Development of Web-GIS Application for Emergency Route Decision and Planning using AHP analysis and pgRouting algorithm

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ABSTRACT

Routing calculation has an important role to play in emergency responses and decisions. For example, it can help ambulances to take one patient to the hospital as fast as possible. This paper presents the implementation of an alternative method to calculate the travel-time of the route, according to the location of an accident and the situation at the destination point. The minimum travel-time from the accident point to the nearest hospital is calculated and some others parameters are taken into account such as the availability of beds in the targeted hospital and the patient's state. The method is based on an adaptation of the pgRouting algorithm with an analytical hierarchy process (AHP) for the Emergency Route Decision and Planning (ERDP). Moreover, as mobile phones are widely used nowadays, the need for mobile web applications rises. Thus, it should be useful for a driver if they could update the real road condition via mobile devices to give the current road condition and also the client GIS can update anytime and anywhere they goes such as a taxi driver everyday they are going to works and sometime if they met some accident or some problem they can update real time traffic road condition via android devices.

The main objective of this work is to implement ERDP system using pgRouting algorithm and AHP analysis, in order to calculate weights of the impedance elements. The routing algorithm is based on the assumption that the patient's condition and the number of available bed in each hospital are known, and that the real road network conditions are available. Using pgRouting algorithms and AHP, the difference ERDP allows us to compute scenarios and to determine the best suitable routes.

1. INTRODUCTION

On a complicated road networks drivers need a map and navigation tools to efficiently compute routes to their destination points. Nevertheless, these navigation tools should take into account factors that would slow down or even stop the transit in specific roads, such as car accidents or natural disasters such as flooding or landslides, because in a traffic network a road can be temporarily blocked because of car accidents or road work and drivers cannot go through that road. If the navigation system did not update the information and take into the database, the routing result might be not given up-to-date traffic condition routing result.

The main concern is to propose a study which provides an easy interface for the server and client, enabling the system to propose an Emergency Route Decision Planning (ERDP) as per user requirements. Therefore the system needs to respond to state variables that must be kept updated in order to represent the current situation of the road network in real-time. Moreover, currently android mobile devices become mostly used it should be useful for a driver if we could update the real road condition via android devices to give the current road condition.

The mobile application is a term used to describe Internet applications that run on smart phones and other mobile devices. Mobile applications usually help users by connecting them to Internet services more commonly accessed on desktop or notebook computers, or help them by making it easier to use the Internet on their portable devices. A mobile app may be a mobile Web site bookmarking utility, a mobile-based instant messaging client, update data via mobile, and many other applications.

The objective of this work is the implementation of a dynamic routing system for ERDP that depends on real-time road conditions which allows the user update the road data via the mobile devices by using Free and Open Source Software for Geospatial (FOSS4G) and OpenStreetMap data set. In particular, the shortest path algorithm is implemented by using pgRouting software.

The use of the shortest distance method is not sufficient to improve the ERDP systems in the context of complex road networks. ERDP is one of the most important methods regarding route planning. Its applications for flooding, forest fires, earthquakes or tsunamis should be optimized and computed efficiently soon after such disasters occur. Such decisions are quite complex because many different elements must be taken into account in the calculations. In order to improve their efficiency, the Analytic Hierarchy Process (AHP) was chosen for our research.

AHP is a theory of measurement through pairwise comparisons in order to assess the relative weight of multiple criteria and to derive priority scales. The comparisons are made using a scale of absolute decisions that represents the importance of one criterion compared to others. The decision may be inconsistent and measuring inconsistency and improving decisions is a major concern of the AHP (Saaty 2008).

pgRouting is a library which support for shortest algorithms like Dijkstra, a-star, shooting-star. These algorithms assume that the edge weights are static and their values do not change with the current road condition. pgRouting extends the PostGIS/PostgreSQL geospatial database to provide geospatial routing functionality.

2. METHODOLOGY

The entire system completely relies on the FOSS4G stack. Figure 1 show the components of a dynamic routing system framework. The system allows the Client GIS up to date the road data via mobile devices. pgRouting algorithm queries the route from the road database and the road database receives the real-time road condition from the Client GIS. When the Users request the new route is computed and send to the users.

