Network Analysis for Finding Shortest Path in Fire Stations Information System

Lei Lei Win
University of Computer Studies (Meiktila)
malei064@gmail.com

Nilar Thein
University of Computer Studies (Meiktila)
mnilar.ucsy.thein@gmail.com

Abstract

As the population increases, the roads network becomes complicated and massive. Finding desired location is becomes difficult tasks. After finding a location people gets confused to reach that location because of the routes comprised a different mode. This problem is even more important for people who may need to visit unfamiliar parts of the metropolis. In case of the fire stations sometimes it is difficult to find the specialized fire station and its shortest path to reach hence takes more time to reach it. In this paper, we tried to solve this problem by representing the shortest path facility for finding the nearest location of the fire stations from fire location. We used the ArcGIS software and the A algorithm to provide the shortest path from one location to another.*

Keywords: GIS, Service area analysis, Shortest path analysis, A* algorithm, Drone Map

1. Introduction

GIS has been used in several areas such as retail site analysis, transportation [3], emergency services, fire petrol station mapping, and health care planning for the measurement of physical accessibility etc. The shortest path problem is a problem of finding the shortest path or route from a starting point to a final destination.[3] We use graphs to represents the shortest path problems, it is mathematical abstract object. It contains sets of vertices and edges. Edges connect pairs of vertices. It is possible to walk by moving from one vertex to other vertices along the edges of a graph. The graph can be a directed graph or an undirected graph. [4]The lengths of edges are often called weights. Weights are normally used for calculating the shortest path from on point to another point. In order to represent a map we can use a graph, where vertices represent fire stations and edges represent routes that connect the fire stations. The problem of identifying the shortest path along s road network is a fundamental problem in network analysis, ranging from route guidance in a navigation system to solving spatial allocation problems. There are a number of algorithms that can be used to determine shortest route between two nodes in a network.

2. Road Network Representation

A public road network is composed by some nodes in this paper, the links connecting two nodes and routings. Define a public road network as G, G={N,E,R}, where N={$1 \le i \le n$} denotes the set of all nodes, and n is the number of nodes; the origin node and the destination node is O, D respectively. E={$1 \le e \le m$} is the set of all transit links, and m is the number of links; R={ $1 \le r \le u$ } is the set of all bus lines and u is the number of links. In this paper, algorithm employs two functions that relate fire stations and bus routes. We use the distance on the road network as the cost in this paper.

2.1. Adjacency Matrices

In this paper, we present the connectivity among locations in transportation networks with adjacency matrices. We designate each location in the network a unique number. The value of a cell $M_{i,j}$ of an adjacency matrix M is set to the number of direct ways that we may travel from a location i to j. The following example, figure (1) illustrates how we represent a simple road network with an adjacency matrix T and distance matrix.

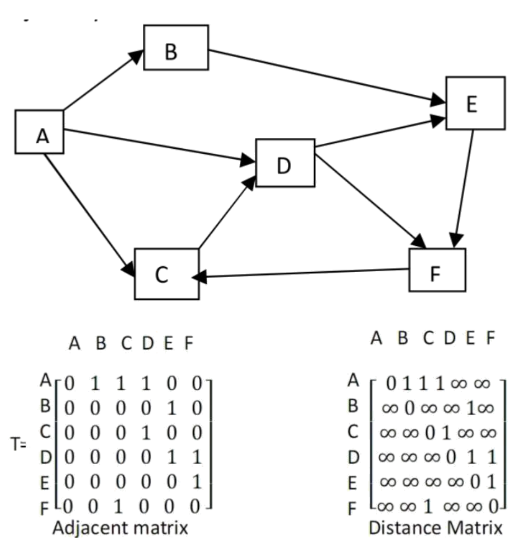


Figure 1. Example fire stations route and its adjacency matrix and distance matrix

2.2. Distance Matrices

Given a weighted graph that represents a street network, a problem instance consists of a number of sources and destinations located in the graph. For these set of nodes we want to know the distances from all sources to all destinations. Hence the result of such an MN query is a matrix of distances. An entry of this distance table denotes the distance from the source corresponding to the current column, to the target corresponding to the current row.

2.3. Drone Map

The Drone Map is used as a base map in this paper. The Drone Map can be used offline, without an internet connection, in a number of ways. The Drones are very popular because mess media networks patronize its functionality and efficiency when capturing videos and images. You will notice and images. You will notice that drones are common in touristy areas due to travel blogger promotions. Video bloggers use drones to further increase the popularity of their videos: hence promoting the device to other new vloggers. Travel companies use drones to maximize the tourism potential of an area that is popular to all tourists. The Drone map is much better resolution about 60 times than the satellite map. It's accuracy are x,y,z at least 5 cm to 10 cm and currently data is up to date. As the drone map's resolution is good as well as the accuracy.

3. System Methodology

3.1. A* Algorithm

A* algorithm is a graph search algorithm that find a path from a given initial node to a given goal node in a mapped area. The A* algorithm by Hart and Nilsson formalized the concept of integrating a heuristic into a search procedure.

It employs a "heuristic estimate" h(n) that gives an estimate of the best route that goes through the node. It visits the nodes in order of this heuristic estimate. It follows the approach of best first search.

