place’s name. For instance, a bus stop ID is FAB, means that the bus stop located at somewhere around the faculty of built environment. A total amount of 56 bus stops have been observed within UTM campus.

### IV. Using Routing System

#### A. Menus

A menu displays a list of commands that are available to the user. Because menus make commands visible and searchable, a user can use them to his advantage while recognizing commands without remembering them. A menu bar, one of the most common forms of a menu interface, is a special area displayed across the top if a graphic user interface (GUI) directly below, the title bar. Table II gives a description of the menu on the general view of routing system and their functionalities.

<table>
<thead>
<tr>
<th>Menu Name</th>
<th>Sub Menu</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>File</td>
<td>Close</td>
<td>Closes project view</td>
</tr>
<tr>
<td></td>
<td>Print</td>
<td>Prints active project view</td>
</tr>
<tr>
<td></td>
<td>Print Setup</td>
<td>Edits the printer and the printing options</td>
</tr>
<tr>
<td></td>
<td>Exit</td>
<td>Exits from the software</td>
</tr>
<tr>
<td>View UTM</td>
<td>Main page</td>
<td>Display the general view of routing system</td>
</tr>
<tr>
<td></td>
<td>Landmarks</td>
<td>Display the view of landmarks within UTM</td>
</tr>
<tr>
<td></td>
<td>Residential College</td>
<td>Display the view of UTM residential college</td>
</tr>
<tr>
<td></td>
<td>Faculties</td>
<td>Display the view of UTM faculties</td>
</tr>
<tr>
<td></td>
<td>By Aerial Photograph</td>
<td>Displays full view of UTM by aerial photo</td>
</tr>
<tr>
<td>Path</td>
<td>Shortest Path</td>
<td>Gives shortest path</td>
</tr>
<tr>
<td></td>
<td>Closest Facility</td>
<td>Gives closest facility path</td>
</tr>
<tr>
<td>Campus Bus</td>
<td>Bus Route</td>
<td>Shows bus route</td>
</tr>
<tr>
<td></td>
<td>General</td>
<td>Give general information about campus bus service</td>
</tr>
<tr>
<td>City Bus</td>
<td>Bus Route</td>
<td>Shows city bus route</td>
</tr>
</tbody>
</table>

#### B. Buttons and Tools

Buttons and tools are used to provide quick access to specific commands or options. Their name and functionality are shown in a tool tip text when a user moves the cursor on them. Buttons and tools bars description is given in Table III and Table IV.

<table>
<thead>
<tr>
<th>Button Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="Image" alt="Save" /></td>
<td>Saves the Project and all associated objects to a project file</td>
</tr>
<tr>
<td><img src="Image" alt="Delete theme" /></td>
<td>Deletes the active theme from the table of contents.</td>
</tr>
<tr>
<td><img src="Image" alt="Open theme table" /></td>
<td>Open the attribute table for the active theme in the view.</td>
</tr>
<tr>
<td><img src="Image" alt="Label" /></td>
<td>Label the features of a</td>
</tr>
</tbody>
</table>

C. Using General Functions

Figure 1 gives the full view of map with all themes in the routing system. Guidelines for general usage of the map are as follows.

i. Legend of the map is shown on the left side of the map.

ii. Turn themes on and off by clicking a checked box in front it to view the desired themes.

iii. Zoom in or out the map using zoom tools.

iv. Use the simple identify tool to display the simple attribute and coordinate value of selected feature.

v. Otherwise, use the identify combo box tool to show the entire record of attribute for the selected feature.

![Figure 1: General view of GIS-based routing system](image)

D. Viewing the UTM Campus

Clicking the “Landmarks” submenu in the “View UTM” menu in order to have a glance of view to the beautiful scenery within campus which as shown in figure 2. Steps are as follows.

Click on the “Landmarks” submenu in the “View UTM” menu.

i. A UTM landmarks view is opened. Active a theme and open its attribute table using “open theme table” button.

ii. Select the record and minimize the attribute table window. A selected record will be highlighted and shown in yellow colour.

iii. Use the “Show Images” tool and click on the highlighted feature. An image window will pop up.

iv. View the image by clicking previous and next button. If the video clip is available,
the “Hot Link” tool will not be shown disable. Use that tool to click on the highlighted feature, a video clip window pop up automatically.

