A WEB BASED 3D CUSTOMIZED ROUTING ENGINE DESIGN AND DEVELOPMENT USING OPEN SOURCE TECHNOLOGIES

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A final year project submitted in partial fulfillment of the requirements for the degree of Bachelors of Engineering in Geo Informatics.

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(June 2015)

CERTIFICATE

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DEDICATION

With consummate sincerity, we continue to affectionately dedicate this project to Pakistan Army.

ACKNOWLEDGEMENTS

Thanks to Almighty Allah for giving us knowledge, power and strength to accomplish this task. We extol our supervisor Dr. Ejaz Hussain and Co-supervisor Dr. Ali Tahir who went beyond the call of our duty in providing us the numerous detailed comments on technical and pedagogical matters. Their supervision, motivation and guidance helped us a lot in achieving our goal. We are thankful to them.

We would like to thank C4I for giving us this project and our committee members Dr.Salman Atif and Ms. Khunsa Fatima for their valuable availability and guidance at the need of time. It has been a great experience to work with them.

Our special thanks to all the IGIS staff especially Mr. Aftab Ahmed, Mr. Rizwan and Mr. Ishfaq for their technical support and help in setting up the working environment.

Among our class mates we would like to thank Mr. Awais Khalid for his terse guidance. The support which has been provided to us by our class mates, juniors and master’s students is commendable. We are highly grateful to all these people.

Finally we would like to thank our families for their moral and resourceful support; we would not have been able to reach our goals without their prayers.

(From Ahsan Mukhtar, Junaid Abdul Jabbar, Muhammad Aqib Shehzad, Shehzad Bacha, Maria Saeed and Mashal Maqsood)

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LIST OF ABBREVIATIONS

Abbreviations	Explanation
AJAX	Asynchronous Java Script and XML
API	Application Program Interface
BFS	Breath First Search
CSS	Cascading Style Sheets
CSV	Comma Separated Values
C4I	Command, Control, Communications, Computers, and Intelligence
FTP	File Transfer Protocol
GDAL	Geospatial Data Abstraction Library
GeoJSON	Geo JavaScript Object Notation
GEOTIFF	Geostationary Earth Orbit Tagged Image File Format
GIF	Graphic Interchange Format
GIS	Geographical Information System
GPS	Global Positioning System
GUI	Graphical User Interface
HTTP	Hyper Text Transfer Protocol
HTML	Hyper Text Mark Up Language
IT	Information Technology
JPEG	Joint Photographic Experts Group
JOGL	Java Open Graphics Library
JNI	Java Native Interface

JSON	**Java Script Object Notation**
KML	**Key Markup Language**
MOD	**Ministry of Defence**
NASA	**National Aeronautics and Space Administration**
OBD II	**On Board Diagnostics, level 2**
OGC	**Open Geospatial Consortium**
OSM	**OpenStreetMap**
PNG	**Portable Network Graphics**
QGIS	**Quantum Geographic Information System**
SDK	**Software Development Kit**
SQL	**Structured Query Language**
SRTM	**Shuttle Radar Topography Mission**
TMS	**Tile Mapping Service**
TTS	**Text to Speech**
URL	**Uniform Resource Locator**
WEBGL	**Web Graphics Library**
WMS	**Web Mapping Services**
XML	**Extensible Markup Language**
2D	**Two Dimensional**
3D	**Three Dimensional**

ABSTRACT

This project "W-CROST" designed to serve the needs of *Command, Control, Communications, Computers, and Intelligence* (C4I), is a complete web based application for providing open source routing solutions. The different customized scenarios implemented in this project include the generation of multiple routes, identification of choke points, automatic snapping, exporting route and multiple user logins. Making use of the OpenStreetMap (OSM) and pgRouting Dijkstra's algorithm, it allows the user to get shortest and fastest route on the basis of distance and time respectively. This application provides the user with driving directions, travelling distance and estimated travel time between two points and encapsulates the capabilities of 2D and 3D route visualization. Designed for Pakistan Army, our project has customized functionality of generating barrier free route and is aimed to work totally offline, so that data security is not compromised.

1 INTRODUCTION

Whenever an organization, in the business of providing mobility, is entrusted with moving people and vehicles, a natural question that arises is how efficiently that organization can provide the services. The basic requirement of efficient mobility of vehicles and people gives rise to the subject area of optimal routing. For some services such as mass transit, trucking firms and postal service, timely delivery is of immense importance. For other services shortest route of service delivery may be the best choice.

An example of routing applications with potentially complex interactions between spatial parameters exists in the military field. Military plays a vital role in every era and mankind since time has a fetish for warfare which continues till today. Only the technologies and methodologies for strategic planning have changed, manual maps have shifted to digital ones. These improvements in technologies play a vital role in dominating a battle area. In wars the most important thing is position, location and the choice of most optimal route to approach the enemy e.g. in a particular scenarios a military application might involve a desire for vehicles to travel on high ground to gain a commanding position or to travel below the horizon to facilitate concealment (Rasmussen, 1997). A GIS based system with the ability to handle elevation data could provide the necessary support to identify a path that minimizes threat (Szczerba, 1999).

The complex interaction between spatial parameters required for optimal routing can be dealt easily with Geographic Information System (GIS). The concept of Command, Control, Communication and Coordination in military operations is largely dependent on the availability of accurate information in order to arrive at quick decisions for operational orders. In the present digital era, GIS is an excellent tool for Military commanders operating in the battle field. The use of GIS applications in defense forces has revolutionized the way in which these forces operate and function. Military forces use GIS in a variety of applications including optimal routing, cartography, intelligence, battle field management, terrain analysis, remote sensing, military installation management and monitoring of possible terrorist activity. Use of GIS for the generation of optimal route can help gaining an upper hand in the battle field and save much potential loses.

Spatial data gathered by Ministry of Defense (MOD) is used in optimal routing, filtering, analyzing and presenting information for decision-making. Optimal routing involves the identification of routes on the basis of different criteria's e.g. shortest path, fastest path, barrier free route etc. The distance between two points can be calculated by the aggregation of lengths of road edges between the points and the estimated travel time can be calculated by using the relationship between distance, speed and time i.e. Distance = Speed x Time. Using this relationship allows the calculation of time parameter with necessary consideration of different road types e.g. a primary road may have a speed limit of 80 km/h and travel time will be computed accordingly. Routing algorithms such as Dijkstra’s algorithm can be used to deal with these parameters of distance and time and generate shortest and fastest routes respectively.

1.1 BACKGROUND

"A GIS lets us visualize, question, analyze, and interpret spatial data to understand relationships, patterns, and trends." (ArcNews, fall 2011). With the recent advancement and development in the field of GIS, it is now the go-to technology for effectively dealing with real time and dynamically changing spatial data. Among many other applications, GIS is widely used for optimization of daily fleet movements (ArcNews, fall 2011).

With the world wide increase in travelling expense, security issues and traffic congestion route selection has become a critical step in the initialization of any project and has significant impact in terms of cost, man power and service quality. Optimal route determination involves consideration of several factors such as environmental, sociological, economical and safety. For a given origin and destination one is always tempted to use shortest distance route, but this route may not always be the best rout e.g. in case of emergency the shortest travel time route would be preferred over the shortest distance route. As a result an optimal route can be chosen through a good understanding and implementation of factors such as slope, traffic congestion, road types, number of lanes, railway crossings, hurdles and vehicle type etc.

Currently the software being used by Army is ArcGIS, which has a very expensive license, does not allow customization and needs to be connected with internet for some of its capabilities, resulting in compromised data security. So our aim in this project is to make use of open source technologies which are generally free and can be properly customized according to the army requirements. Some of the advantages of open source software's are:

- Open source software's generally free and affordable by anyone.

- Open source software’s are continually evolving in real time as developers continue to add new functionalities and modify them, which means they can be more secure and less prone to bugs than proprietary systems, because these software’s have wide no. of users poring over them and weeding out bugs.

- Using open source software means you are not locked in to using a particular vendor’s system rather you choose between wide varieties of systems.

- Open source software’s allow easy customization. You can modify and adapt them according to your own business requirements, something that is not possible with proprietary systems.

- Open source software’s use open standards that are accessible to everyone; thus, they don’t have the problem of incompatible formats that exist in proprietary software.

- Lastly, the companies using open-source software do not have to think about complex licensing models or acquiring pirated versions.

1.2 RATIONALE

Pakistan Army is one of the leading IT Sectors in Pakistan with 17 data domains within the field of information technology. Over the past few years Pakistan Army has been revolutionized in inducting many different disciplines such as Computer Science, Software Engineering, Computer Engineering and GIS. GIS is an emerging avenue in decision making for the Pakistan Army. GIS approach is more significant and accurate in decision making processes and can save a lot of resources. Pakistan Army is also looking forward for setting up secure and cost effective systems that allows the determination of optimal route for troops and vehicles movement for the improvement of following operations:

- Command and control
- Battlefield management
- Intelligence gathering
- Mission planning
- Search and rescue

The main purpose of Army is to implement above mentioned operations and requirements into an offline system. In the battle field quick actions and responses are required. Accuracy is the key feature during attacks. Approaching that area and locating the enemy positions become easy with the help of routing. For example in search and rescue operation if army has multiple routes for approaching that area then it will be more beneficial than having information of only one path. Other factors like choking junctions. Having said this, the aim of this project is to make use of open source technologies integrated in an offline web based system where security of the data is not compromised and has the capabilities of generating multiple routes, identification of choke points, automatic snapping, exporting route, multiple user logins and 3D route visualization.

1.3 AIMS & OBJECTIVES

The aim of this project is “to perform web based routing on customized scenarios using open source and offline technologies”. Open source software is available to the user with its source code and a license which gives user the rights to study, customize and distribute it to anybody for any purpose. Our main goal is to increase the use of open source technologies within Pakistan Army, so that customization becomes easy, performance is enhanced and dependencies on the proprietary software can be decreased. The proprietary routing software’s provide specific routing scenarios or capabilities which are usually not sufficient for C4I. Therefore we are aiming to incorporate all possible routing scenarios that will be useful. An additional capability that we are aiming to include in our application is the 3D visualization.

1.4 SCOPE

This project is based on a purely focused approach to provide open source and secure routing solutions to C4I. This project will pave the way for increased use of open source technologies within Pakistan Army and allow C4I to have a routing application that is neatly customized according to their requirements. Currently designed only for C4I, W-CROST has much potential for further customization and serving other units within Pakistan Army.

1.5 SCENARIOS

Routing scenarios implemented in this project are as follows:

1) **Generating multiple alternate routes for the same start and endpoints and identifying choke points, driving directions and road classifications.**

Figure 1 illustrates the above scenario much comprehensively; multiple routes can be seen as three different blue lines (routes) between same source and destination points. The reason for implementation of this scenario lies within the day to day situations experienced by Army e.g. in a particular scenario, where two battalions have to move between same source and target points but have to follow different routes, in this case they would need to have the information of multiple routes e.g. shortest and fastest route for same source and destination, driving directions, road classifications and the identification of choke points in order to know whether the two battalions will meet each other at any point along the route or not.

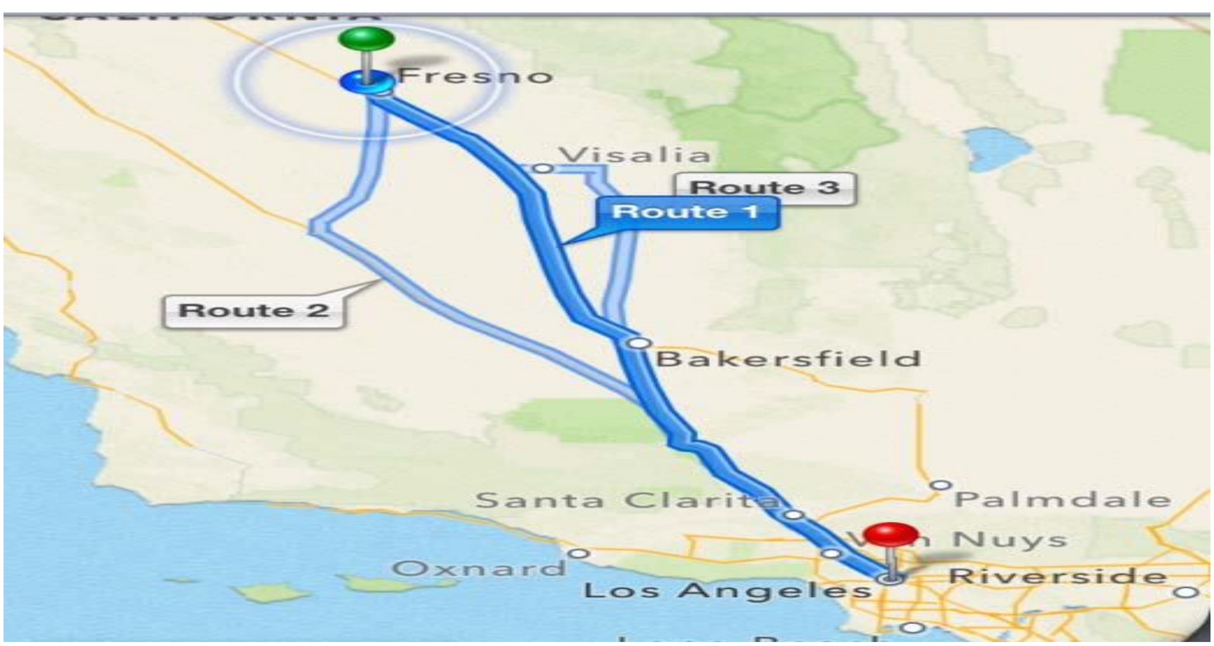


Figure 1: Multiple Routes

2) **Identifying choke points, driver directions and road classification for multiple routes with different start and end points.**

This scenario deals with a situation much likely as in scenario 1, except the Army units now have to get the route information between different source and destination points. This scenario requires the identification of junction points where two or more routes intersect each other and requires the retrieval of driving directions and road classification for these routes. Figure 2 illustrates multiple routes and choke point between different source and destination points.