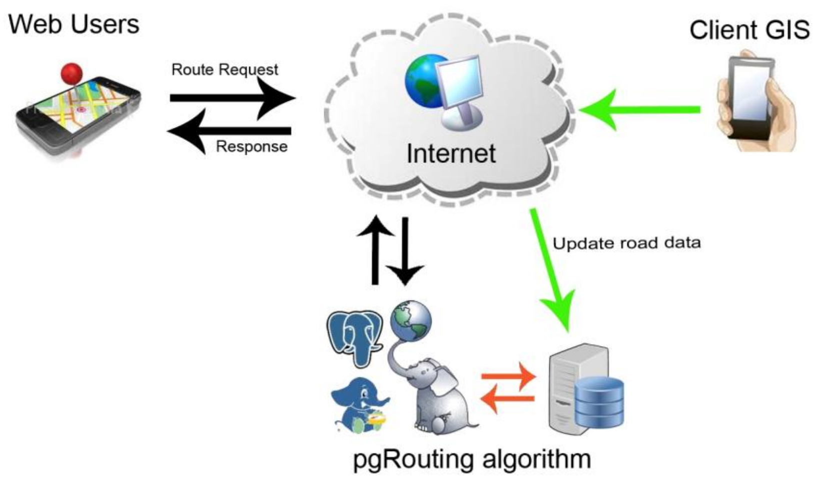

Figure 1 The components of the dynamic routing application

2.1 System Architecture

Figure. 2 show the system routing framework. pgRouting software queries the route from the road database and the road database receives the real road condition information from GIS clients which can update data via mobile devices using jQuery Mobile OpenLayers. The road network data values are including the priority values after calculated using AHP analysis. When the real road condition data is received, the values in the database are updated and then a new route is computed.

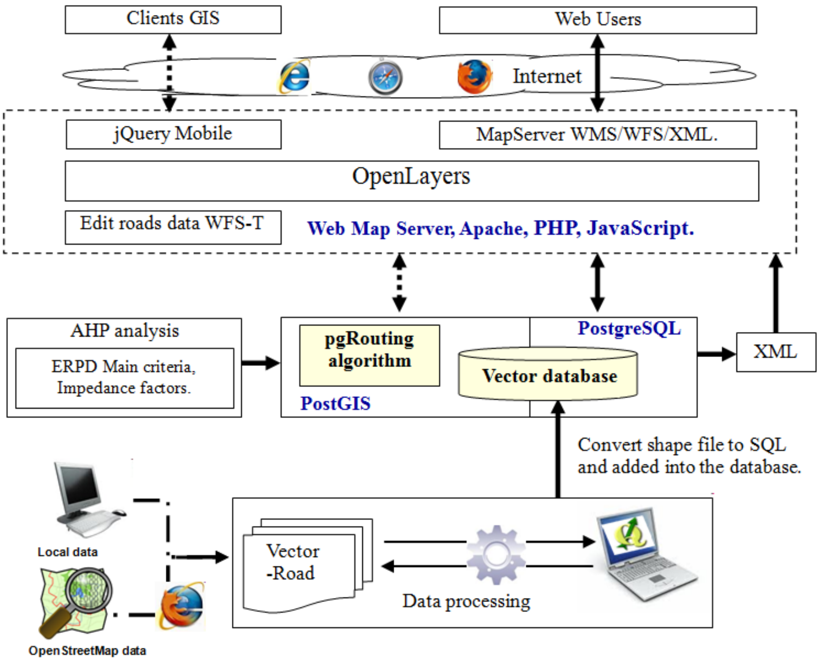

Figure 2 Show the system framework

2.2 jQuery based user interface

jQuery Mobile (jQM) is a set of jQuery plug-ins and widgets that aim to provide a cross-platform API for creating mobile web applications. In terms of code implementation, it is very similar to jQuery User Interface (jUI), but while jUI is focused on desktop applications, jQM is built with mobile devices in mind. jQM providing dynamic user experience in the browser and helping to make traditional desktop applications increasingly rare for web-based applications running on mobile devices (Ableson 2011). jQM uses HTML5, JavaScript and CSS3 features to enhance basic HTML markup to create a consistent mobile experience across supported platforms.

2.3 structuring the hierarchy for evaluation

The AHP method is used to make the arrangement of the problem as a hierarchy. In general, the AHP method divides the problem into three levels. First define a goal for resolving the problem and then define objectives for achieving the goal and finally determine evaluation criteria for each objective (Saaty, 2008).

The hierarchical structure of evaluation is presented in Table 1. The first level is the goal level, and the ultimate goal of evaluation for the ERPD is to determine the condition of road and the condition of the destination point. The second level is the objective level, which includes road condition, patient's state and availability of beds. The third level is the criteria level, which includes 3 main criteria and 3 sub-criteria.