Figure 2: An image view from the selected feature

E. Searching for Features in UTM campus

Following are steps for searching desired features such as faculties, residential colleges and cafe in UTM campus.

i. Click on the button "Search and Find"
ii. Key in the desired feature’s name or block number in the text box, click OK. The selected feature will be highlighted in yellow colour, as shown in figure 3.

Figure 3: Searching for feature in UTM campus

F. Shortest Path Module

This shortest path module for finding the shortest path and provide the approximate travelled distance and time to user, as shown in figure 4. In order to use this module, the steps are as follow:

i. Activate the road network theme. Click on the button or the “Shortest Path” submenu in the “Path” menu.
ii. A shortest path window will pop up. Change the travel cost from mile to meter or minute by clicking the “properties” button.
iii. There are two method to insert the origin and destination to “Label” column. One is using “Add location” tool, another is using “Load Stops” button.

Using “Add location” tool:

i. Insert the origin and destination using the “Add location” tool to pick the specified location on the map.
ii. After two point is picked on the map, the Label column will have the “graphic pick 1” and “graphic pick 2” in the record.
iii. Click on the “Solve Network” button
iv. The dialog will show the total route cost for that particular path. And the travelled route will be highlighted and shown in the map.
v. Change the route symbol to arrow using the “Legend Editor” button or double-click on that activated theme. Double click the symbol to edit it.

A resulting route is displayed on the map as shown in figure 4.

Figure 4: Searching for the shortest path with picked origin and destination

Using “Load Stops” button

i. Insert the origin and destination using “Load Stops” button in route window.
ii. Select the stop from the choose theme drop-down list. Repeat twice in order to insert origin and destination.
iii. Repeat the steps mentioned above in order to get the shortest path on the map.
iv. The directions from the origin to destination will be displayed by clicking the “Directions” button, as shown in figure 5.
G. Closest Facility Module

The closest facility module is for finding nearby facility from any location on the road network. Steps for finding closest facility are as follows.

i. Activate the road network theme. Click on the “Closest Facility” submenu or click on the button.

ii. Select the desired facility in the facilities drop-down list.

iii. Choose the number of facilities to find.

iv. Give a cutoff cost to determine the area for finding closest facility. Leave it blank means no limitation.

v. Click on the “Load Events” button to select the location from nearby facility. Select the location from the choose theme drop-down list.

vi. Check the box either “Travel to event” or “Travel from event”.

vii. Click the “Solve Network” button.

viii. Change the route symbol to arrow using the “Legend Editor” button or double-click on that activated theme. Double click the symbol to edit it.

A resulting route from a location to nearby facility is shown in figure 6.

H. Bus Service Module

In order to establish a systematic plan for bus service, UTM campus has been divided into four zones as follow:

i. Zone 1 – KTC, KP, K9, K10

ii. Zone 2 – KTDI, KTHO, K11, KTR

iii. Zone 3 – KTF, KRP, K12, K13

iv. Zone 4 – K14, K15, K16, K17

Hence, this view enables user to comprehend the bus route within campus for itinerary planning. Steps involved are as follow:

i. Click on the “Bus Route” submenu in the “Campus Bus” menu.

ii. Select the desired bus route to view.

iii. Use the “Identify Combo Box” tool to select any route on the map, in order to recognize the passed bus type, as shown in figure 7.

V. Future Scope
The proposed routing system can be modified further to an Internet GIS-based application, so that the user can have easy access to it via internet. Further, this routing system can be provided with several routing systems to allow users to select from one of several objectives used to direct the path search. Besides, the database system can be further upgraded to suit the entire user requirement for example, administration purpose.

VI. Conclusion

Routing systems are most widely deployed ITS application areas. With the rapid increase of the Internet and wireless communication in recent years, the application of Internet-based and wireless GIS-T applications to routing systems is growing rapidly (such as the ROMANSE project in Europe) [5]. Implementation of GIS in combination with other advanced communication computer technologies to user information systems enables the dissemination of information pertaining to fixed route facilities, such as offices, educational institutions, health facilities, sports and recreation places. In addition, route planning and spatial and attribute information on transportation facilities within the campus is established. The developed system has the following capabilities:

- viewing UTM campus
- search engine—which searches the features within UTM campus
- finding the shortest path based on distance and drive time
- finding the closest facility and its path based on distance and drive time
- campus bus routes
- provides bus schedule

References