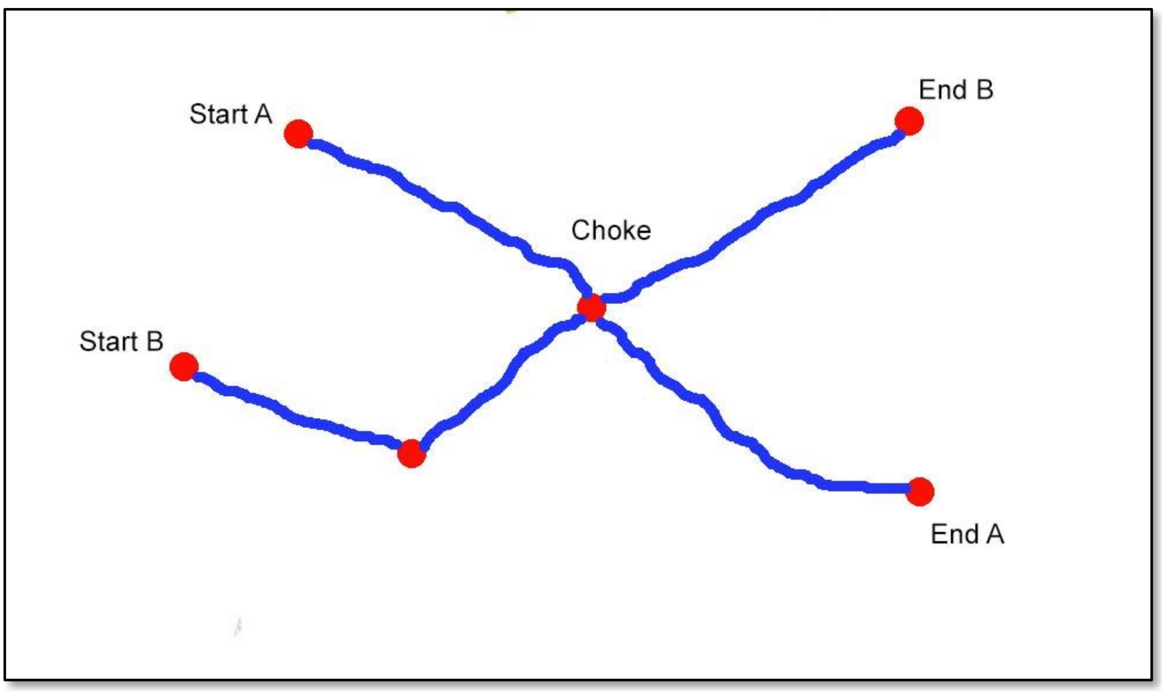


Figure 2: Choke Points

3) **Giving user the provision to get route information according to the speed limit for different types of road classification, so that user has an idea of journey time for different routes.**

Scenario 3 deals with the provision of route information such as total travelling distance, estimated travel time etc. according to different types of roads e.g. if the road type is primary, the respective speed limit may be 80km/h and the travel time is computed accordingly.

4) **Automatic snapping of nearest network nodes if user inputs incorrect start or end point.**

Scenario 4 deals with the automatic snapping of the nearest node if user specifies incorrect start and end point. Figure 3 shows snapping tolerance, if the point is within the buffer radius made by search tolerance then it will automatically snap to the nearest network node otherwise the route will not be displayed.

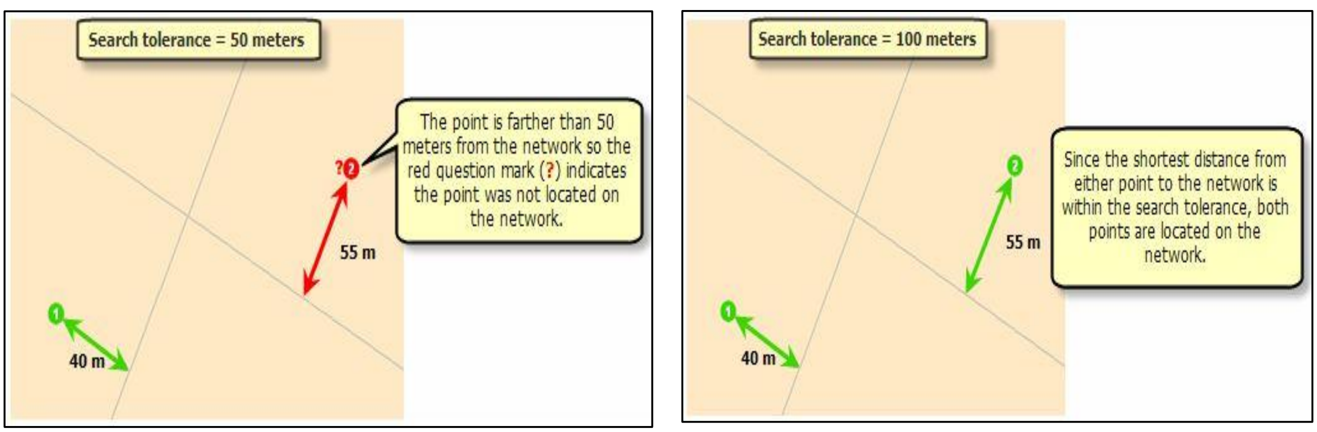


Figure 3: Automatic Snapping

5) **Capabilities that allow user to generate a new route depending on their requirements e.g. avoiding barrier or specific land features like water bodies etc.**

In most cases, the movement of Army units has to secret and safe. In scenarios where there lies a potential threat on the route e.g. enemy vehicle or any other unwanted features, the route now needs to be updated so that the security of convoys is not compromised. The capability of barrier free route is implemented in this application as a solution to scenario 5.

Having all these customized scenarios implemented in this application, user is given the ability to generate multiple routes and identify choke points, a barrier can be added on run time and W-CROST will provide the user with a barrier free route. This routing engine will help C4I with the selection of opt routes according to run time specifications.

1.6 LITERATURE REVIEW

Survey of literature on web based military routing applications; open source technologies and 3D visualization have allowed us to identify some of the existing applications that helped us to formulate methodology for our own application. These applications are documented below:

1.6.1 IRRIS

IRRIS (GeoDecisions White Paper, 2004) is a web-based routing solution designed by US army for military use, national defense and security. It integrates the data from variety of sources and has the ability to present data in the form of charts and maps. It manages the data and presents it for mission critical operations enabling the user to make informed decisions. IRRIS takes the information of the existing infrastructure as an input from already present online maps and is also capable of taking real time data input to track and monitor the shipments. The datasets integrated together are

- Infrastructure data
- Transportation logistics
- Real-time tracking

IRRIS allows the user to specify points and calculate distances between them along with the determination of accurate positions of these points for getting shipment location. Another capability of IRRIS is the provision of turn by turn information, it gives detailed information about driving directions and also informs the user about the time required to reach to a specific destination point. This application is a decision making facility that allows generation of multiple routes e.g. the shortest or the fastest path. Another capability of this application is of tracking, if the driver deviates from his path, this application notifies him that he/she has deviated from the correct route and needs to get back on track. Weather conditions are also considered for routing purposes in this application. Cameras are used to have real time picture of the surrounding environment at intervals of 60 seconds, this information (traffic speed, traffic congestion, road type) acquired is then used in the determination of routing criteria.

It also tracks general freight traffic to provide total asset visibility for tracking containers moving through different routes. Tracking is done through satellite communication systems and information is transmitted through secure FTP. IRRIS is capable of modeling effects and predictions about the hazardous materials present at any particular location through different color coded plumes which are all mapped. IRRIS model also suggests emergency response guidelines. The additional component of query builder adds the ability to show textual data into tabular format and running of spatial queries to search features in specific areas entered by the user.

IRRIS provides comprehensive set of functionalities that are helpful for the convoys to choose the path especially when it comes to security. Another capability of this application is that it can provide information about the nearest facility, its exact location and what services are provided there. Being a web based application IRRIS has many functionalities that closely relate to our project, however one big difference is the use of commercial software's in contrary to our aim of using open source technologies.

Figure 4: IRRIS (GeoDecisions White Paper, 2004)

1.6.2 GREEN GPS

In Green GPS (Ganti et al., 2010) fuel efficient routing is done to find the best alternative path. Open source routing software Gosmore[3] is used to find the optimal routes. On Board Diagnostics, level 2 (OBD -II) is used to find the internal condition of vehicle like coolant temperature and engine idle time. The final route is generated after considering many factors like type of vehicle, traffic conditions, speed of vehicle and manufacturing date. In Green GPS data is collected by individuals to find the routes. The main impact of this application is on fuel consumption and directly results in minimizing the travel cost. Green GPS uses prediction models for fuel efficient paths. Three different types of routes are generated in the end; shortest route, fastest route and the most fuel efficient route. This is also possible that fuel efficient route is same as shortest or fastest or maybe not.

With reference to military, convoys need routes which are the most suitable for them. Heavy vehicles like tanks and trucks used in convoys and their fuel consumption is high with respect to other simple vehicle. Furthermore if we have a fuel efficient path for troops and convoys than cost of fuel can be minimized but timings in convoy movements are also an important factor which has to be considered on time and fuel efficient routes for attacking an enemy area. The other important part of paper which is related to our project is data collection through individuals to increase the efficiency of best fuel consumption route. If we cater that part in our military project than it will be quite useful as data about the vehicles are important. For example every tank has its own fuel consumption depending on manufacturing year, speed of vehicle, road conditions and capacity of road to bear the load. The other factors while finding the route are traffic conditions on roads because fuel consumption totally depends on the speed of vehicles. Consider the scenario in which Army units have to move convoys and heavy machinery from Khariyan Cantt to Wagha Border. In this case Army convoys have two routes i.e. shortest and longest. Shortest may consume more fuel than the longest path. Longest path may take more time but it might be the best route in terms of fuel consumption because of the good speed and less traffic jams.

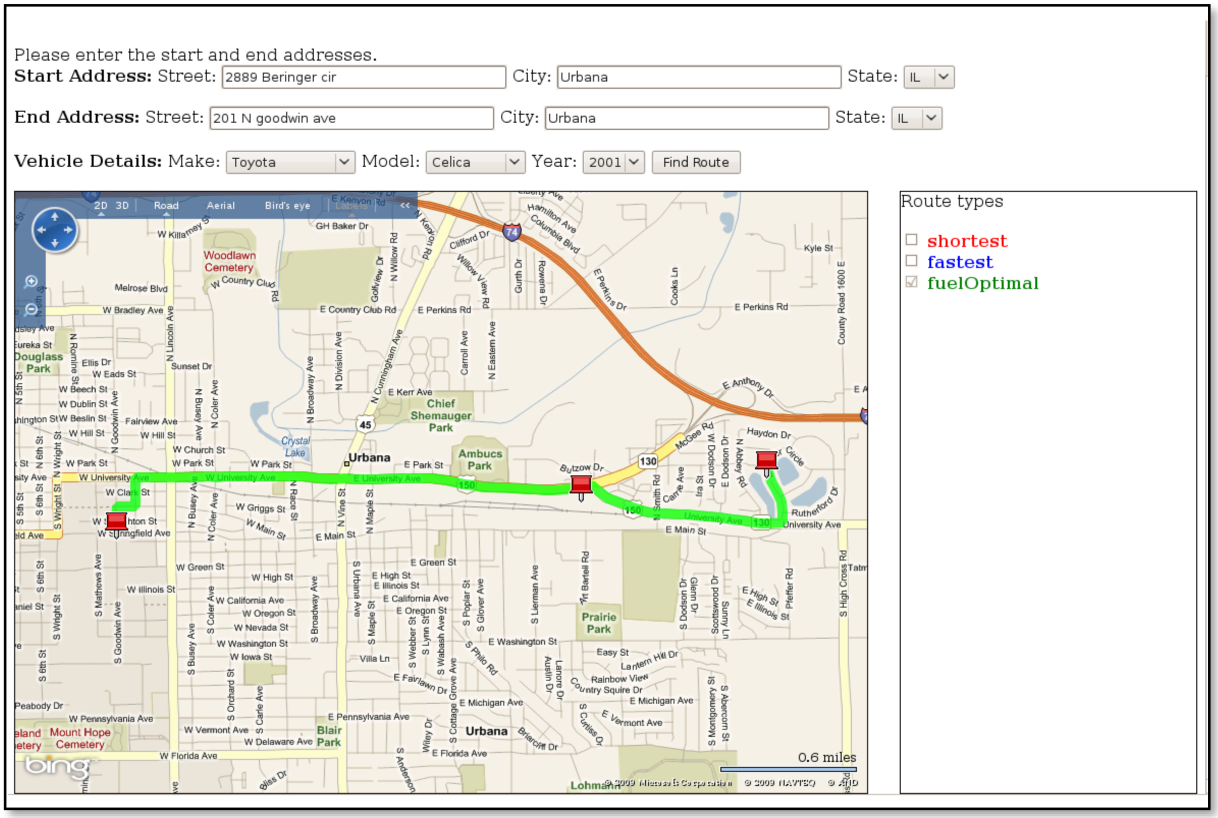


Figure 5: GREEN GPS Interface (Ganti et al., 2010)

1.6.3 Scenario Authoring and Visualization for Advanced Graphical Environments (SAVAGE):

This paper (Blais et al., 2001) demonstrates how Extensible3D and Virtual Reality Modeling language (VRML) are used for 3D visualization of amphibious operation. The main objective is to give better understanding of battle space in 3D visualization to operation planners and executors. For the purpose Extensible Markup language (XML) document is transformed to VRML/X3D objects. X3D is better than VRML as it addresses many issues that were faced using VRML 97 including better visualization , compatibility issues , file format , compatibility with specified standards . It uses XML to represent the features' geometry and behavior like VRML without any unwanted distortion. SAVAGE project will be able to represent important and critical aspects of battle space like coordination measures, terrain information, positions of objects, force dispositions, maneuvers etc. This project is designed to represent the complex military operations in web environments and enables the user to implement the operational scenarios.

The 3D component of this application allows the visualization of objects movement relative to one another and relative to user's viewpoint or angle. It enables the user to visualize different objects at different zoom levels and different views, allowing the user to pan over the globe without any major distortion in the scene. Furthermore the user can change the type of the vehicle e.g. tank or helicopter and see their 3D movement using real physics logic.

It also provides the user to visualize layers individually or in different combinations for different manipulations. In addition user can add the time based information for exploration in battle space. The application also allows the user to toggle between 2D and 3D views. In our routing application we have to use Java OpenGL (JOGL) for 3D visualization instead of X3D.

This paper suggests different scenarios that we can incorporate in our application to enhance visualization. Figure 6 shows interface of this application.

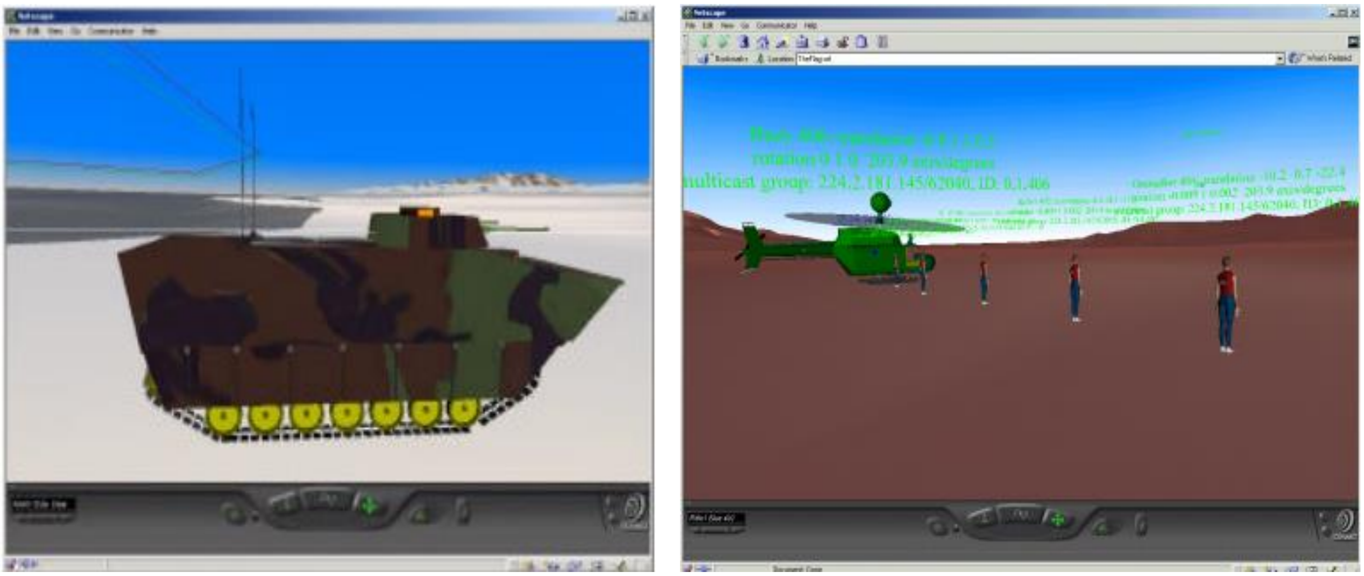


Figure 6: 3D visualization of objects in SAVAGE Project (Blais et al., 2001).

