GIS Enabled Travel Assistance System for Public Transportation

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Abstract—Passengers using public transportation systems lacks sufficient information at their fingertips when they need to use them as the travel mean. They may not know the routes to use at all or want to minimise cost or time or want to access other resources while reaching the destination. This study provides sufficient information required by a passenger to decide which bus routes to take when travelling from a known source to a destination, considering such constraints. Possible bus route combinations, the travel times and travel fair are provided. The system is accessible via a web map interface, mobile application, Simple Message Service and mobile web. An application Programming interface is provided to use the functionalities as a web service. The route finding is based on Breadth First Search Algorithm. The system is implemented using free and open source technologies including open source GIS tools. A prototype application is designed and implemented based on short distance bus routes in Kaduwela and suburb areas of Sri Lanka.

Keywords—Geographical Information Systems, Free and Open Source Software, Public Transportation

I. INTRODUCTION

According to National Transport Commission of Sri Lanka, public transport accounts for nearly 73% of the total motorized passenger transport in Sri Lanka and serves as the only means of transport for majority of the population. Of this, bus transportation accounts for nearly 68%, with state owned bus service share of 23% and private operator share of 45% provided by small scale operators. Sri Lanka Railway accounts for only 5%, carrying 120mn passengers per year [1].

Passenger travelling by bus in Sri Lanka is the main area considered in this study. Any single bus is assigned to a pre-determined bus route and bus fair and bus halts are also well established. Bus fare is determined based on sections of which the boundaries are decided using major bus halts. Bus time tables are also established for majority of routes. There are two categories of bus routes based on the distance covered within the whole routes, namely long-distance routes and short distance routes.

When bus is used as the mode of transportation, it is common that several combinations of bus routes exist to reach the same destination starting from a single place. Several parameters affect the decision of selecting the best bus route in such a situation. Travel Time, bus available time, bus fare, number of intermediate transfers to different buses and requirements to access some service points before reaching the final destination (e.g., access ATM before going to a hospital) can be identified as the parameters affecting the decision of selecting a particular combination of bus routes.

When a requirement arise to travel to a unfamiliar destination for the first time the general public is depending heavily on other people to get to know about the bus route. It is common that passengers get to know about the bus fare after get in to the bus or waste time as best bus routes to use are not known. There is no system available for a bus passenger to obtain required information to decide which route to select and the total bus fair amount.

This study is aimed at providing an integrated solution to assist passengers to plan the bus tour beforehand where a bus passenger can obtain

1) All possible bus route combinations to travel between a known source and destinations
2) The bus fair and bus route section information for routes identified in (1) above
3) Know the service points within any bus route combination identified in (1) above
4) Know all bus route services available in particular route section

The services are provided through a web and mobile interface. A prototype application is developed based on Kaduwela and surrounding areas. All the short distance routes within the area are considered. There are 17 routes and 154 bus sections in the sample data set.

Additionally, it provides an Application Programming Interface (API) to access the results, which can be used by third party application developers.

II. BACKGROUND OF THE STUDY

Several algorithms exist for finding suitable paths between two known locations, based on different requirements. Shortest path algorithm like Dijkstra's algorithm, Bellman-Ford algorithm etc. is used most of the application[2,3]. Although these algorithms are optimum, they are not capable of dealing with certain real scenarios [4].

Breadth-first search (BFS) is a graph search algorithm that begins at the root node and explores all the neighbouring nodes [5]. For each of those nearest nodes, it explores their unexplored neighbour nodes, and so on, until it finds the goal.

Breadth-first search (BFS) is a general technique for traversing a graph. A BFS traversal of a graph ‘G’,

-Visits all the vertices and edges of G.
-Determines whether G is connected.
-Computes the connected components of G.
-Computes a spanning forest of the G.
-Setting/getting a vertex/edge label takes O(1) time.

In general breadth-first search is optimal since it always returns the result with the fewest edges between the start node and the goal node [5]. Heuristic methods can be used to speed up the process of finding a satisfactory solution when adopting BFS, where an exhaustive search is impractical. Further it illuminates duplicating data.
III. Methodology

A geo-enabled decision support system which provides passengers with relevant information to make a better judgment about bus tour planning is designed and prototype application of it is implemented in this study.

