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An approach for web based GIS Route finder system

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Abstract: ***The rapid rises in population along with increased urban land use have generated considerable travel demand as well as numerous transport problems. The congestion, safety and environmental problems has increased to such an extent that it has become increasingly difficult to navigate due to the combined effects of rapid motorization and urbanization. With the development of Intelligent Transport System (ITS) and Geographic Information System (GIS), the increasingly intensive demand of route guidance system in real time has coincided with the increasing growth of roads in real world. A route guidance system helps to tackle many of the transportation problems by minimizing congestion and ensuring uniform utilization of the road network. For this purpose modeling of real road network into digital map format is necessary that requires large amount of preprocessing time and human effort. The main impetus behind this project is to develop a Web Based GIS Route Finder System that not only models and process the real road network to digital format on the fly but also provide user with different route finder options. The main aim of the developed system is to minimize number of re-computations for finding shortest route and alternate route. This leads to less memory consumption and less wastage of resources resulting in minimized response time. The work implemented in this report is a small contribution to the major work implemented by great researchers.***

Index terms*—ITS, TIS, TdOpR, OpR, GIS, TMS, GPS, P2P*

1. Introduction and Motivation

The goal of Intelligent Transport System (ITS) is to apply Information Technology concepts, Communication Networks, Internet and other technologies to Transport Management System (TMS) to improve travel time, safety, reliability, passenger convenience and mitigating traffic congestion. Continuous efforts have taken place to resolve the problems related to road and traffic management system. Simultaneously the improvement and progress in Information Technology has also speedup the deployment of various systems of Intelligent Transport System. Continuous rapid growth in number of vehicles and roads lead to recursive demand of better search techniques and frameworks to tackle not only the social and economic impact of deploying ITS but also the environmental impact. A GIS can help visualize and communicate the effects of roads on their environment. Merging of GIS in TMS comes from the problem caused by traffic congestion since, roads are part of the infrastructure that makes up the spinal cord of modern society, but these can just easily turn into bottlenecks therefore route planning is one of the most popular applications within TMS and planning it in advance of a journey is one way to enhance the efficiency of TMS. But, modeling large real road network into database format requires great amount of preprocessing time, human effort and manual working. In this project we introduce a new way of modeling and processing of real road network into database format. For the purpose, we have developed a **Web Based GIS Route Finder System** that helps you to figure out how best to get where you want to go. It helps us to find better paths to travel from source to destination. The better route is defined over set of constraints considered by user during route selection process. The main aim of Web Based GIS Route Finder System is not only to plan a shortest route between source ‘s’ and destination ‘t’ but also to plan a alternate or next available shortest route when an edge breaks or gets congested in s→t with minimized number of re-computations of programs. The system also provide different route finder options like shortest path finder, alternate path finder, facility based path finder, hierarchical path finder, top-k shortest path finder and multimodal path finder with the help of Java programs, PostGIS database and Geoserver.

2. Background Study and Literature Work

2.1. Basic Concepts

2.1.1. Intelligent Transport System (ITS)

To understand fully about the advantage and benefit of search techniques, we must first understand the commercial environment where these techniques are applied. Intelligent Transport Systems (ITS) are those that utilize the technologies and engineering concepts to enhance the capabilities of transportation system. Many route finding systems are in development worldwide. It is the name given to the application of computer and communications technologies to manage transport problems. In a rapidly changing society the emphasis on road technology improvements to assist in road management has been identified. As ITS technologies are advancing, they have enabled the collection of data or intelligence which provides relevant and timely information to road managers and users. ITS basically fall into two main categories, centralized and de-centralized systems [6].

2.1.2.Centralized ITS are linked to an information center which collects and processes road and traffic condition and provide route guidance to a driver on request.

2.1.2. De-centralized ITS on other hand offers information computed by individual driver on board using local information sources. Such system contains road and traffic information on optical devices with GPS facility enabled.