1.6.4 Selection of Optimal Route Using Virtual Reality and GIS:

Virtual reality is a computer simulated environment that can simulate physical presences in places in real world or imagined world. In this paper virtual reality is used with GIS for finding the optimal route. Roads play vital role in infrastructure and have great impact on economy. Nowadays many goods are transported only through roads. In business transportation the shortest distance can be good and may be fewer details are required for path while in ground military based operation multiple factors are considered. The most important factors are elevation and topography for troop's movement. In this paper optimum routing is done to plan traffic situation in the city. Roads slope, inclinations and horizontal curves are also considered while finding the best route. Three different alternative routes are generated with 3D incorporated. Routes are including each point of 3D construction that composes the polygons. Finally it generates the driving simulation for better understanding of surrounding areas.

Military troops are always on risks because enemy's presence is ubiquitous. In this case need for multiple options for reaching destination is required. In case of multiple routes we need a lot of information like road conditions, peak hours, type of road either its one way or two ways, slope and elevation. Incorporation of topography can be more appealing and appreciable to see the position of enemy.

One of the scenarios we are implementing demands generation of multiple alternative routes and 3D visualization of the route. Multiple routes are required when time constraint is present and different convoys have to move to the same place. Chances of traffic congestion in junctions of roads are high. Multiple routes help us to avoid that congestion. 3D visualization can help us in finding the details about that area such as type of obstacles, slope and elevation.

In the light of the above mentioned routing applications, some of the key factors that need to be considered while performing routing for military purposes are as follows:

Obstacles and barriers identification:

When planning a route, use of map to identify existing obstacles that can hinder movement is crucial. Planning route around such obstacles can be difficult and challenging task. In addition to existing obstacles, we can also predict where the enemy may emplace reinforcing obstacles (either independently or tied into existing obstacles) to disrupt, turn, fix, or block the movements. While route planning, it is also important to identify those known existing or reinforcing obstacles that can help protect our movement and select our route accordingly to take advantage of such protective obstacles.

Routing criteria:

On the basis of observations and obstacles we can decide which route is best for our troops to move as software can generate alternative routes on the basis of observations and provide the user with shortest, fastest or barrier free route.

Terrain Visualization:

Key terrain is any terrain in your area of operation that provides a marked advantage for anyone who controls it. When route planning, we must analyze the terrain that the enemy would consider as key terrain and may have a post set up over there and then plan your route away from it or around it, to avoid enemy observation and fields of fire. For that purpose 3D visualization of the route is helpful. Cesium plays a vital role in visualization and understanding the terrain of area.

2 *MATERIALS AND METHODS*

2.1 STUDY AREA

Islamabad is the capital city of Pakistan and is located at 33.43°N 73.04°E.. The capital is divided into many zones and sectors based on their usage. It is present on the Pothohar Plateau. Elevation of capital city is around 540 m and covering an area of 906 sq km. Further 2,717 sq km area is present with the Margalla hills in the north and northeast. The region has historically been a part of crossroads of Punjab and Khyber Paktunkhaw with the Margalla pass as a gateway between two regions. Srinagar, the capital of Indian state of Jammu and Kashmir lies 300 km away from Islamabad. Climate of Islamabad has a humid subtropical climate with five seasons. These seasons are winter, summer, autumn, spring and monsoon. The hottest month is June, where average temperature exceeds 38 °C. Wettest month is July, with heavy rain falls. Coolest Month is January. Islamabad's climate is regulated by three artificial water reservoirs: Rawal Dam, Simli Dam, Khanpur Dam.

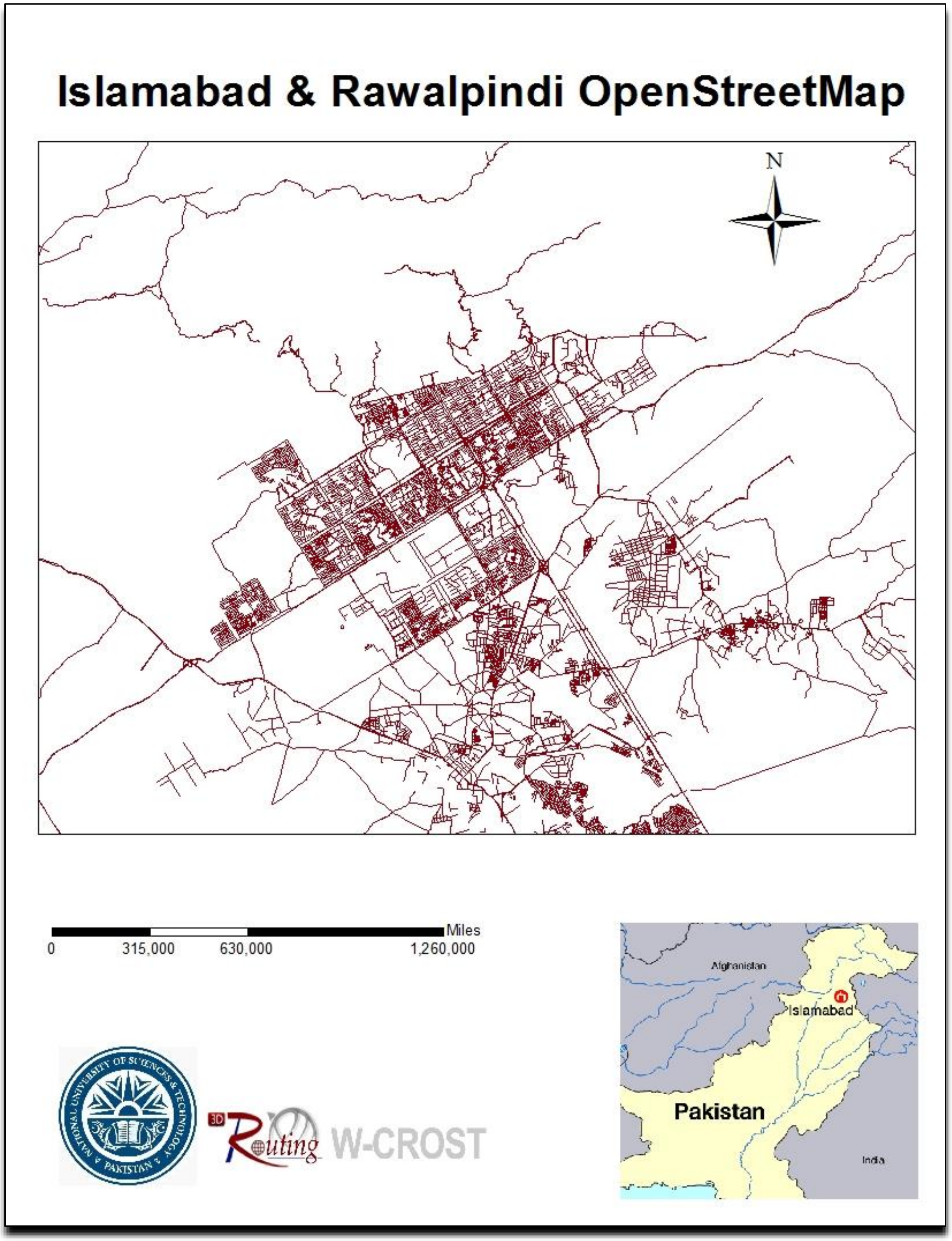


Figure 7: Study Area Map

2.2 DATA SOURCES, QUALITY AND LIMITATIONS

The datasets used for this application are:

- OSM data
- Google maps
- Bing imagery
- Real time node/point allocation

OSM Data:

OSM is free and open content license map of the world, which is editable by anyone. Many volunteers have built it from scratch to useful form. Anyone can download the OSM of any area and fetch the attributes from the map and use those attributes in application. Many web applications are based on OSM data because of its high functionalities. Size of OSM dataset increases as the study area increases and for processing on large amount of datasets more time and effort is required. So we only acquired the desired data as per our study area. OSM data can be download in various ways using various ftp or http protocols. Other than official service of OSM, there are many other web services which are providing OSM data freely.

Google Maps:

Google Maps are product of Google, which provides mapping services online. Incorporates offers satellite imagery, street maps, and 360° panoramic views of streets real-time traffic conditions and route planning. Google Maps uses the same satellite information as Google Earth. The satellite images of Google Maps are not updated in real time. Google Maps uses the

Mercator projection, therefore it is not reliable for taking measurement around poles. They also provide high-resolution aerial satellite images for most urban areas of the world. Google is not an open source organization so its products are all commercial, they are not freely available. They provide free services up to some extent but not fully free. Their services are not very efficient in term of freely available as OpenStreetMap.

Bing Imagery:

Bing imagery is provided by Microsoft Bing suite. It is basically a web mapping service for 3D visualization. Any track or road network can be observed in 3D using Bing Imagery. Bing Imagery services can be uses as WMS or WFS standards in web applications. The interesting feature of Bing Maps is the Street maps. Street maps include the topographically-shaded areas. Maps include public collection, business collection, and location of basic facilities and public user created point of interest. Five street map views are available and are classified as: Road View, Aerial View, Bird’s Eye View, Street Side View, and 3D View.

The description of each view is as follows:

- **Road view**: Road view displays the vector imagery of roads, building and geography.
- **Aerial view**: Aerial view overlays satellite imagery onto the map and highlights roads and major landmarks for easy identification amongst the satellite images. Bird's-eye view displays aerial imagery captured from low-flying aircraft. Bird's-eye images are taken at an oblique 45-degree angle, showing the sides and roofs of buildings giving better depth perception for geography.

- **Street side:** Street side provides 360-degree imagery of street-level scenes taken from special cameras mounted on moving vehicles.
- **Venue Maps**: Venue maps provide a way of seeing the layout of the venue. For example how the hospitals or airports look like.
- **3D Maps:** The 3D maps feature allow users to see the environment e.g. buildings in 3D, with the added ability to rotate and tilt the angle in addition to panning and zooming. To attempt to achieve near-photorealism, all 3D buildings are textured using composites of aerial photography.

Bing imagery has a great advantage in visualizing the vector and raster layers in 3D. It can easily be incorporated in web applications using Open Geospatial Consortium (OGC) standards such as WMS, WFS. Bing imagery may easily be integrated with other open source applications such as cesium and JavaScript functions can easily be deployed on it. Bing maps are flexible in nature, there different components can be used with multiple applications.

Table 1: Data Sources

Data type	Source	Use
OSM	Data downloaded from OSM site	2D routing
Google Maps	High resolution from Army Survey Group	3D offline data
Bing imagery	Used by Cesium during online data display	3D visualization
Real time point allocation	Entered by User	To get route

Table 1 illustrates different data types and major sources of those data and what are the major purposes those data types are uses. In the table OSM data types are downloaded from official online web service most of the times but there are also many other web services which provide raw OSM dataset as well as processed OSM dataset such as projecting data in different projection systems. Google Maps are available online but in our applications we obtained those maps from Army Survey Group because of high resolution imagery availability. Bing imagery is used for Cesium to develop 3D visualization of routes. Real time estimation is position of source and destination of route which are needed to generate a route.

Base Data:

Base data is the data which is used as a reference to the application. In most of GIS and Remote sensing applications maps are used as base data, these maps may include topographical sheets, satellite imagery, aerial photographs etc. as a reference to the mapping application. Map layers can be added by users containing data of roads, utilities or any other vector data as well as the raster data and that can also be displayed in the application base data/base map. Many web applications uses OSM as base map in their mapping components. The base data we used for our project is OSM data. Imposm shapefiles of OSM is used as the raw dataset. Imposm is OSM dataset available online free of cost. This dataset was chosen after experimenting different datasets, as it best served our needs in term of creating databases, assigning projections systems, creating topology and node networks. Dataset was made routable by making its topology, creating node network by applying multiple queries that were implemented in PostgreSQL. Dataset layers for generating routes were created in GeoServer to use them WFS services in GeoJSON format for Open layers 3. GeoServer is another open source software, freely available and has a high functionality to represent spatial data on the web. Osm.bz2 files were used to load OSM for offline base data because of the fact that it has the capability to import data directly using ogr2ogr extension of PostgreSQL. Bing imagery is also used as base map to visualize the routes in 3D.

Real Time Feed:

User interface will provide the user the ability to enter the real time query to generate route using different source and destination and providing different route parameters such as fastest or shortest route. User will provide source and destination to query the route and that source and target will be passed into GeoServer layers and the route will be displayed using WFS

GeoJSON services of Open Layers implemented in JavaScript libraries. Alternative route can also be generated by putting an obstacle (barrier) mark on the route. All such type of queries are applied by the user at real time on front end without interacting with server side or middle ware.

