Exploring the Shortest Route Options: Applying Environmental Indicators to Calculating Shortest Route

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Abstract

Studies suggest that a large percentage of traffic congestion occurs during peak hours [1]. *Many location based services and systems today exist that assist traffic routing to maximise on travel time and reduce trip lengths (e.g. Garmin, TomTom). The objective of this study looks at enhancing these systems by adding functionalities and variables that favour fuel savings as well as shortest route. A system is developed using Open Source GIS (using the PostGIS and pgRouting extensions for the DBMS: PostgreSQL), whereby a number of variables, including weather conditions, road network, traffic status, vehicle specification data and road gradient are manipulate by the user to achieve shortest and most fuel efficient route.*

Index Terms

Geographic Information Systems, Shortest Path Routing, Fuel efficiency.

1. Introduction

Geographic Information Systems (GIS) can be used for different uses, particularly Location Based Services (LBS). This study aims to enhance currently available routing systems with options that take into consideration weather, traffic direction in the road network and road (slope) gradient. These factors impact vehicle fuel efficiency. This system will be operable both of desktop or mobile devices with the latter having a randomised point representing the current location. This concept model uses some randomised data providing route planning dependent on the type of route chosen by the driver, and also taking into consideration weather and roads, with live data in order to avoid blocked roads due to for example an accident or flooding.

1.1 Location Based Services

LBS are considered by many as the driving force of Mobile Commerce. Such services are normally based on clients' geographical location [2]. LBS are not limited to business applications but to emergency and social services such as in the US, Canada and Japan [3], [4], [5] and the EU [6].

1.2 Transport Geographic Information Systems (T-GIS)

GIS are being applied in many industries mainly but not limiting, public safety, resource management, government roads, road networking and so on. A GIS can be seen as a stack of different map layers, be it raster or vector, where each layer is geographically aligned to each other [7].

The challenges in T-GIs's are related to Data Management, Data Manipulation and Data Analysis. Dueker & Butler [8] argue that sharing T-GIS data is "*both an important issue and a difficult one"*. The different applications also affect how streets are broken into logical statements which can be prepared for information extracts. For example routing software would accept a straight highway as three line segments, ensuring that the driver starts the highway and does not exit before the end of the line (broken down in a few segments). In accident recognition software, the same highway has to be segmented in smaller and more manageable slices for the accident to be located more effectively. In contrast with what Thill [9] claims with regard to the lack of data manipulation required by society, Downey [10] claims that these techniques have improved. Similarly by Wootton & Spainhour [11], that state the recent improvements with regard to data manipulation tools in GIS. One other development has been Open Source GIS.

PostgreSQL is a widely known open source RDBMS which can be extended with PostGIS. The main core functions of PostGIS were developed by Refractions Research and follow the OpenGIS "Simple Features Specification for SQL”. PostGIS supports all the standards that are supported by Open GIS Consortium (OGC, OGC SQL functions, OGC Simple Features) [12].

1.3 Finding the Best Route

Studies conclude that optimization techniques in solving pickup and delivery problems are not promising [13]. The main application of these techniques is when a route is needed between a source vertex and a target one. Thus routing algorithms can be deemed more successful when the starting and ending vertices are known prior to the exercise, rather than trying to minimise paths when visiting vertices [13]. Different studies propose different algorithms to identify a route starting from a single vertex can reach all the rest of the vertices in the network. These are called single-source SPAs or single-source queries [14]. A benefit of these queries is that they can be enhanced to allow for secondary constraints, such as Boolean weights or differential costs. Such queries are also used in this study, where the starting and ending vertices are known, and the constraints will be passed as Boolean weights.

1.4 Fuel Consumption

Lin [15] looked at fuel use by applying the expertise of (taxi) drivers, in preparing their routes within the city. Many of the routes chosen were very similar, given the time of the day. This contrasted with Leshed et al. [16] where many of the responses showed that a consideration of time of day, speed, fuel consumption and congestion. These results have led Chang, Wu & Ho [17] to develop a network system which took into consideration fuel consumption, speed, and real-time traffic information.