All possible route combinations are generated using breadth first search algorithm which run on bus route network. A spatially enabled bus route network with section breaks and fair information is used here. For each section the fair is known and each node of the bus route become section break points (SBP). Fig. 1 illustrates sample network diagram of bus routes with SBPs.

The main features of the network are as follows
a. SBP ‘A’ knows the existence of its adjacent SBP B. ‘A’ knows to reach ‘B’ via 177 bus service (bus route).
b. SBP ‘B’ knows the existence of its surrounding SBP, A, C, and D. SBP ‘B’ knows which bus routes to take to reach its surrounding SBP.
c. Same principle applies on all the SBPs and sections of the route network.
d. Distance between each adjacent SBPs (edges) are known
f. The bus fare for travel between each adjacent SBPs (edges) are known
f. All service points (ATMs etc) are attached to one or many edges of the network.

The bus route network information is stored in the spatial database with actual coordinates of SBPs. It enables the generating of selected routes over the road network and renders the results as a digital map. To generate all possible route combinations available to reach a destination SBP from a source SBP, Breadth First Search Algorithm is used. As the bus fare of all sections are known, once the route is calculated the bus fare is calculated based on bus fare of each section. By searching alone routes, available service points available alone the route is also identified.

The system is allowed to be accessed via three different modes, web interface, mobile access through Simple Message Service (SMS), mobile access through mobile web and mobile access on android mobile phones. This is aimed at reaching wide audience. Mobile phone is considered as the most suitable mode to reach the general public due to its wider acceptance of general public. Web interface shows the results in text and map format both while other modes provide text based information. Apart of these, a sample implementation of developer API based on REST[6] technology is provided which can be used by third parties to develop application based on results. For an example an external system may need to know all the ATM locations within ‘Kaduwela’ to ‘Rajagiriya’. API function is implemented to provide external services so the developers can call the services and obtain the relevant responses.

IV. Design

![Fig. 2. Overview of the functionality of the system](image2.png)

![Fig. 3. System components](image3.png)

![Fig. 4. Network of routes with service points (resources)](image4.png)
Functionality of the system is illustrated in Fig. 2. The main components of the system are as per Fig. 3. It has four main layers:

- Data layer – stores spatial and non-spatial data relates to routes and services
- Server logic layer - web server and map server
- Application logic layer – BFS algorithm, searching and other core functionalities are handled by this layer
- User interaction handing layer -deals with five types of users namely web users, SMS users, Android application users, mobile web users and third party application users. Each user interaction mode works based on the results issued by application logic layer.

For an example, for the sample network with resource points in Fig. 4, assume an end user wants to travel from A to D. Following result set will be available to the end user according to his selections.

- Supporting bus route numbers for all possible route combinations for traveling from A to D.
- Route A-E-F-D
  - A-E: 177
  - E-F: 163
  - F-D: 176
- Route A-G-D
  - A-G: 993
  - G-D: 119
- Total distance for all section combinations of particular routes.
  - Eg: A-E-F-D = 16 Km
  - A-G-D = 10 Km.
- Total bus fair for all section combinations of particular routes.
  - Eg: A-E-F-D = Rs. 30
  - A-G-D = Rs. 25
- Total time taken to travel for each route.
  - Eg: A-E-F-D = 30 minutes.
  - A-G-D = 15 minutes.
- Availability of resources for a particular route.
  - Eg: A-E-F-D supported with ATM machines and grocery stores.
  - A-G-D supported with schools.
- Number of sections within origin and destination.
- The least cost route (by total expenditure, distance or time).

### V. IMPLEMENTATION

System is implemented using free and open source software tools. The database is implemented using PostgreSQL/Postgis database technologies. The core system is written in java 1.6. It uses JSP/Servlets to implement the presentation tier. CSS, Jquery and java Scripts are used to enhance the user interfaces of the system. GeoServer[7] is used as map server technology to render spatial data as map images. OpenLayers is used as the map viewer in web application. Smart phone application is implemented using Android 2.2. Mobile web implementation uses HTML 4 and CSS. SMS gateway is implemented with trail version of Ozeki NG server[8] to send and receive SMS messages. The API is implemented using REST technologies.

The data set used is of 1: 10000 scale and is in local coordinate reference system. It consists of locations of ATMs, police stations, hospitals, hotels and food cities as service points. Following section explains the implementation of different components of the system.