2.3 WEB ARCHITECTURE:

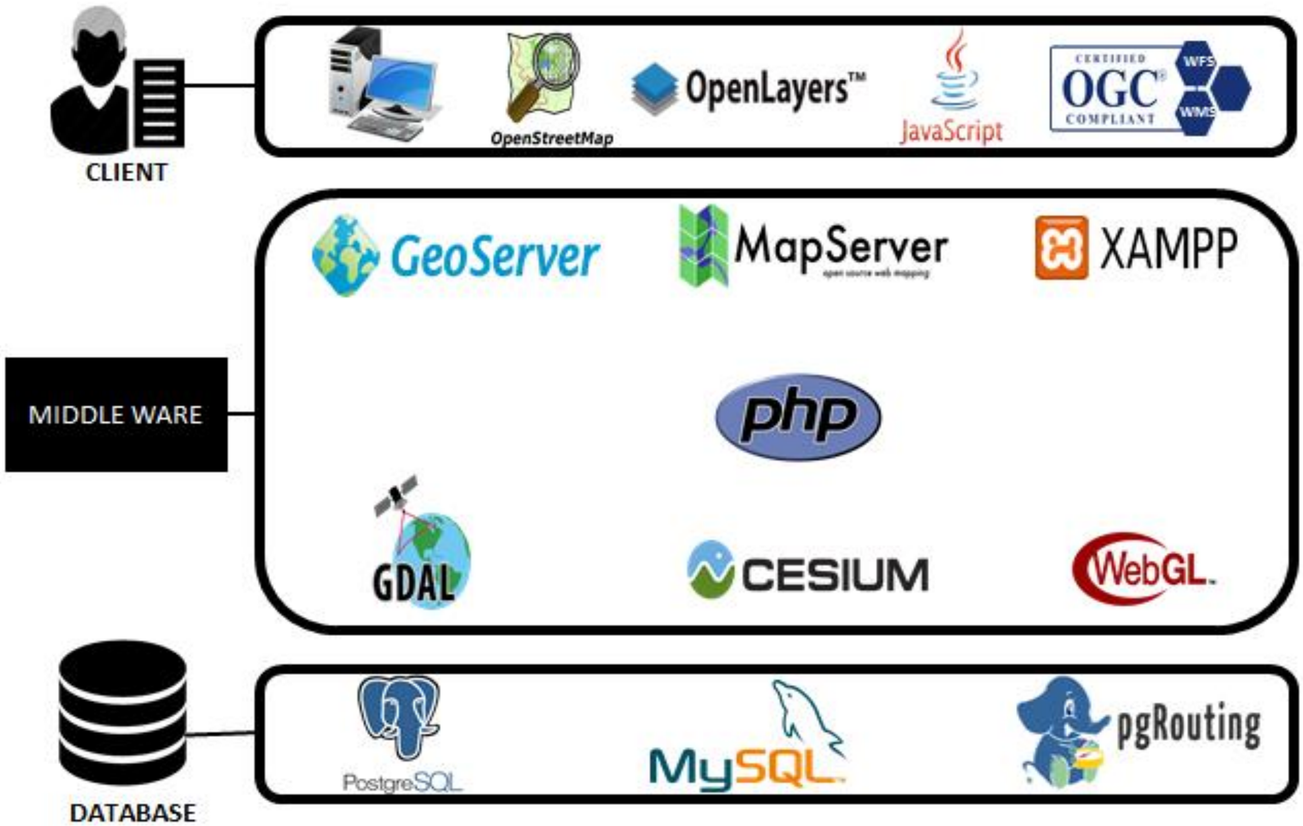


Figure 8: Web Architecture

Figure 8 shows the overall framework of project that consists of three tiers is as follows

- Backend Tier (Database)
- Middle Tier(Middleware)
- Front Tier(Client)

Backend Tier (Database):

Database tier is the low level tier, also known as backend tier. There are many Database Management system utilities available at commercial and open source level such as Oracle, Apache hive, PostgreSQL, MySQL etc. All of them are differentiated from each other based on their availability (commercial or open source), and they are also differentiated from each other based on their capability of dealing with spatial data. PostgreSQL is widely used when it comes to deal with spatial databases, and it has very high compatibility with other open source geospatial utilities such as Geo Server, Map server. First of all Imposm dataset was download because of its high compatibility with PostgreSQL, then that data was imported into PostgreSQL using ogr2ogr extension on created database of PostgreSQL with implementation of PostGIS and pgRouting extensions. After importing data into database, processing was applied on the data. First of all topology was created in the database. Once topology is correctly created on the database, node network was generated using SQL queries and providing accurate parameters. Once node network is generated final topology was created again on the node network. Once the final topology is run, we have database in routable format and now it can be used to retrieve the routes from the database. This database then is used in pgRouting algorithms. pgRouting algorithms help in finding optimal path between different nodes using queries and user specified cost parameter. Other than PostgreSQL database management system, MySQL was also used.

MySQL was used not to deal with spatial component but to maintain the databases holding user information that is provided by creating account for using the application. MySQL database contains complete information of the user. MySQL database was also used to provide guest users limited functionality, and provide routing application to only those who have authenticated accounts.

Middle Tier:

After the database was prepared a network was built in database and then published in GeoServer through SQL Views with pgRouting algorithms such as Dijkstra's algorithm which involves SQL queries. Using OpenLayers 3 and WFS services of GeoServer the route against different scenarios was displayed. Additionally cesium and WebGL were used for 3D visualization. PHP was used for directly managing GeoServer layers from PostgreSQL database.

Middle Ware consisted of the following technologies

- GeoServer
- MapServer
- XAMPP
- GDAL
- Cesium
- WEBGL
- PHP

Front Tier:

The routing applications can be accessed using remote connection to the server, and getting different outputs according to different criteria without knowing the server side or middle ware processing. At front end anyone can create a new account or if user already has an account he can login and use the routing application services.

Front tier technologies include:

- Open layers
- JavaScript
- HTML
- CSS
- OGC standards

The front end web development languages were used to prepare the end user interface. Hyper Text Markup Language (HTML) was used for the designing and layout of the front end. It is the main web language needed to create web page with multiple documents and graphics. For styling Cascading Style Sheets (CSS) is used which is designed primarily for the separation of document from the presentation. Presentation of documents includes layouts, colors and fonts. This separation helps in improving content accessibility, more flexibility and control in the specifications in presentation. It further reduces the complexity and repetition in the structural content. JavaScript has a main part in this project. It's used because it is much speedy at the client side and can be integrated with other languages and offer wide range of application development. It is a language to program the behavior of web pages. Most commonly used as a part of web browsers, whose implementation allow client side to interact with the application , control the browser , communicate and alter the displayed content. JavaScript is a lightweight programming language that is why it is widely used and easily integrated with the web pages. OGC standards are used for displaying spatial features such as routes, markers, base maps, vectors and raster layers in OpenLayers3.

Operating System:

Windows are widely used for the development purposes among other operating systems such as Linux, Mac due to ease of use and provide a good platform for integrating multiple technologies into one framework. In our case we have chosen windows 7 because it is widely used in office work and its flexible environment. Windows 7 has almost 54% share in the market that makes open source technology relatively easier to use and encouraging for developers.

[1]

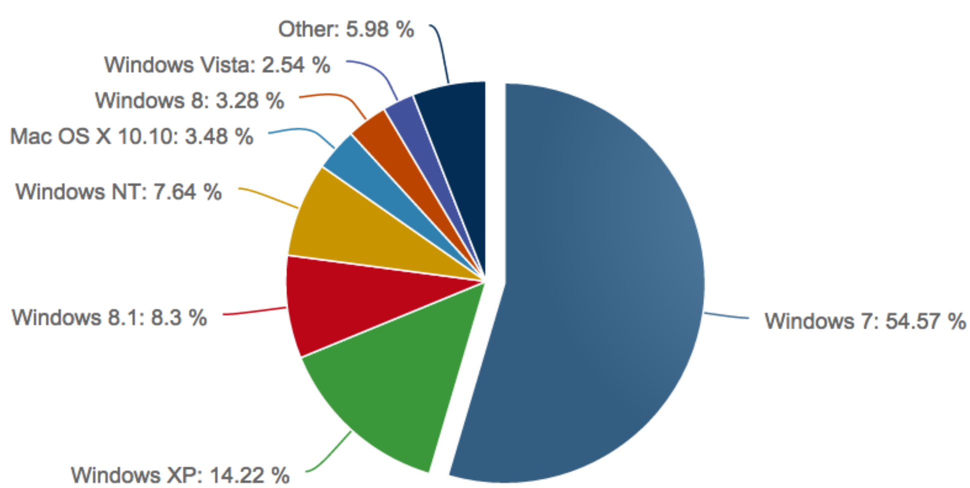


Figure 9: Pie chart of Windows share in Desktop OS

[1] http://www.netmarketshare.com/operating-system-market-share.aspx?qprid=10&qpcustomd=0

Server side development:

In order to bring the results of query from database to front end a server is required such as GeoServer of MapServer because they are used for geospatial utilities. In order to bring route data to browser we made layers on GeoServer for the database using SQL views, and then that was published on the web using OpenLayers3.

PostGIS (data base):

PostGIS is a spatial database extender for PostgreSQL object-relational database. PostGIS turns the PostgreSQL Database Management System into a spatial database by adding support for spatial type, spatial indexes and spatial functions. PostGIS automatically inherits features from PostgreSQL as well as it supports well-known open standards. It adds support for geographic objects allowing location queries to be run in SQL. PostGIS has become a widely used spatial database, and the number of third-party programs that support storing and retrieving data. In our case data is saved in PostGIS along with PgRouting extensions.

GeoServer:

Geo server is an open source product written in Java that allows users to share and edit geospatial data. The aim of GeoServer is to operate as a node within free and open spatial data infrastructure. Designed for interoperability, it publishes data from any major spatial data source using open standards. GeoServer is an OGC compliant implementation of a number of open standards such as Web Feature Service and Web Map Service. GeoServer can import data in both vector and raster data formats. The data can also be displayed in different formats e.g. PNG, KML, JPEG, Shapefiles.

MapServer:

This platform is an open source to publish the spatial data and other mapping applications. It is supported by all types of operating systems i.e. Windows, Linux and Mac OS X. MapServer has a connectivity with the PostGIS databases, which is used to display layers using geometry of tables in PostgreSQL. Map server is used here to display offline OpenStreetMap that is by providing OpenStreetMap data into tables of PostgreSQL database and connecting those tables with MapServer layers. It provides outputs with full customization if required. Maps rendered are of the high quality and it has support for different types of development environments including PHP, Python, Java, and JavaScript. It has the ability to display the vector as well as raster data. MapServer is run as Common gateway interface (CGI) that is why it is supported by many programming languages. Map is requested through the URL by the user and then it is displayed through the map file. The request may also return images for legends, scale bars and values displayed over the map.

pgRouting:

pgRouting is an open source utility and is used to provide routing capability and functionality to the data that is stored in PostGIS database. It extends the functionality of geospatial data of PostGIS/PostgreSQL and provides routing geospatially. It enables the user to create the topology and calculate the shortest distances using different algorithms. Most common and widely use algorithm is Dijkstra’s algorithm. Algorithms in pgRouting generate output using “cost” parameter. The cost in pgRouting can be any value. It can be time, distance, and fuel efficiency. Using the cost parameter in pgRouting it provides solution for shortest distance for one path, for multiple paths, provides vehicle routing, driving distance, network analysis and many others. Advantages of the database routing approach are:

- Data and attributes can be modified by many clients, like QGIS or directly using Pl/PgSQL. The clients can either be PCs or mobile devices.
- Data changes can be reflected instantaneously through the routing engine. There is no need for pre calculation.
- The “cost” parameter can be dynamically calculated through SQL and its value can come from multiple fields or tables.

In order to run pgRouting, first of all topology is created on the OpenStreetMap dataset using SQL queries. After topology is created node network is generated from the OpenStreetMap dataset. Once node network is generated then topology for that node network is created again. After creating final topology, cost parameter values are computed for each record such as for total length of each road geometry of each record is used to calculate the length of each road and to calculate the travel time distance formulae is used. Now pgRouting algorithms can be applied on the dataset prepared.

Cesium:

Cesium is an open source that is based on Apache 2.0. Openlayers-3 supports cesium for 3D visualization. Cesium is based on JavaScript library. There is no need for additional plug-ins for web support. Cesium supports different widgets for-example full screen widget to toggle into full screen mode. Similarly navigation incorporated helps the widget to follow instructions by the movement of mouse, and selection widgets are used to highlight any features present on the globe. There is also an option of views of the globe i.e. 2D, 3D and Columbus view. Finally an inspector widget is used to debug advanced graphics. It provides different camera views to the user. It also draw and create features. Vector data can be drawn from GeoJSON and TopoJSON. User can also draw 3D models. Imagery layers can also be added or created using OSM, Bing imagery, WMS and TMS.

OpenLayers:

OpenLayers web mapping library is redesigned to produce OpenLayers 3. It is rewritten from basics to the advanced functionalities and modern technologies. It provides much functionality of OpenLayers version 2 with many advanced features i.e. support for wide range of open-source vector data formats. Other improved display functions are present in this version for example ability to rotate or animate maps. OpenLayers 3 is enabled to use HTML 5 features like WebGL. Vector data formats can be quickly displayed using WebGL. 3D maps can also be displayed using Openlayers 3. OpenLayers 3 requires updated and recent browsers as the technologies it is using are also advanced. OpenLayers 3 map API is the core component to display the map.

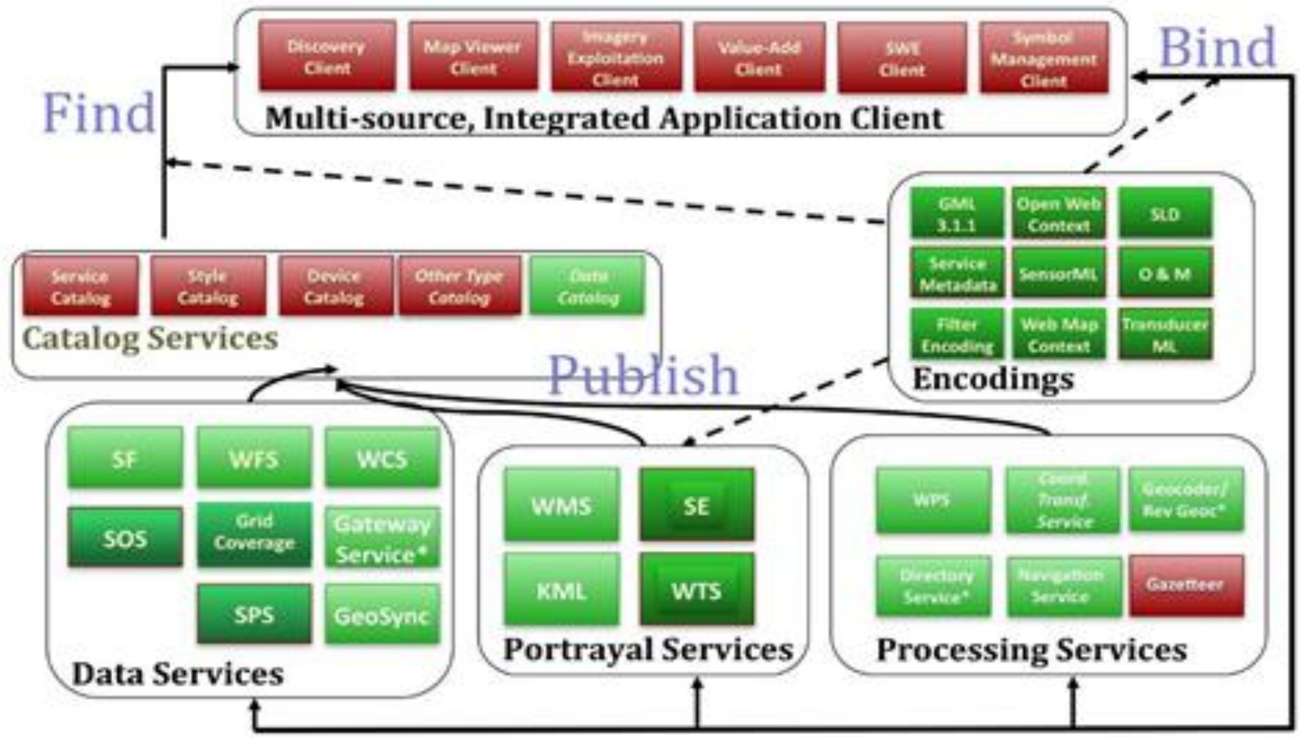
In this project Openlayers 3 was used because of its utility to provide 2D and 3D visualization of the vector and raster layers simultaneously. For displaying possible routes for the user under defined criteria the route will be displayed in 2D and then the same route will be displayed in three dimensions by switching between different modes. 3D visualization is done using Cesium because of its high compatibility with OpenLayers3 and its provision within software development kit of GeoServer but OpenLayers2 has compatibility issues with Cesium.