2. Methodology

This study proposes a routing system able to operate for both desktop and mobile users (Figure 1).

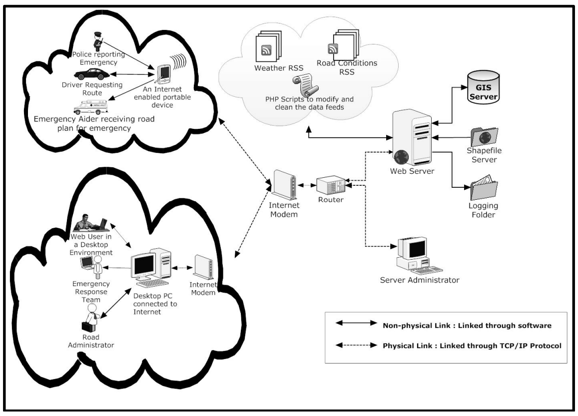

Figure 1. System Overview

The study tests different routing algorithms based on changes in:

- Weather conditions;
- Road conditions including:
    - planned road blocks;
    - temporary road blocks such as traffic congestion or accidents.
- Vehicle used(engine and type of vehicle);
- Road gradient

The Dynamic Systems Development Methodology (DSDM) was applied to this study and MoSCoW (Must Could Should Would) requirements were drawn up in order to prioritise the core requirements (Table 1).

From the start of the project, the main aim of this research was to deal with dynamic routing. This makes the choice of variables a key factor in the planning of the system. Based on the literature review, a number of variables affecting dynamic choice of the route, but which are not particularly used in the industry and research have been identified. Despite the obvious choice of some variables others were not so obvious. This section does not only base the discussion on what types of variables were chosen but also on how the data associated with such variables were collected and processed.

2.1 Traffic Conditions

Identifying a good quality dataset was a key concern in this study. The dataset needed to feature different gradient type of streets and traffic directions (One-Way and Bi-Directional segments).

Traffic conditions are affected by weather and network information. The weather website used for this study (www.wunderground.com) provided an updated RSS feed. The reports from wunderground.com are not very specific, so it is left to a randomizing engine to decide the effect on weather over the streets. Such technique was computed following Gera [18].

Network information was more difficult to find. A randomizing engine was created to simulate traffic block on the roads. For the scope of the project, it was decided that a random generating function for disabling roads would be needed, producing an XML file. A Sample RSS reader was scripted to extract the random generated data. The generated data will have random type of events with a corresponding randomised time factor (Table 2). This randomising technique was inspired from Karl et al. [19].

2.2 Choice of Data

After extensive research for the desired data, including gradient and turn restrictions, GRASS data book was used [20]. After reviewing the data, clarifications from the data collection team, [21], was sought to clarify details in the metadata. The gradient in the available raster files was not useful to street segments. GRASS software was used to combine the raster files with the vector files. This new Shape file was checked for altitude changes, and after successfully exporting the data into a 3-D plane, the Shape File was exported to PostGIS using OGR tool. The dataset chosen is made up of sixteen types of road classes, three State road segments, about two thousand highway segments, another circa twenty five thousand primary road segments and almost ten thousand secondary road segments.

2.3 Modifying the Data

The technique used to enable or disable roads included the creation of two columns in the table, one showing attribute access for normal vehicles, and one for emergency access. So as to keep such dynamic data apart from the main spatial data, views were used. What is stored actually on the database is the Expiry data of the ban, which when compared with the current timestamp of the query, if it is earlier, it means the road can be used (having a TRUE status) else, status will be set to FALSE making it impossible to be called for routing. Thus in the database only the expiry date is stored making it possible to be heavily indexed by using B-Tree Indexing method. A similar technique was used to display the reason, if the segment was banned:

$$\begin{array}{l} CASE\ WHEN \\ \ streets\_proper.unavailable\_until\ <\ 'now' \\ \ ::text::timestamp\ without\ time\ zone\ THEN\ '' \\ \ ::text \\ \ ELSE\ streets\_proper.reason \\ \ END\ AS\ reason \end{array}$$