2.1.3. Route Guidance: Route Guidance is an essential component of Intelligent Transport System (ITS) and Traveler Information System (TIS) which provides road condition, traffic information and travel recommendation to driver to help them make better travel decision. Route guidance can be provided to a driver on demand by information center (Centralized ITS) or can be computed by individual driver (De-centralized System). Route Guidance can be divided into following major categories of guidance, Descriptive or Prescriptive, Static or Dynamic, Reactive or Predictive and System optimal or User optimal [9].Route Guidance Information System (RGIS) take help of route guidance that can provide guidance to all the drivers at the same time or can provide guidance to individual driver based on the road network condition.

2.2. Proposed Search Techniques

2.2.1. Dijkstra Algorithm

Dijkstra algorithm is single source shortest path algorithm i.e. in one computation it gives shortest path to all vertex from single source vertex. The algorithm works from a source (s) by computing for each vertex v pertaining to V the cost d[v] of the shortest path found so far between s and v. Initially this value is set to 0 for the source vertex s (d[s]=0), and infinity for all other vertices, representing the fact that we do not know any path leading to those vertices (d[v]=∞ for every v in V, except s). When the algorithm finishes, d[v] should be the cost of the shortest path from s to v (or infinity, if no such path exists).The basic operation of Dijkstra's algorithm rests on the essence of DP and is named "Edge Relaxation". Let's suppose that we are looking the shortest path that goes from s to v. If we know the shortest path from s to all possible u's connected to v and if there are edges from those u's to v, then the shortest known path from s to u (d[u]) can be obtained through a path (the best path) from s to v by adding edge (u,v) at the end. This path will have length d[u]+w(u,v). If this is less than the current d[v], we can replace the current value of d[v] with the new value. Edge relaxation is applied until all values d[v] represent the cost of the shortest path from s to v. The algorithm is organized so that each edge (u,v) is relaxed only once, when d[u] has reached its final value.The algorithm maintains two sets of vertices S and Q. Set S contains all vertices for which we know that the value d[v] is already the cost of the shortest path and set Q contains all other vertices. Set S starts empty, and in each step one vertex is moved from Q to S. This vertex is chosen as the vertex with lowest value of d[u]. When a vertex u is moved to S, the algorithm relaxes every outgoing edge (u,v).

2.2.2.Floyd Warshall Algorithm

Floyd warshall algorithm is all pair shortest path algorithm i.e. In one computation of algorithm, it gives shortest path between each and every vertex. The Floyd-Warshall algorithm is based on the following observation. Under our assumption that the vertices of G are V = {1, 2,..., n}, let us consider a subset {1, 2,..., k} of vertices for some k. For any pair of vertices i, j V, consider all paths from i to j whose intermediate vertices are all drawn from {1, 2,..., k}, and let p be a minimum-weight path from among them. (Path p is simple.) The Floyd-Warshall algorithm exploits a relationship between path p and shortest paths from i to j with all intermediate vertices in the set {1, 2,..., k - 1}. The relationship depends on whether or not k is an intermediate vertex of path p.

- If k is not an intermediate vertex of path p, then all intermediate vertices of path p are in the set {1, 2,..., k - 1}. Thus, a shortest path from vertex i to vertex j with all intermediate vertices in the set {1, 2,..., k - 1} is also a shortest path from i to j with all intermediate vertices in the set {1, 2,..., k}.

- If k is an intermediate vertex of path p, then we break p down into $i \xrightarrow{p1} k \xrightarrow{p2} j$ p1 is a shortest path from i to k with all intermediate vertices in the set {1, 2,..., k}. Because vertex k is not an intermediate vertex of path p1, we see that p1 is a shortest path from i to k with all intermediate vertices in the set {1, 2,..., k - 1}. Similarly, p2 is a shortest path from vertex k to vertex j with all intermediate vertices in the set {1, 2,..., k - 1}.