#### A. Application logic layer

Application logic layer contains the java implementation of the routing algorithm. It accesses the postgresQL database and retrieves all routing information and build a networked tree. The routing algorithm traverse through the tree until it finds a matching result for the given origin and destination. While traversing through the tree, it collects all the relevant spatial data from the database to render the final map. Finally it performs all the calculations such as distance calculation, total expenditure and the number of sections per route for presentation layer to display. The spatial information is passed to the map server which is implemented using GeoServer. GeoServer renders the spatial data and pass them to Open Layers map Viewer to display. With the support of Open Layers users can perform actions such as panning and zooming the map.

#### B. User interaction handing layer

Users are allowed to interact with the system in many ways. All the user interactions are handled under user interaction layer. It provides user interfaces and gate ways to access the services of Lucid Maps.

1) **Web interface**

The Main system provides the Web interface which allows the users to connect to the system via World Wide Web using a web browser. It allows the user to enter origin and destination and provides features to select the resources which they want to achieve. The resulting spatial information is displayed on maps as highlighted routes and non spatial data is displayed on tables in a user friendly way. Web interface provide features to view summaries and in detailed reports for each and every resulting route.

2) **Mobile web based application**

Any featured phone having mobile browsing facility can access the system using mobile web client. This version is designed with limited features to serve in an efficient way on mobile browsers. Following the guidelines in [9,10] the mobile web interface is designed to serve the mobile clients. It inherits all the basic features from the main system and uses the same back ends processes.

3) **Android Smart Phone based application**

A smart phone comes with all the high tech resources. They have a considerable processing power and storage to run an application independently. An on-line mobile application which works using 3G or GPRS in smart phones and inherits all the features from its main system is implemented targeting at Android based systems.

4) **SMS application**

The user is allowed to get the services using SMS. The messages follow a simple format and only text based results are sent to the user. Registered users can send origin and destination in a predefined format to the system as a text
message. The system will reply the user with a text message including related routing information to reach the destination.

VI. RESULTS

Fig. 5. to Fig. 8. shows sample results shown on several output mediums for the source node “Kaduwela” and destination node “Pagoda”. Fig. 5. and Fig. 6. show all possible bus route combinations as text based output. Fig. 6 shows the same results on the OpenLayer based web map interface. Fig. 7. shows the main interface of Android application and Fig. 8. shows the results on the same interface.

<table>
<thead>
<tr>
<th>Route</th>
<th>Distance (m)</th>
<th>Sections</th>
<th>Cost (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Kaduwela Kotailawa Pittugala Malabe Koswatta Battaramulla Ethulkothe Pittukotte Pagoda</td>
<td>15405</td>
<td>8</td>
<td>27</td>
</tr>
<tr>
<td>2: Kaduwela Kotailawa Pittugala Malabe Koswatta Battaramulla Ethulkothe Pittukotte Mirihana Pagoda</td>
<td>15651</td>
<td>9</td>
<td>28</td>
</tr>
<tr>
<td>3: Kaduwela Kotailawa Pittugala Malabe Koswatta Battaramulla Ethulkothe Rajanjira Nawela Nugeoda Junction Pagoda</td>
<td>17655</td>
<td>10</td>
<td>30</td>
</tr>
</tbody>
</table>

Fig. 5. All possible routes as tabular results

![Fig. 6. All possible routes highlighted on the web map.]

Fig. 6. All possible routes highlighted on the web map.

VII. CONCLUSION

The prototype application proved that it is capable providing sufficient detailed information for better judgments regarding selecting bus routes to wider audience using a low cost approach. It showcases the success of adopting low cost GIS tools in local context to provide better solutions for general public.

In a real world implementation, the system can be enhanced in several ways. Only the short distance routes are covered in the study. The long distance routes can be integrated to the system to provide a total solution. The constraints relate to minimum sections which can travel and starting nodes etc. are imposed on long distance routes and
these has to be considered separately when integrating long distance routes to the system. The other mean of public transportation in Sri Lanka, railway routes also can be integrated to the same system.

The map interface can be improved for better user experience and local language support can be incorporated reach the general public of Sri Lanka.

The BFS algorithm can be enhanced by using the heuristics based methodologies. More API functionalities can be implemented to make it more available to third party application developers.

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REFERENCES