Table 1. MoSCoW Requirements

Priority	Description
Must	To build up a Location Based Service for mobile customers which act as an intelligent route planner.
Must	To plan a route should allow the user to specify which planning has to be used
Must	To design and build a Geography Information System that will act as the backend for the system offering these services.
Must	To design and build a Web-Interface front end for the users to communicate with the backend.
Must	To allow queries to be planned against live data and thus minimizing risks of finding traffic jams.
Must	The Web-Interface needs to be compliant to W3C Standards. It must be correctly viewed on Gecko Engine.
Must	All software used in this project need to be Open Source and confirm to Open Standards.
Should	Such a Web-Interface should be accessible from mobile devices for the route planning section.
Could	To prepare different types of Users, each with a separate login and a login class.
Could	Syndicate data from a Traffic and Weather update site.
Would	Use Maltese data instead of American one
Would	Instead of synthetic use real data, especially Traffic conditions
Would	Use GPS locators instead of a random point on the map

2.4 Computing the Route

This function, extends the Shortest_Path_SP() PL/PGsql function in the pgRouting package. This function was modified to accept another parameter. The wrapping function makes also possible capturing the source and target edges, something which required two extra SQL calls in the pgRouting function. Another enhancement provided on this function is the ability to allow the specification of the rule column to use when doing the routing. What one must point out from the algorithm is that where possible, the extents start on a small scale, and *var_max_dist* denotes the extent by which the point is searched, keeping it as small as possible. This is done so as to limit the function processing time. Wherever possible, the function is using both spatial and non spatial indexing. For example the "*&&*" notion make use of the GIS index present on the geospatial table.

Table 2. Types of Random Road Blocking

Blockage Type	**Minimum Blocking**	**Maximum Blocking**
Accident / Road Lights Malfunction	2 Hours	1 Day
Road Works	1 Week	3 Months
Road Maintenance / Road Construction	6 Months	2 Years

The Shortest Path function returns the closest edges, however, the custom function written for this project, extends this by forming an additional path between the vertex and the edge, so as to be able to guide the driver for the first and last sections of the journey. This extension is made by looping through the first and last result set, and making use of PostGIS function line_locate_point() to find out the nearest point from the edge to the source or target. A set of points is created in order to join lines was created so as to join the starting and ending point to the route.

Such algorithm is explained in Figure 2. This flowchart summarises the algorithm used in this methodology. Starting from computing the vehicle to rain level ratio, thus taking into consideration the height of the vehicle from the ground, it progresses to obtain the starting point of the route and the target point. The route is computed by checking that all points which need to be traversed by the vehicle respect the gradient to vehicle ratio, and also the vehicle to rain level ratio. Such ratio prevents the vehicle traversing road segments which are blocked due to adverse weather or steep gradient which force the driver to use low gears thus consuming more fuel [22]. Needless to say that such algorithm computes the route only from the available road segments, thus taking into consideration only those road segments 'WHERE status = TRUE'.