2.2.3. A* Search Algorithm

The search techniques discussed so far does not take into account heuristic approach. For a real time road network, the graph contains thousands of numbers of nodes an it is not posible to traverse through each node to find the optimal route. So, we need some Search heuristic based approach.A-star (A*) falls into such category. When the underlying network is euclidean or approximately euclidean like road network then it is possible to improve the average case run time of non heuristic based search algo. The average case run time become worse when the topology of road network changes frequnetly. Thus, there is an important necessity of heuristic based search approach.The A* algorithm by Hart and Nilsson [8] formalized the concept of integrating a heuristic into a search procedure. Instead of choosing the next node to label permanently as that with the least cost (as measured from the start node), the choice of node is based on the cost from the start node plus an estimate of proximity to the destination (a heuristic estimate) [11]. This algorithm places more importance on paths leading towards *t* than paths moving away from *t*

In essence the A* algorithm combines two pieces of information:

- The original distance from source 's' to current node , and
- An estimate of the distance from a current node of the search tree to the destination node 't'

Thus,

$$f(i)=g(i)+h(i)$$

Where, *h(i)* is known as 'evaluation function'. The closer is the estimation of *h(i)* the better is the quality of A* search. Hence, merit of A* depends highly on evaluation function *h(i)*.

3. Classification of Problem

3.1. Optimal Route Problem

Optimal Route (OpR) can be defined as the shortest path on a directed graph. Using our network notation, given two distinguished vertices source 'u' and destination 'v', the optimal path P(u,v) can be defined as the path in G from 'u' to 'v' with minimum cost. If the cost is some static parameter such as distance or number of traffic signals then the optimal route problem can be formulated and solved efficiently using traditional search algorithms but if the cost is dynamic parameter and changes frequently then we need to employ some other approach to avoid running search algorithm repeatedly. One of the major drawbacks using static cost parameter is that they employ static cartography and are unable to provide real time information on the status of the traffic network thus unable to reflect time-dependent changes in the network. Hence these systems are primarily used for pre-trip planning and not within trip guidance [9].

3.2 Traffic Dependent Optimal Route Problem

Traditional optimal route problem do not consider the real time traffic condition and hence cannot be used within trip guidance [9]. In Traffic-Dependent Optimal Route Problem (TdOpR) cost is not only based on the static parameter of the edge but also on the amount of traffic on that edge. Thus, travel time is a function not of the edge alone, but also on the amount of traffic measured by the number of vehicles on that edge.

The optimal route P(u,v) can be defined as the path in graph G from source 'u' to destination 'v' with minimal cost that involves an estimate of traffic.

The optimal route in this case may be dependent on traffic in two ways:

- An estimate of the traffic based on the historical data, and
- An estimate of the current state of traffic.

Thus, the amount of traffic on each road segment at the time it will be traversed is computed from combination of the amount of traffic on each road segment based on historical data and the amount of traffic on each road segment measured in present.[9]

4. Related Works:

4.1. Google Maps (formerly **Google Local**) **Google Maps** is a web mapping service application and technology provided by Google. It offers street maps, a route planner for traveling by foot, car, or public transport and an urban business locator for numerous countries around the world. It is "a way of organizing the world's information geographically".

4.2. Mumbai Navigator

Mumbai Navigator plans travel within the city of Mumbai using BEST buses and local trains, hence providing shortest bus route scheduling. It also gives information relating to bus routes. The advanced version of Mumbai Navigator helps to find a multimodal route also.

4.3. MapmyIndia

MapmyIndia is India's leader in premium quality digital maps and consumer navigation services. With India's best maps, MapmyIndia helps to arrive at destination. It also helps to search online for maps, directions and points of interest. MapmyIndia offers consumer products like GPS navigation System and business solutions along with online search of map and directions.

4.4. OpenStreetMap: To increase the efficiency of these algorithm researchers do manual modeling and preprocessing of graphs [13]. This requires too much of preprocessing time, human effort and manual working. To minimize the this time we have developed a new **Web Based GIS Route Finder System** that not only models and process the road network automatically but also provide different route finder options like Hierarchical, Facility based, Multimodal, Top-k, Alternate path and Shortest Path Route Finder to be handled under one roof. We process the graph to model it into the automatically created database upon the loading of graph into memory. Once modeled, it is ready for performing route finder operations. Figure 3.1 shows overall view of the system, with different tools used for mapping of real road network into database format and then showing the output and map on the web browser based on the route finder query of the user.