XAMPP:

XAMPP is a free and open source platform web server which includes Apache, MySQL Database, PHP and Perl Programming Language. XAMPP is an acronym consists of five words. “X” stands for cross platform. “A” stands for Apache. “M” stands for MySQL. “P” stands for PHP and last “P” for Perl. It is easy to install, and with XAMPP we do not have to install components individually, it comes with complete package at one place. Many features are by default disabled to make it more secure. Our whole applications is prototyped on XAMPP. Accounts services are created on MySQL of XAMPP.

Open Geospatial Consortium (OGC):

Open Geospatial Consortium is an international volunteer organization which includes commercial, government, non-profit organizations in their consensus process. It is established to encourage development and implementations of standards for geospatial services. A large number of standards have been built by OGC and members of Abstract specifications are continue to develop more standards to server specific need for interoperable and geospatial technology. Additionally all those standards are available to public free of cost.



[2]

Figure 10: OGC Framework

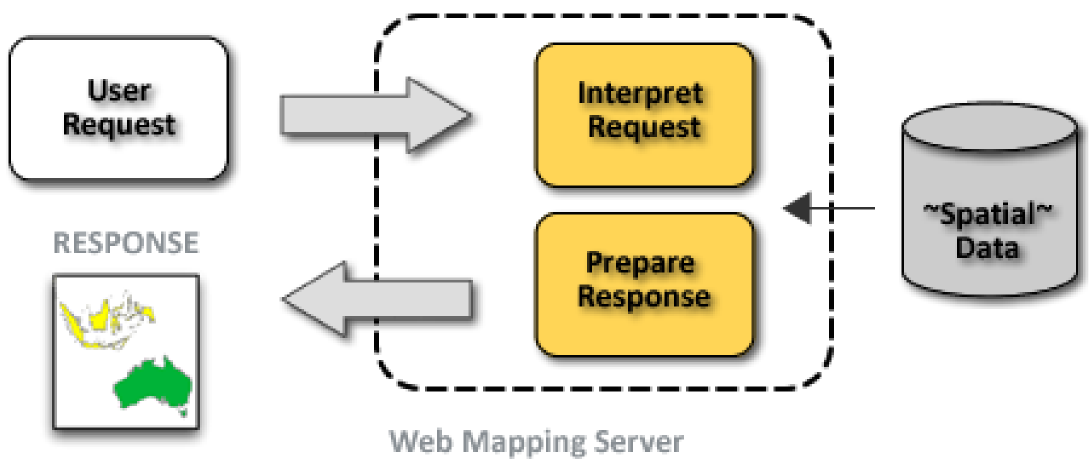
In Figure10 a framework for geo processing of standards developed by Open Geospatial Consortium is represented. Web Mapping Service (WMS) and Web Feature Service (WFS) are two OGC standards which are used in this project.

Web Mapping Service:

Web Mapping Service or shortly known as 'WMS' is a standard protocol create by Open Geo Consortium that serves with geo-referenced images over the internet that are generated by some map server using data stored in a map database. WMS server usually supports the bitmap format e.g. PNG, GIF or JPEG. Additionally vector graphics can be included such as lines, point's texts and curves. WMS provides a standard interface for requesting a geospatial

[2] http://live.osgeo.org/en/standards/standards.html

map image. The benefit of this is that WMS clients can request images from multiple WMS servers, and then combine them into a single view for the user. The standard guarantees that these images can all be overlaid on one another as they actually would be in reality. Numerous servers and clients support WMS. Web Mapping Service reformed the Online Mapping experience, especially with the introduction of Google in 2005. The idea was not just helpful in making maps available online only for viewing in a quick and easy manner rather it produced the possibility of creating a mash up through different Application Programming Interfaces (APIs) like Google or Open Layers; leading many to proclaim the "democratization of mapping". Web Mapping Services impacted the Map World with vast benefits including possible areas for future development.



[3]

Figure 11: Web Mapping Service Architecture

[3] http://presentations.opengeo.org/2012_FOSSGIS/suiteintro/geoserver/server-mapping.html

In this project WMS is used to display some layers such as OpenStreetMap, road intersection point’s layer, and Bing imagery. Some of these WMS layers has URL which has accessed using internet such as OpenStreetMap and Bing imagery while some layers such as intersection point’s layer are created in the GeoServer, so their URL are of localhost without any internet connectivity.

Web Feature Service:

Web Feature Service is also known as “WFS” is a standard developed by OGC which provides the interface to allow requests for geospatial features across the web using platform-independent calls. WFS is used to include vector data such as lines, multiline, polygons in the web application. WFS data manipulation operations includes following abilities:

- Querying features based on their spatial and non-spatial components.
- Creating new feature instances
- Deleting features instances
- Updating feature instance

There are many open source and commercial implementations of WFS including GeoServer as an open source. There are many WFS formats available in GeoServer such as GeoJSON, KML, GML, which represent the data in different platforms. In this project WFS services are used to generate route information. GeoJSON format of WFS layers published on GeoServer is used to get information and then that information is parsed into JavaScript functions to highlight the route form source to destination. GeoJSON representation of route includes its geometry and other information.

2.4 IMPLEMENTATION

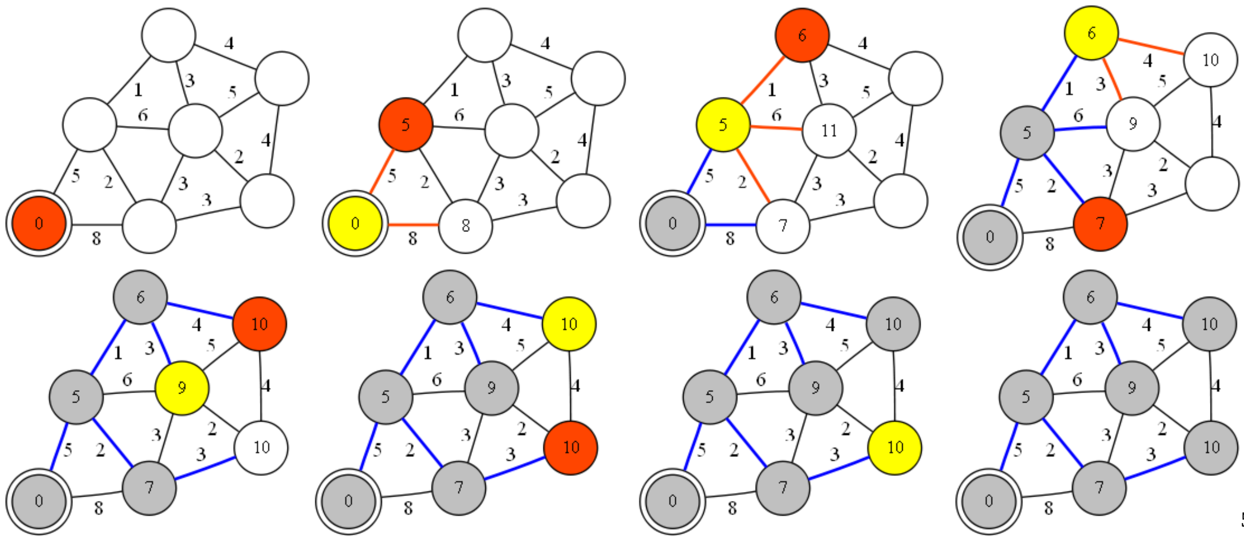
After extensive review of literature on various aspects of routing both technical and associated technologies are required for successful implementation and deployment. Implementation of the scenarios and technologies is the major task. Our software is generating routes on the basis of distance and time. Shortest path is calculated based on distance constraint and fastest path is based on time criteria. Shortest path is calculated on the basis of Dijkstra's algorithm in our project. For the understanding of this algorithm we consider an example:

For example one has to go from home to office but want the shortest route to that area. Shortest path is based on the distance that is minimum distance which a traveler needs to cover from the house to the road. Shortest path is not the fastest route sometimes because of traffic congestion at peak hours. Shortest path are mostly based on Dijkstra's algorithm. Dijkstra's algorithm is called the single-source shortest path. It is also known as the single source shortest path problem. It computes length of the shortest path from the source to each of the remaining vertices in the graph. Dijkstra's algorithm works on breadth-first search (BFS) and finds the shortest path between the nodes in a graph. Road network is required in case of our project which we are taking from OSM.

Breadth first search (BFS) explores vertices by spreading out as new vertices are found. From the starting vertex , the distance to the nearest vertexes are measured and the shortest distance is selected , Similarly from the shortest distance vertex next vertexes are compared until it reaches the end or destination vertex. Distances are found until the entire network is searched. The algorithm is as follow

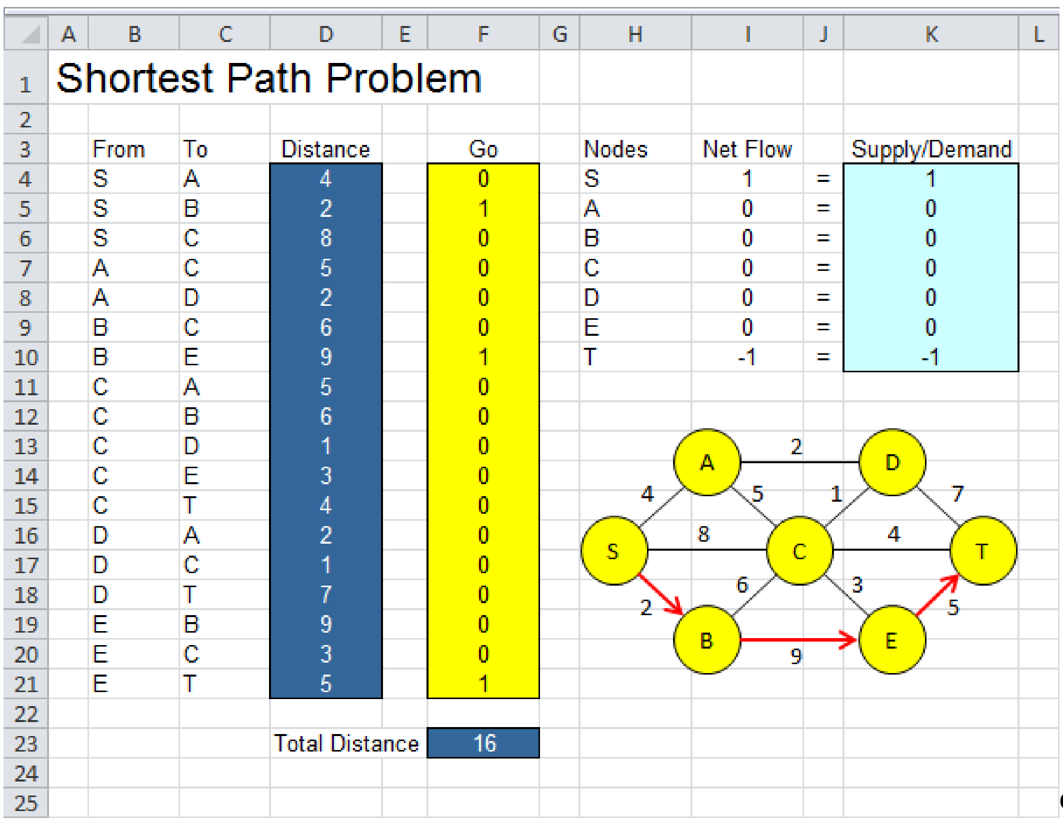
```
function Dijkstra(Graph, source):[4]

    dist[source] ← 0                 // Distance from source to source
    prev[source] ← undefined          // Previous node in optimal path initialization

   for each vertex v in Graph:  // Initialization
      if v ≠ source:          // Where v has not yet been removed from Q (unvisited nodes)
         dist[v] ← infinity          // Unknown distance function from source to v
         prev[v] ← undefined          // Previous node in optimal path from source
      end if
      add v to Q                  // All nodes initially in Q (unvisited nodes)
   end for
    while Q is not empty:
     u ← vertex in Q with min dist[u]  // Source node in first case
     remove u from Q
     for each neighbor v of u:          // where v is still in Q.
         alt ← dist[u] + length(u, v)
         if alt < dist[v]:             // A shorter path to v has been found
            dist[v] ← alt
            prev[v] ← u
         end if
      end for
    end while
return dist[], prev[]
end function
```

[4] http://www.gitta.info/Accessibiliti/en/html/Dijkstra_learningObject1.html



[5]

Figure 12: Node Diagram



Shortest Path Problem

From	To	Distance	Go
S	A	4	0
S	B	2	1
S	C	8	0
A	C	5	0
A	D	2	0
B	C	6	0
B	E	9	1
C	A	5	0
C	B	6	0
C	D	1	0
C	E	3	0
C	T	4	0
D	A	2	0
D	C	1	0
D	T	7	0
E	B	9	0
E	C	3	0
E	T	5	1
		Total Distance	16

Nodes	Net Flow		Supply/Demand
S	1	=	1
A	0	=	0
B	0	=	0
C	0	=	0
D	0	=	0
E	0	=	0
T	-1	=	-1

[6]

Figure 13: Calculations of shortest path

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[5] http://www.math.cornell.edu/~mec/Winter2009/Thompson/search.html

[6] http://www.excel-easy.com/examples/shortest-path-problem.html

Importance of Dijkstra's algorithm:

We have chosen Dijkstra's algorithm in our project because of the following reasons:

- Dijkstra's algorithm is applied to automatically find directions between physical locations, such as driving directions on websites like MapQuest or Google Maps.
- In a networking or telecommunication applications, Dijkstra's algorithm has been used for solving the min-delay path problem (which is the shortest path problem). For example in data network routing, the goal is to find the path for data packets to go through a switching network with minimal delay.
- It is also used for solving a variety of shortest path problems arising in plant and facility layout, robotics, transportation.

While going from home to office fastest path will be calculated on the basis of time constraint that is take that route in which minimum time will be taken. For example some of the streets are two-way, and some are one-way. Furthermore, traveling down a street in one direction might not take the same time as in the other direction for instance, if there is some construction taking place on one side of the street or some traffic congestions. Now we will take the alternative path which is based on less time spent that is fastest but in terms of distances it might be more than the actual path.

In our project for path calculations following steps were done:

- Data is imported into PostgreSQL database using ogr2ogr extension.
- Topology is created on this dataset using SQL queries.
- Once topology is created, node network is generated.

- After creating node network, topology is created again on node network.
- Length of each record is added using length functions.
- Travel time for all record in database is calculated by dividing the distance with road type speed limit.
- Dijkstra’s Algorithm is used to get route based upon cost parameter value which can be time or distance depending upon user’s requirement.
- Boundless SDK and Openlayers 3.0 is used to create web routing application.
- SQL views are created in GeoServer to update the route as user changes source and target markers
- URL’s for SQL views created in GeoServer are used to return the optimal path information in .json format.
- GeoJSON information is then retrieved form layers of GeoServer to fetch the records of SQL views and then representing route using JavaScript functions.
- Ajax is used to reload only a part of applications rather than updating or fetching whole web pages. In our applications Ajax is used to reload new route according to user specified requirements i.e. different source and destination, different cost parameters for routing.