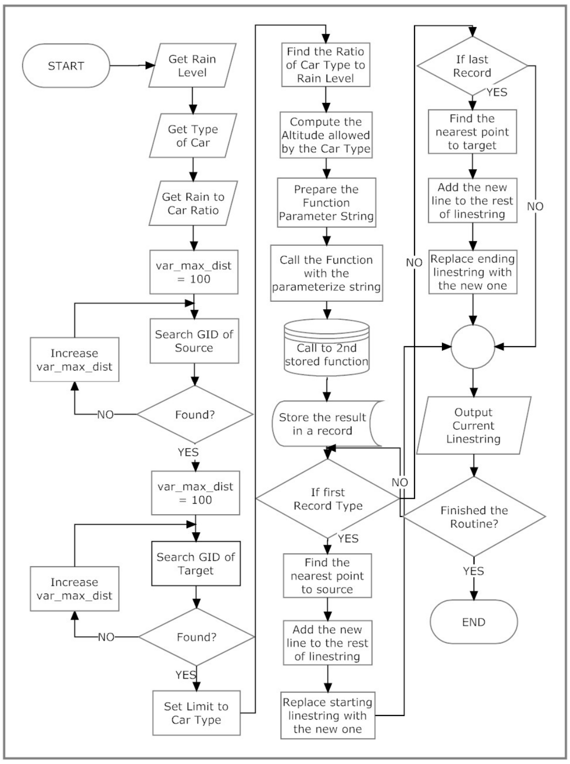

Figure 2. Flowchart designing the Fuel Friendly Function

As explained earlier, the routing depends also on the default vehicle which the user is using, since both the rain and slope ratios depend on it. Using UML's Sequence Diagram, the sequence of events in this scenario is explained. Figure 3 shows how data is being passed from one source to another, until the user views the route. One can note that the system is making use of a three-tier topology [23].

The result of the sequence diagram can be viewed in Figure 4, where a screenshot is taken of the output computed by the system with regard to the vehicle details previously entered. Such routing is comparing the route given to a small (800cc) vehicle and a large one (5000cc). In this scenario the route is being limited by an over flooded road segment.

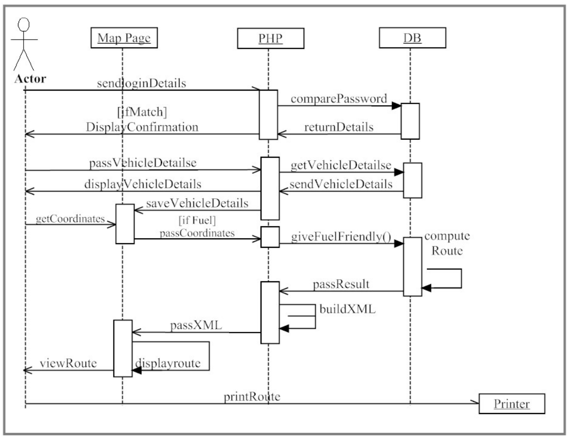

Figure 3. Sequence Diagram for Fuel Route

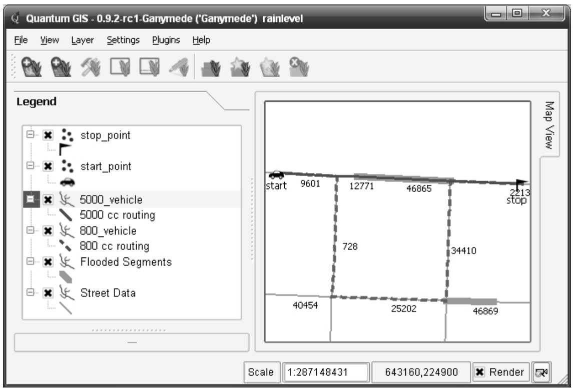

Figure 4. Screenshot of Least Fuel Result

3. Discussion

The proposed algorithm, in conjunction with the available Open Source Algorithm for routing the shortest path, can lay the foundation for better environment friendly routes. The way the functions proposed in pgRouting have been extended, allows for further development on this area. This can lead other project teams, working in the Open Source field to continue enhancing this model. By using Open Source methodology, the study feels like a steps tool for further development, thus making use of other code available.

Another enhancement seen in this project is the outcome of the fuel consumption technique. This technique, when used in a real life situation should minimize consumption. In contrast with techniques used earlier on, such as the one used by Ericsson et al [24] and by van der Voort et al [25], this technique does not rely on the driver. This technique, relies on the route it is chosen. Whilst keeping a shorter distance helps fuel consumption, efforts done by the engine are minimised. An engine to vehicle ratio is kept so as to help this technique work, basically ensuring small engines to be offered a plane or downhill route as much as possible, whilst, vehicles with big engines, being offered steeper roads.

Having the network updated with current traffic and weather situation, enables the system to provide the user with a closer picture to reality. Needless to say that the current traffic situation found on the database, will never be the real world situation.

4. Conclusion

This paper has reviewed the process of preparing, developing and reviewing a T-GIS as a LBS. The service needs to be user friendly in order to ease the interface between the user and the system. The system, enhanced with GIS, needs a stable methodology to handle it. Also discussion on the future of this project, how it can be used by other systems, was conducted.

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