The main goal of the project is to minimize the number of re-computations for route finding between any source 's' and destination 't' along with finding of alternate route when any edge breaks between them. To achieve this, all the coding of our project is implemented in JSP and Java1.5 with the help of following tools:

- **Net Beans**: It is a cross platform Java Integrated Development Environment (IDE) allows applications to be developed from a set of modular software components called modules in Java. It uses JVM and JDK is required for developing web application. In our project we have used Net Beans 6.7.1 to develop the Route Finder application.
- **PostGIS**: It is an open source software program that adds support for geographic objects to "spatially enables" the PostgreSQL open source relational database. The database can then be used to store and query spatial data (points, lines and polygons). Thus allowing it to be used as a backend spatial database for Geographic Information Systems (GIS). In our project we have used PostGIS 1.8.4 as a backend.
- **Geo Server**: It is an open source software server written in Java that allows users to share and edit geospatial data and is the realm of GIS. Geo Server implements the Web Map Service (WMS) to display the spatial information as raster images (maps). In our project we have used Geo Server 1.6.1 to display maps on web pages, where the user can zoom and pan around.

All the experiments are performed over windows 2.66 GHz machine with 2 GB of memory. The sample dataset is chosen as Hyderabad road network that consists of 1476 roads, 4272 edges, 3977 nodes, 27 railway stations and a total of 41 facilities of 5 facility types (Figure shown in Appendix A). The following java packages are used in development of the system

- **Postgresql-8.4-701.jdbc4:** Package to connect Java with PostgreSQL (PostGIS loaded) database.
- **Colt:** Package for making memory matrix a sparse matrix.

OpenStreetMap creates and offers free geographic data such as street maps to anyone who wants them. OpenStreetMap is a non commercialized web mapping service that provides data in the form of xml, gml, osm, image and pdf free of cost, thus allowing any organization to use them as they want.

5. Conclusion

One of the basic problems in Transport Management System (TMS) is to find the shortest route between two points in a road network. Despite of development of major algorithms which requires less space and running time, there is always a need for better algorithm due to increasing number of vehicles on road which in turn causes to increase number of roads. The accuracy of these algorithms highly depends on how accurately data is modeled and processed.

The work in this project not only try to minimize the number of re-computations needed for computing shortest route or alternate route from source to destination but also models and process the data automatically upon loading of road network graph into memory. To achieve this goal we have designed a Web Based GIS Route Finder System that does not require any preprocessing of real road network as many of the system does [2]. The system provides the following functionalities:

- Modeling and processing of real road network into digitized form that can be stored in database automatically upon loading of road network into memory.
- Minimized number of re-computations for quick response to any query for computing shortest route.
- Computing top-k shortest path between source and destination to fully utilize the road capacities.
- Finding alternate route from source to destination when any intermediate edge gets congested or breaks.
- Compute shortest route using different cost driving constraints like distance, speed or time and traffic depending on the user's need of finding shortest route from source to destination.
- Provide user with different options like hierarchical, multimodal and facility based route finder.

The system uses Dijkstra and A-star for computing point to point pair (P2P) shortest route and Floyd Warshall for computing all to all pair (A2A) shortest route [7]. The system is developed using Java that does not support memory matrix creation of size 4000 * 4000 therefore different packages have been used to make it a sparse matrix. By doing so the time complexity increases drastically.

From experiment results, we have seen that our approach of route generation seems to be much better in terms of time and space complexity from normal approach. The result also shows that if Floyd Warshall is allowed to generate path and distance matrix once then we don't need to run algorithms again for any shortest route finder query until the graph topology remains the same. Hence our approach provides less number of re-computations for any shortest or alternate route finder query.

Prior works like Mumbai navigator performs only bus scheduling routing (not shortest path routing) with distance constraint and multimodal scheduling. It neither provides any information related to other constrains like traffic and time nor it provide any mechanism of handling alternate paths when any edge is broken or congested while in comparison our works provides routing on different constraints as well as it also provides alternate routing when any edge is not accessible in between shortest path.

6. Future Work

Future works includes GPS based data to be integrated into our system. This will help to understand peak times when the traffic is much congested thereby enabling less utilized road to be maximum utilized. It also includes study and generation of some good Consistent Anticipatory Route Guidance (CARG) [9] algorithms.Future works also includes paralyzing the algorithms to run it on distributed machines to make computations much faster.

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