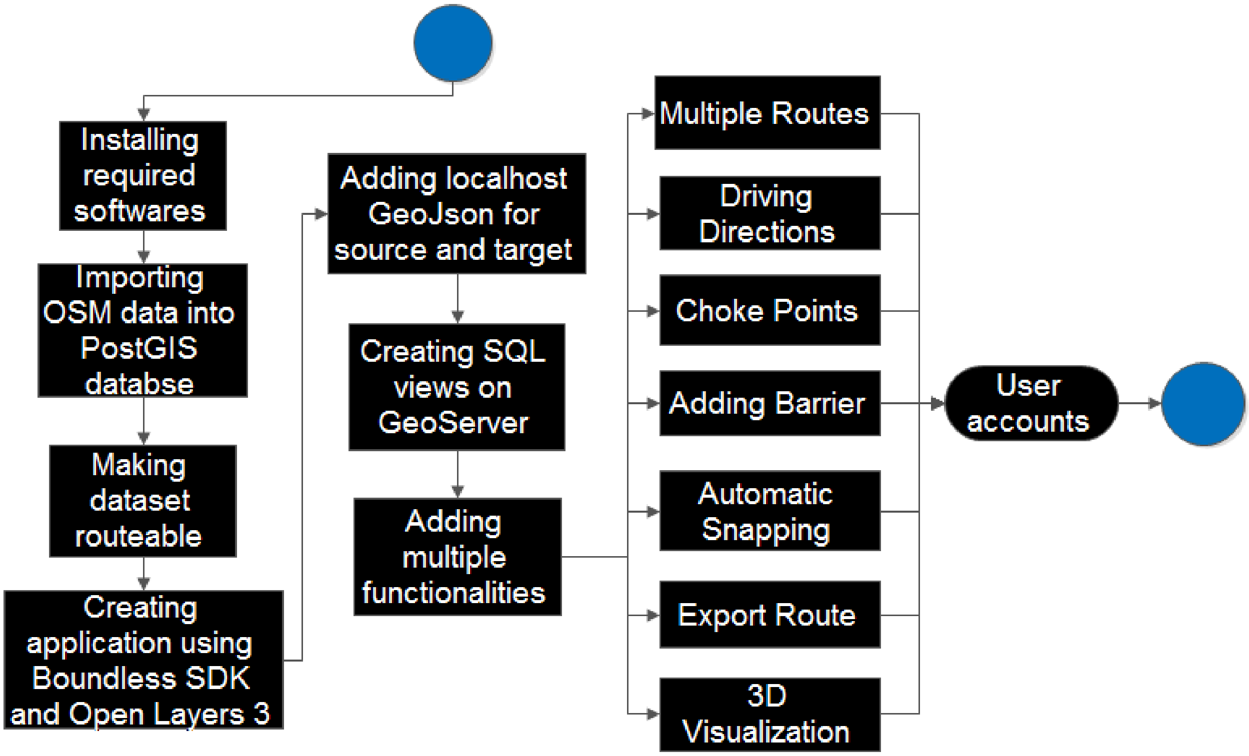

Figure 14: Basic Work Flow

Figure 14 illustrates the overall workflow of the project. It represents the flow of work from installing software to creating user account services. Use of all backend, frontend and middleware technologies is clearly visible in work flow chart.

User Interface:

This application provides a user friendly interface. To use this application fully i.e. to use routing application users are needed to have an account, if the user is not registered already, then user has to sign up for an account by providing necessary credentials. Once user has successfully created account, he/she is able to login to the application. After log in to the web application a new tab will appear in the browser which will navigate user to routing page. In that routing page a 2D map of the area is displayed. There is left menu, in which different criteria are given to the user in order to use this utility according to his requirements. User can select shortest or fastest route based on his/her needs. Shortest route will be displayed with red line and fastest route with blue. In the left menu bottom all the route information will be written such as starting point, ending point, total travel distance and total travel time. User can also get directions, road name, and time by clicking the road layer on the map and display it in the form of popup. This application also allows the user to add barriers and generates barrier free routes, so that it can suggest alternate route. Export map utility in the form of button is also available in the right menu, which allow user to export his/her current map to analyze it later. User can also switch view from 2D to 3D in order to visualize the route in 3D by toggling them in global view.

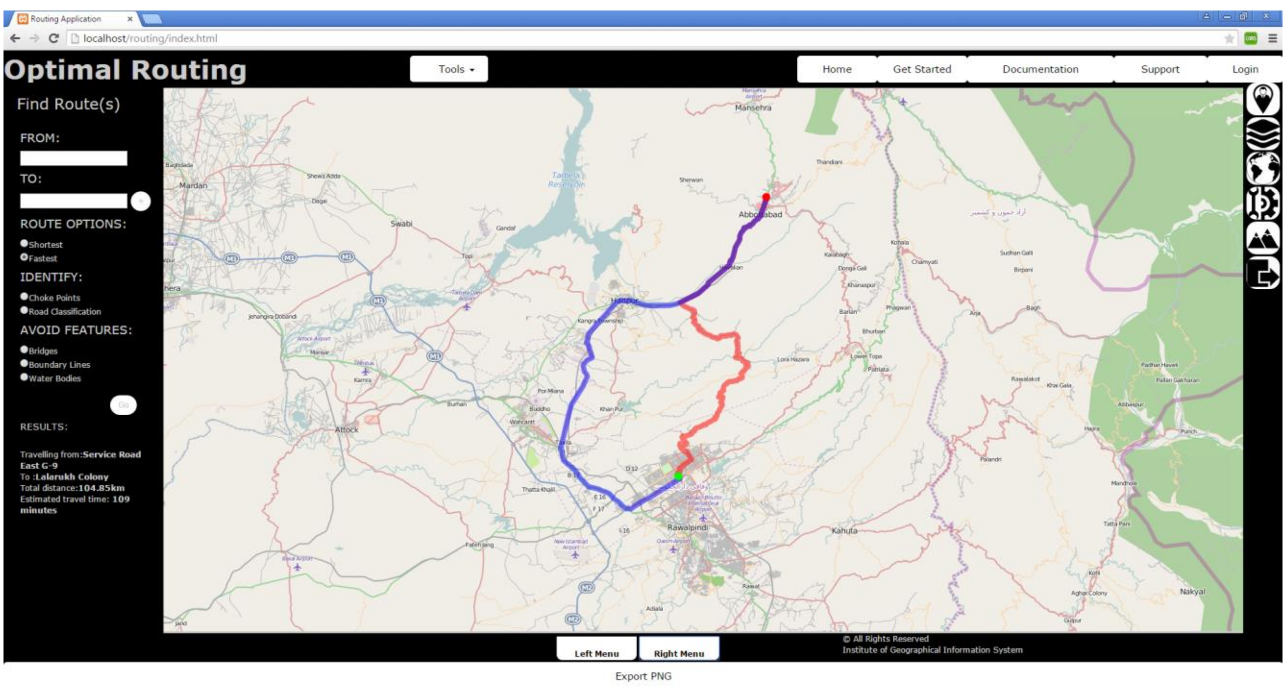

Figure 15: Interface of the application

Figure 15 demonstrate the interface of web applications after a user has log in to the application. We can clearly see the left and right menu in the figure. Two route layers are also visible on the map which represent different types of routes such as red color layer is representing shortest route and blue colored layer of route is representing faster route.

What Is Achieved By This Application?

This application is completely open source application with implementation of OGC standards. Offline control over 2D representation of OSM is achieved, i.e. OpenStreetMap data is completely offline and nothing is taken from the internet at the real time when application is running. The route displayed properly over 2D surface and application provides the user different options for acquiring the route i.e. the shortest and the fastest route. It allows the user to get information about the intersection points of different routes and road classification and if the barriers are place in user path, alternate path will be generated. The route can be visualized in 3D as well. It gives the user zoom in, out capabilities. Toggle view, at which angle he/she wants to see the area.

3 RESULTS AND DISCUSSIONS

3.1 APPLICATION FUNCTIONALITY AND EFFICIENY TESTING

Usability testing is an important step to check the efficiency of an application whether web or desktop. It also checks how much effective the application is. It also check whether it follow certain standards. For example in our case whether it is generating the right path with the right parameters and it's fulfilling our aims.

LOGIN FLOW:

Figure 16 shows user's account utility flow chart. It is showing the process that how to use account services in order to utilize routing functionality in the application. First of all, when user will navigate to application, no routing page would appear, and user will have to navigate to accounts tab. If he already has an account he will login and a session will be created and a new tab "Get Started" would appear in browser which will show routing page. If user does not have an account, he would have to sign up and all the information would be stored into MySQL databases. After successfully creating an account user will login to the application and a session would be created to use routing utilities in the application.

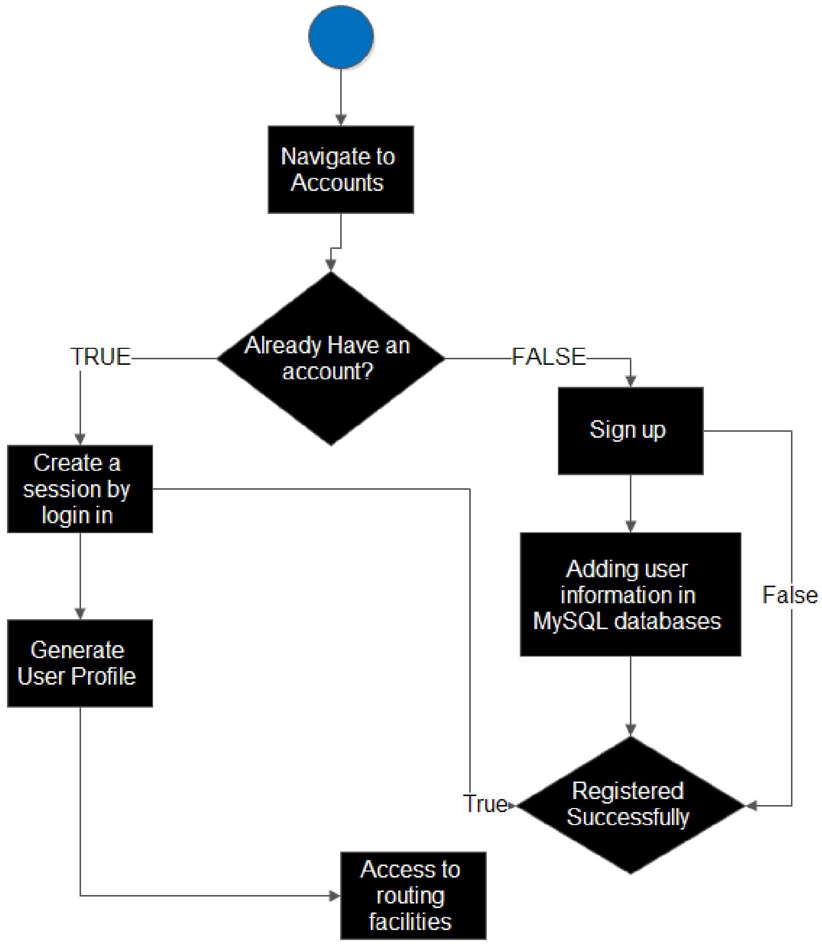

Figure 16: Login flow

GET ROUTE:

In figure 17 a complete work flow is shown to get and represent the route on the web. In getting route first step is to specify marker positions which are source and destination for output route. After specifying source and destination, user would have to specify the type of route that he/she wants to generate i.e. Shortest or fastest route. After specifying the required credentials the route information would be generated in JSON format and that information would be parsed into JavaScript library where multiple function would be implemented on that JSON format, and a route layer would be represented on the web.

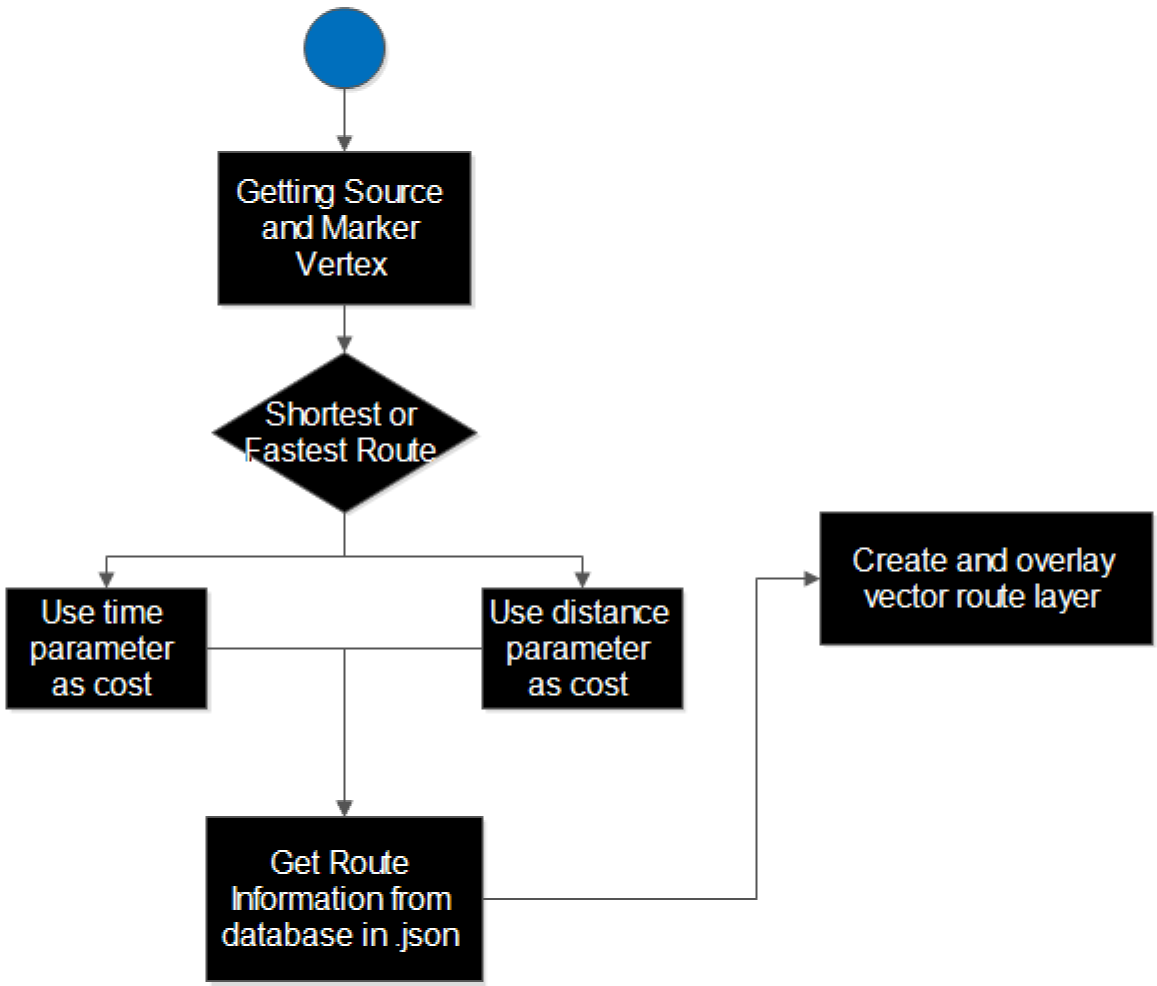

Figure 17: Get Route

ADD BARRIER:

In Figure 18 another important utility's work flow is represented, which is adding barriers/ obstacles on the routes in real time and to get barrier free route. This is important as to get alternative route if suddenly some obstacles are placed during the movement from source to destination. First of all user would have to generate a route which may be fastest route or shortest route. Once route is generated then the marker would be placed over the route and Add barrier button would be pressed, which would send information to JavaScript libraries and using server side language i.e. PHP the information would be parsed into PostgreSQL databases and once the information updating process is completed barrier free route can be displayed on the web using barrier free route button available in the left menu. Once the barrier has been placed and barrier free route is generated, barriers/ obstacles can be removed using remove barrier button available on the right menu of the routing page interface.