Table 1 Evaluation hierarchical structure for ERDP

Goal	Objectives	Criteria
ERDP	1. Road Condition	Distance, Speed Limit and Junction Delay
	2. Patient's State	Red Code, Normal State
	3. Available of Beds	Yes/No

2.4 Integration of the AHP priority weights value with the pgRouting algorithm

Based on the pairwise comparison between criteria in main criteria and sub-criteria, the priority weight of each element was taken into account to compute the weight value. In order to combine AHP weighted elements with pgRouting, each segment of the road network data must be redefined in the minimal travel-time for ERDP depending on the PS and the AOB values. The combination of the weighted elements with the road length is needed to compromise the impedance element for the ERDP, which results in the minimal travel-time for ERDP. The concept of integrating AHP into the classical Dijkstra algorithm is presented in the following Figure.3.

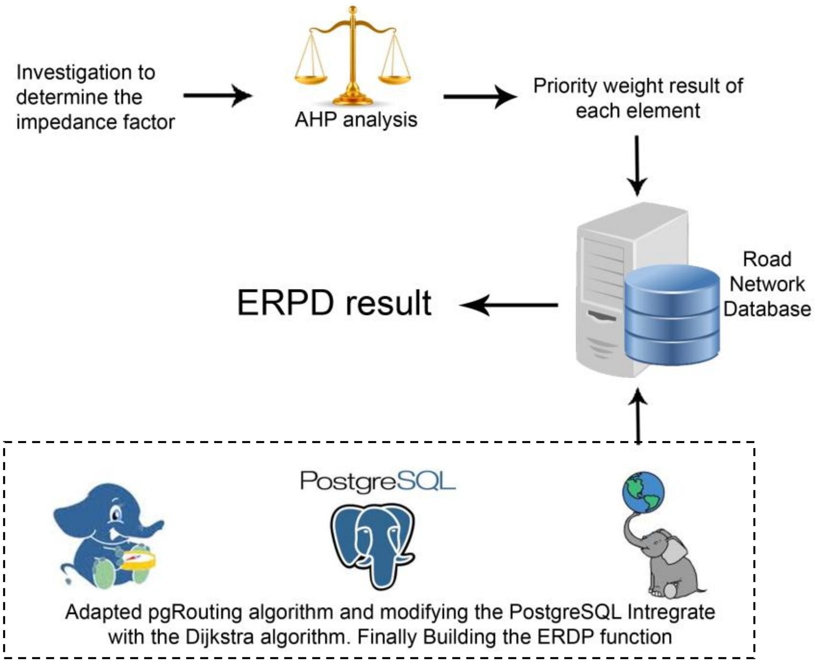

Figure 3. The integration of AHP and the Dijkstra algorithm for ERDP

3. RESULTS

A Web Interface was developed using JavaScript libraries such as jQuery Mobile and OpenLayers. HTML and PHP languages were also used. This web client interface allows the user to edit the cost value of each street segment, using simple touch events and mobile optimized HTML forms. Figure 4(a) shows the system interface rendered into the iPhone device default browser (Safari). The arrow shows an example road segment where an accident occurred and the road is blocked. The road condition thus needs to be updated into the database, in order to get the current real-time road conditions when the users compute the route. This can be achieved by the user by touching the road segment to get its GID value. as shown in Figure 4(b). The cost value is then automatically updated from another window, where the user must provide the GID value, as shown in Figure 4(c). This will update the database after submitting that form. The black line in Figure 4(d) then highlights the road segment that was just edited. Figure 5(a) finally shows the ERPD result from start point A to end point B. In this example, if the state of the patient is not in the Code Red condition (A "Code Red" means that the patient needs to be resuscitated or needs very intensive care), and hospital A, hospital B and hospital C have no AOB, then the shortest part from the start node (accident point) to hospital D is computed. Figure 5(b) presents the new routing result after the road condition was updated.