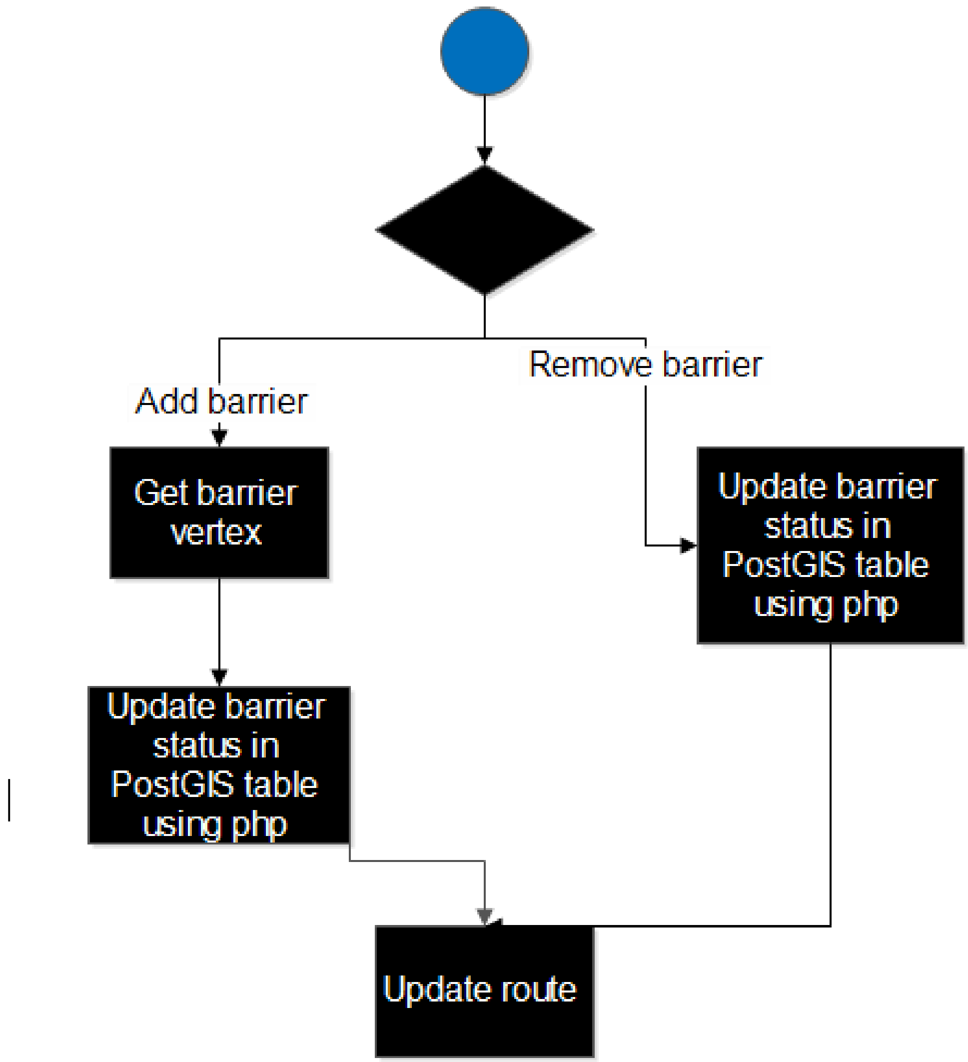

Figure 18: Add Barrier

Choke points:

Choke points/ Intersections points between two routes is important to find as to get where two routes would meet, and what are possible chances that two vehicles moving on different routes would have a chance to collapse and at what place.

Figure 19 shows a workflow for getting intersection points between two layers and then displays them on the map as WMS service. First user would have to generate two different routes. Those routes can be of any type such as one can be fastest and other can be shortest. The starting and ending points of both routes would be obtained and those points would be sent into JavaScript libraries where JavaScript functions would parse that information into PHP scripts which would manipulate the database in the PostgreSQL and pgRouting algorithm would be implement through PHP, and using other spatial SQL queries the intersecting points of both route layers would be stored as a separate entity in the database and that information would be stored as a layer in GeoServer and that layer would be added into the web using OpenLayers3 (WMS) to represent all the intersecting points as single layer. Styling of all those points would be done in GeoServer to easily differentiate with other points on the interface.

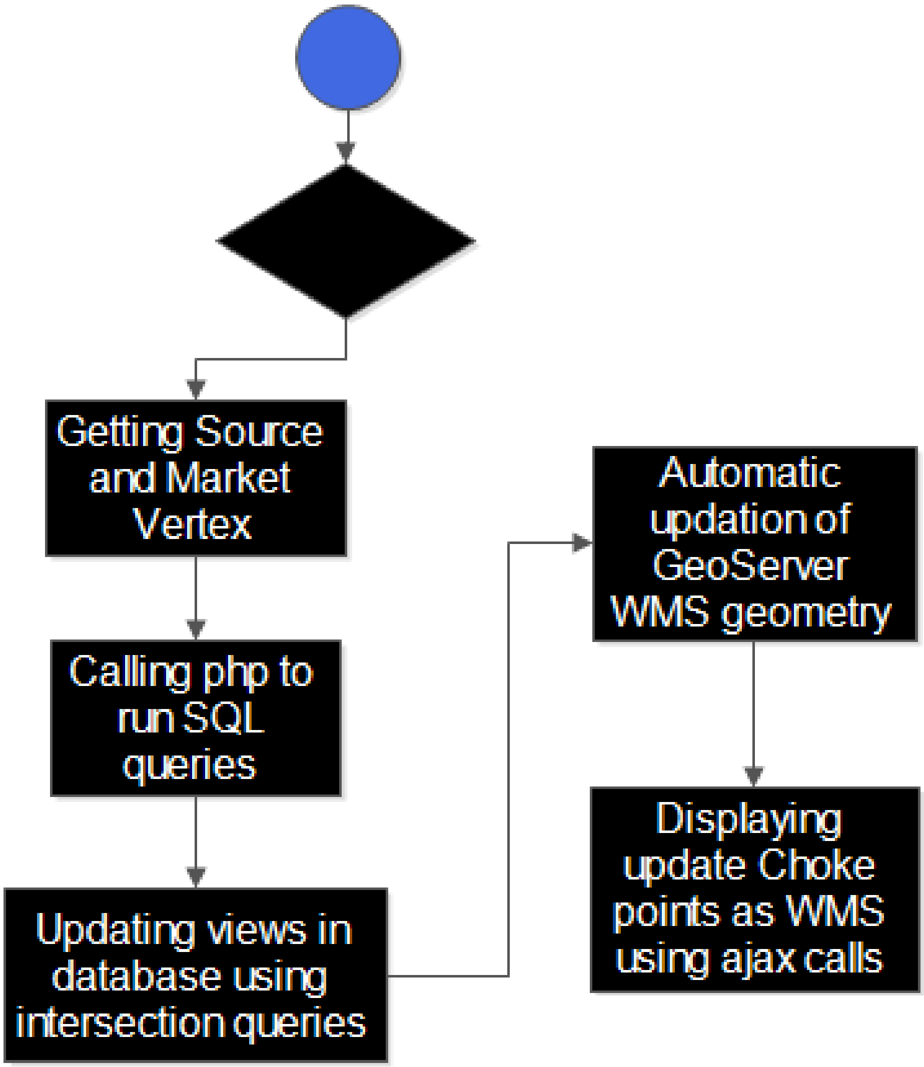

Figure 19: Choke points

Offline OSM basemap:

Figure 20 shows the steps required for the preparation of offline basemap. OSM data is first downloaded and added to a PostGIS database using osm2pgsql. Cygwin is used to download world boundaries shapefile for achieving complete offline functionality. A map file is automatically generated using Cygwin commands and the URL for this map file is used with OpenLayers 3 to view the OSM basemap offline.

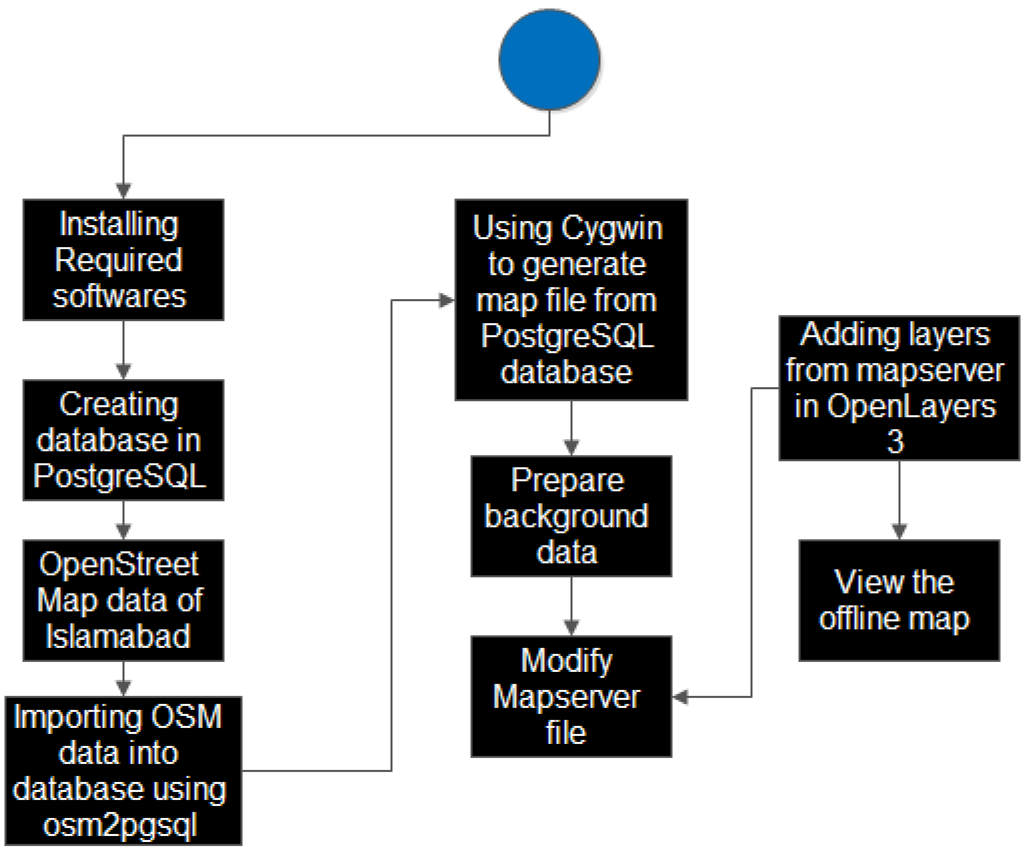

Figure 20: Offline OSM basemap

User Interface:

In any application the major and most important thing is user interface. Without the easy and friendly interface users can distract from the software. While designing an interface user points of view should be kept in mind. Figure 21 illustrates Accounts interface, where a login and sign up utilities are available for the users.

Figure 21: Login Interface

Automatic Snapping:

Automatic snapping is utility which make routing application more reliable and efficient. In automatic snapping the software moves the user specified marker to the nearest possible node of the network created based on tolerance value so that proper routing application can be run on the dataset and when visualizing the route it would make a sense.

In Figure 22 illustrates results, to the left side we can see that user has placed a marker on a land, but to the right side that marker has automatically moved to the nearest node and a route has been generated.

Figure 22: Automatic Snapping by our Application

Alternative Routes by the Application:

Alternative routes for same source and destination allows users to choose the route that is best suited according to their needs. Fastest and shortest routes can be generated in this application for same source and destination to provide user different analysis. Figure 23 is depicts an application interface showing shortest (red line) and fastest route (blue line) for same source and target. Now users can select route base on their needs i.e. shortest route or fastest route.

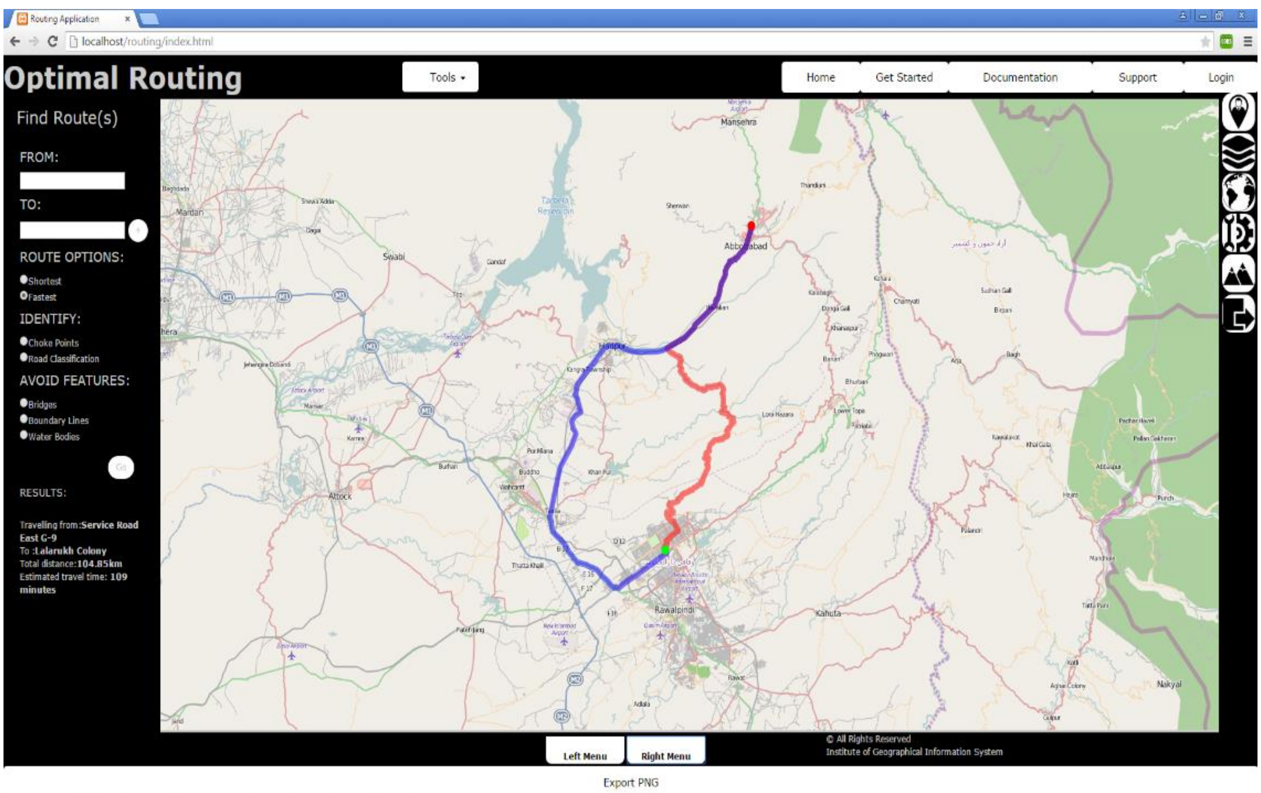

Figure 23: Alternative routes by the Application

Shortest and Fastest Route for Different Source and Target:

Shortest and faster route from same source and target are always not an option for the users. Sometimes they want to get different types of routes for different source and destination. This application also provides users the ability to generate multiple routes with different source and destination.

This application has generated two different routes shown in blue and red with different source and destinations where blue route is fastest route and red is shortest route. (See Figure 24)

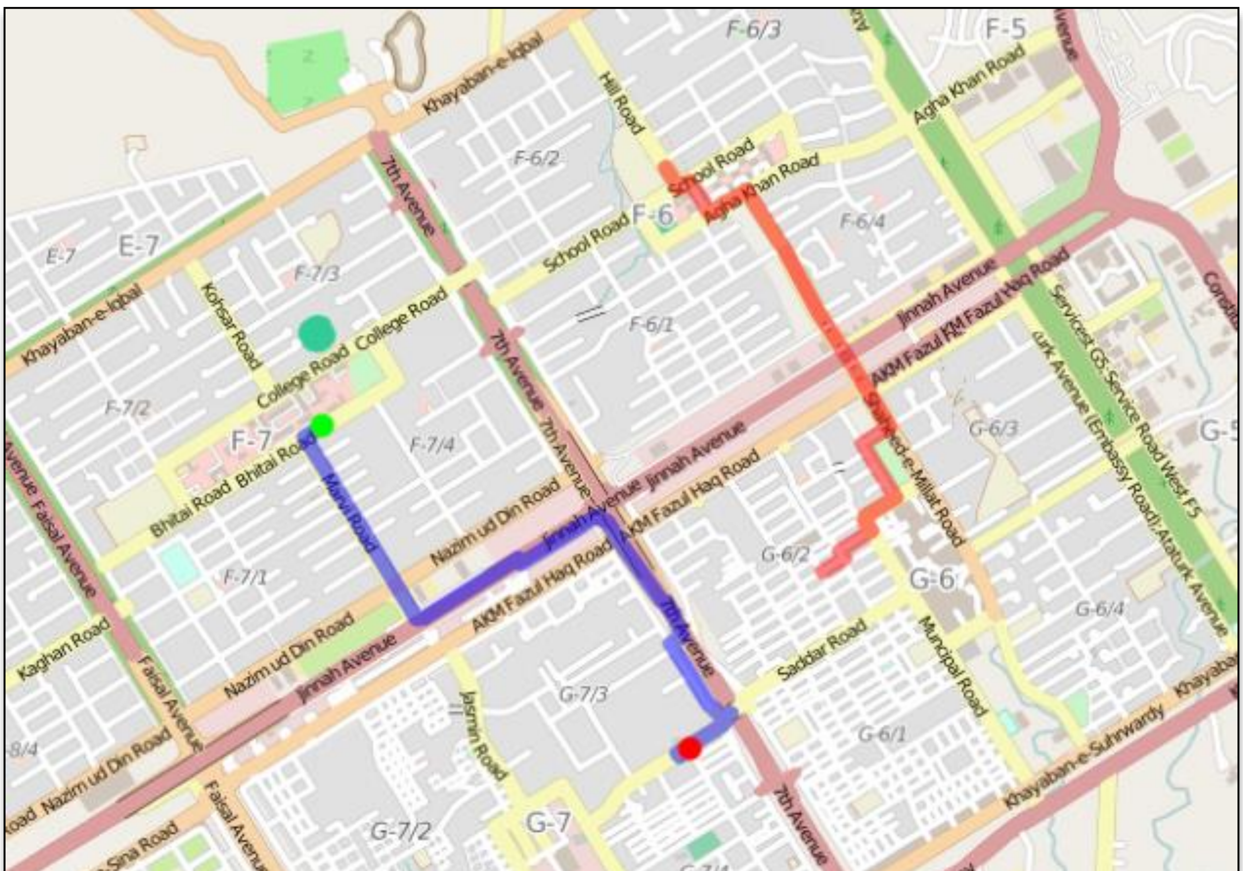

Figure 24: Shortest and fastest route for different source and target

Route Information and Driving Directions:

User must be able to know the information about each segment of the road and driving directions on the road. Our application provides users the ability to highlight the route information by clicking on the route and displaying the information in Popup.

Figure 25 shows a route layers with popup highlighted information, the information shown includes travel time, distance for a particular segment of the road. The information for whole route is available at the bottom of the left menu screen with starting and ending point, travel time and travel distance.

Figure 25: Route Information and Driving Directions

3D route visualization:

3D visualization of routes on the web is another interesting utility, which allow the analysis of the road according to the terrains in the area. It can be used to get the elevation information of the generate route. It can also be used to identify the spots which are most likely to be used by some enemy on your movement from source to target to attack you.

Figure 26 shows a 3D visualization of Bing map. We can see route layers on the elevations. As visualizing routes in 3D would help to identify routes with respect to terrain. This is useful from military point of view.

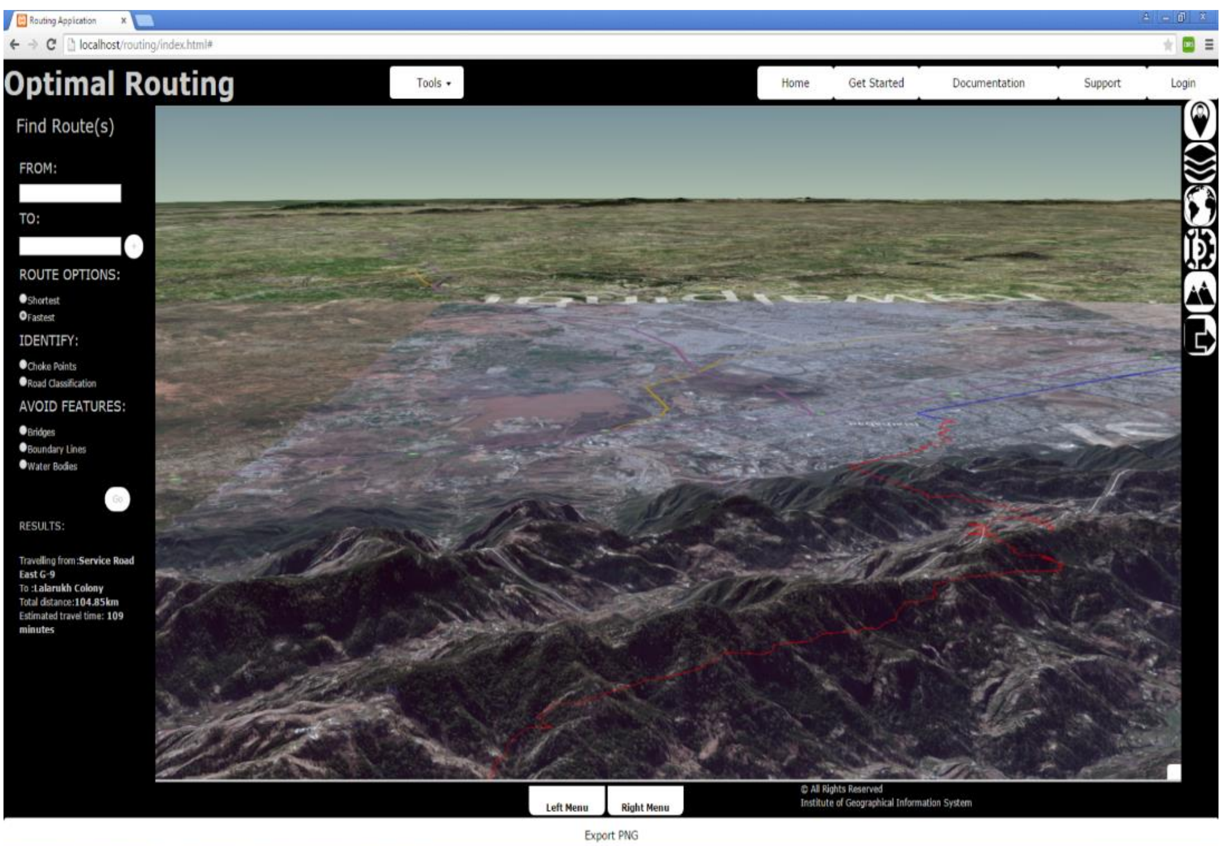

Figure 26: 3D route visualization in Cesium

Offline OSM:

Offline OSM tells the fact that OSM can be used in mapping applications without the connectivity of the internet, which makes this application more reliable and trust worthy. All the datasets of OSM are prepared in database management systems such as PostgreSQL. In this application MapServer has been used to load OpenStreetMap data from PostgreSQL database.

Figure 27 illustrates a web interface of OSM which is generated in offline mode using MapServer. It is shown in browser using OpenLayers and it has the same functionality and efficiency as online OSM.

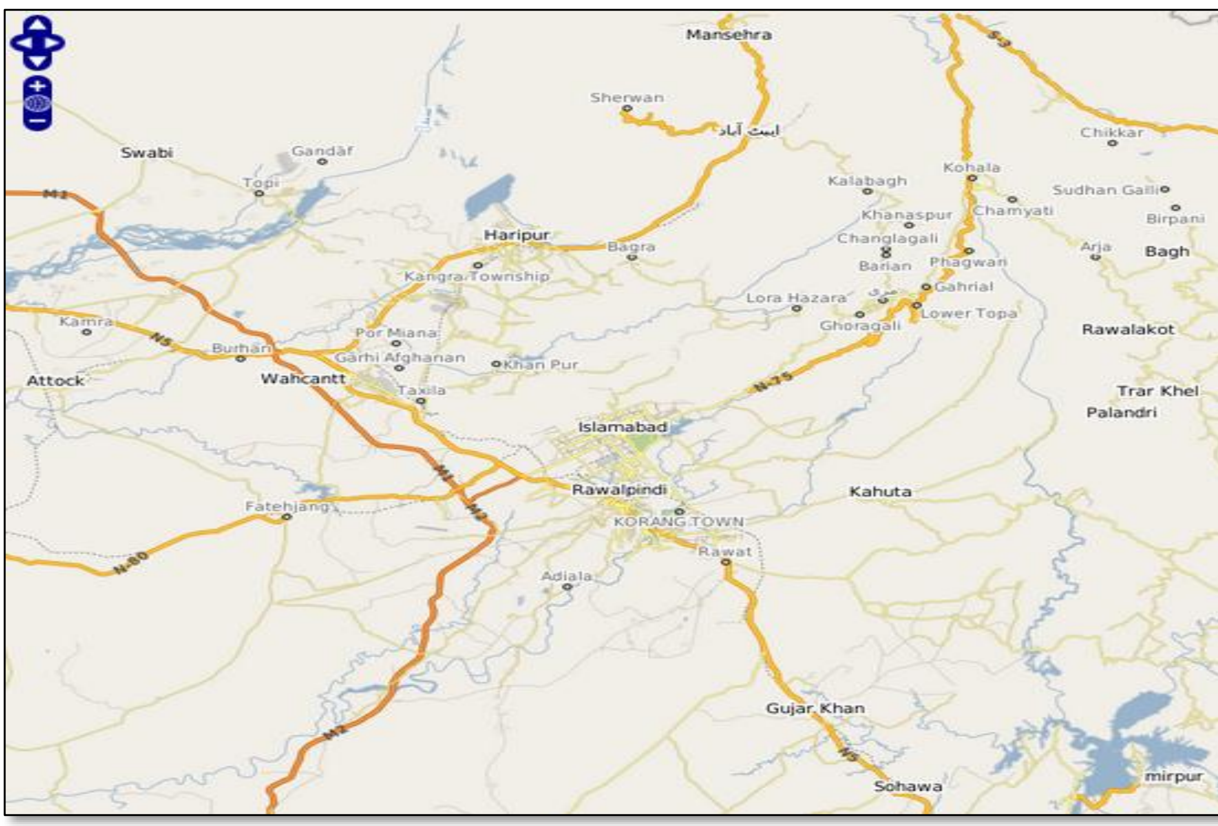

Figure 27: Offline OSM data.

4 *CONCLUSION AND RECOMMENDATIONS*

4.1 CONCLUSION

The application is successfully implemented which provides user friendly interface. All the scenarios are implemented as delivered by C4I. This application is developed using open source technologies and hence is an attempt to ensure data security. Customized routing was successfully implemented considering different criteria i.e. shortest, fastest routes, alternate route (if barriers are place by the user), driving directions along its travel time is also provided by this application. Advance technologies are used such as OpenLayers3 to get more efficient utilities. Major strengths of this application are: the base maps (OSM) used for 2D visualization which is completely offline, scenarios are customized and implemented according to user's need. All customizing functionalities are provided in real time without the interaction with any database or middle ware by the user. The routes (vector data) were given third dimension that is elevation by adding "z" value in the database. Same route can be displayed on 3D globe i.e. cesium in order to get more insight into generated route.

4.2 LIMITATIONS

This application was designed such that it should give routes to the user in both 2D and 3D using the offline data. We accomplished offline control over 2D (OSM) but for the 3D data to be offline, Google images were used to display them over cesium but images were not displayed when the toggle view icon is used.

- Migrating from OpenLayers 2.0 to OpenLayers 3.0 is challenging. Our routing application is completely created in openlayers 3 that is the advanced version. But there were limitations faced in case of different functions especially offline 3D data representation.

- Performance issues in serving MapServer offline base map (total 145 layers). The layers were overlaid over each other, application takes time to load the map when it is zoomed in or panned.

- Including elevation values for all the points, points can be reduced by using Douglas-Peucker algorithm (Douglas, D. H., & Peucker, T. K. (1973)). There is a need to add elevation information for each point in the route so that it can properly run along the terrain profile

4.3 RECOMMENDATIONS AND FUTURE WORK

This application is highly secure as it is based on open source. Similarly customization can be very easily done which enable the application to be altered in the future. A prototype is developed as a proof of concept which can be used by C4I. Many different criteria can be set by the developers for more secure use and to upgrade its functionality. For example adding another scenario of route with less terrain and slope effect, to give user an option to select route with specific utilities e.g. petrol pumps, hospitals etc. A basic platform has been developed which can be used for future consideration.

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