Figure 4. Show the updating road interface

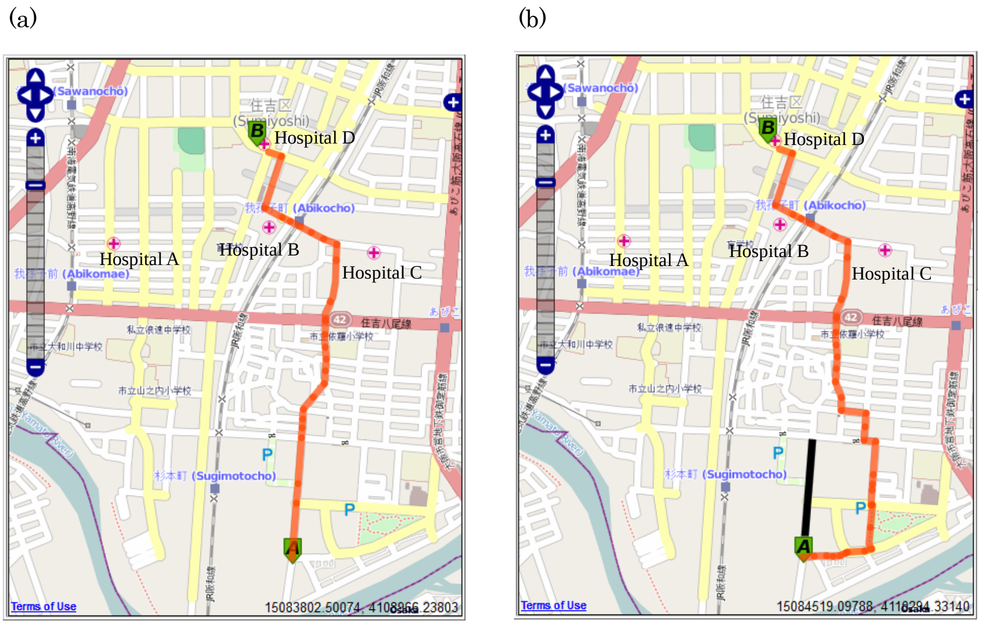

Figure 5. Show the routing result from start point A to end point B
(a) is showing the routing result before the road block.
(b) is showing the new routing result after update data the blocked road

4. CONCLUSION

The use of Free and Open Source Software library such a pgRouting algorithm is recommended to find the shortest path on the graph. However, providing only the shortest distance is not sufficient to improve ERDP system in the complex road networks, and the minimum travel-time is an important element to take into account.

pgRouting algorithms, such as Dijkstra algorithm, were enhanced, by modifying them for taking into account dynamic changes in the road conditions. This paper suggests a new concept of calculation of travel-time in case of ERDP by integrate pgRouting with AHP to calculate and give the priority weight for each element. The routing navigation also supports dynamic changes information with pgRouting to develop a routing algorithm for solving the real road network condition problem. Using jQuery Mobile Openlayers to implement the system allow the Client GIS update the road condition value via mobile devices.

AHP allows the decision makers to determine which criteria calls for greater consideration based on their subjective preferences, especially when the factors in consideration do not have a common scale of measurement, or are intangible with no existing scale of measurement.

This study suggests that AHP analysis can be integrated in pgRouting and that it can be used to analyse accessibility and compute the best suitable routes. Using this method, a preferable route scheme can be achieved which have a significant meaning in emergency routing for ambulances. Finally, the analytical method maybe useful to analyse and improve emergency responses for other disaster evacuation planning needs.

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6. REFERENCE

Choosumrong, S., Raghavan, V. and Realini, E. (2010) Implementation of dynamic cost based routing for navigation under real road conditions using FOSS4G and OpenStreetMap. Proceedings of GIS-IDEAS 2010, Hanoi, Vietnam, 9-11 December 2010, JVGC Technical Document No. 5, pp. 53-58 (ISBN 978-4-901668-76-7).

Choosumrong, S. and Raghavan, V. (2011) Real-time Cost Update Based on Current Traffic Condition for Optimal Routing Planning. Proceedings of The 32nd Asian Conference on Remote Sensing (ACRS 2011), Taipei, Taiwan, 3-7 October 2911.

Choosumrong, S., Raghavan, V. and Bozon, N. (2012) Multi-criteria Emergency Route Planning Based on Analytical Hierarchy Process and pgRouting. Proceedings of Geoinforum 2012, Tokyo, Japan, 21-22 June: Geoinformatics 23(2), pp. 92-93 (ISSN 0388-502X).

Ableson, F. (2011) jQuery Mobile and JSON, Learn how to create mobile web applications powered by jQuery Mobile. 40 p.

Saaty, T.L. (2008) Decision making with the analytic hierarchy process, Int. J. Services Sciences, Vol. 1, No. 1, pp.83-98.