A* algorithm are the building of a "closed list" to record areas already evaluated, an "OPEN list" to record areas adjacent to those already evaluated, and the calculation of distance traveled from the "start point" with estimated distance to the "goal point". The heuristic used to evaluate distances in A* is:

$$f(n)=g(n) + h(n) \qquad (1)$$

Where g(n) is the cost of the path from the starting node to any node n, and h (n) is the heuristic estimated cost from any node n to the goal.

3.2. A* Algorithm Steps

1. Create a search graph, G, consisting solely of the start node, n_0. Put n_0 on a list called OPEN.
2. Create a list called CLOSED that is initially empty.
3. If OPEN is empty, exit with failure
4. Select the first node on OPEN, remove it from OPEN, and put it on CLOSED. Called this node is n.
5. If n is a goal node, exit successfully with the solution obtained by tracing a path along the pointers from n_0 to n_n in G. (The pointers define a search tree are established in step 7).
6. Expand node n, generating the set, M, of its successors that are not already ancestors of n in G. Install these members of Max successors of n in G.
7. Establish a pointer to n from each of those members of M that were not already in G (i.e., not already on either OPEN or CLOSED). Add these members of M to OPEN. For each member, m, of M that was already on OPEN or CLOSED, redirect its pointer to n if the best path to m found so far is through n. For each member of M already on CLOSED, redirect the pointers of each of its descendants in G so that they point backward along the best path found so far to these descendants. Record the list OPEN in order of increasing f(n) values
8. Go to step 3.

3.3. Heuristic Function

Heuristic search has been widely used in both deterministic and probilistic planning. The heuristic function can be used to control A*"s behavior. Euclidean distance is a common method for h (n).

$$\text{Distance}=\text{sqrt}(dx^2+dy^2) \qquad (2)$$

- x_2 = coordinate of the goal location
- x_1=coordinate of the current location
- y_2=coordinate of the goal location
- y_1=coordinate of the current location
- dx=|x2-x1|
- dy=|y2-y1|

If h (n) is always lower than to the cost of moving from n to the goal, then A* is guaranteed to find a shortest path. If h(n) is exactly equal to the cost of most of moving from n to the goal, then A* only follow the best path and never expand anything else, making it very fast. If h(n) is sometimes greater than the cost of moving from n to the goal, then A* is not guaranteed to find a shortest path, but it can run faster. At the other extreme, if h(n) is very high relative to g(n), then only h(n) plays a role and A* turns into Best-First-Search.

4. System Design and Development

In this paper, the fire stations information for Meiktila downtown region such as fire stations name, fire stations type, latitude and longitude position are stores in spatial database. Time complexity in A* algorithm is O (n log n); n is the number of node. This system can be used without internet connection.

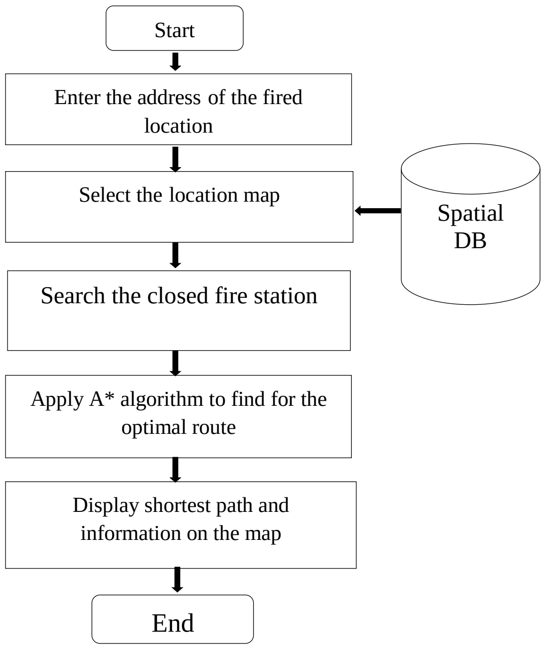


Figure 2. System design

4.1. Data Collection

4.1.1. Base Map

It is the first and important step towards the completion of the project. For this work Meiktila distinct (20º 50´ 09.4250" N and 95º 50´ 00.4688"E) is considered as the study area which is situated in the Mandalay Division of Myanmar. Toposheet of Meiktila distinct is obtained from the "Department of UAV Research Myanmar Aerospace Engineering University" having traced and scanned, which is considered as the base map (Figure 3)

Figure 3. Toposheet of Meiktila city

4.1.2. Fire Stations

The Fire Stations information can be obtained by visiting the desired fire stations and taking the important information about the facilities provided the specialty of fire stations etc., The attribute data like name of fire stations , contact number specialty, type ,address etc., are need to be stored in the separate database. The data required is in the form of spatial and attribute data. Spatial data required is road network and the fire stations. This spatial data is obtained through the process of digitizing base map of the Meiktila city. Attributes taken for Fire Station such as Name, Address, Type, Contact number were collected by surveying of each Fire Station (figure 4). The coordinates of the fire station were taken by using Global Positioning System (GPS). For Fire Station spatial data, it must be connected to the information services provided at each Fire Station. Attribute data that need to be stored in the database are roads name and length and name of Fire Station and their address.

Id	Longitude	Latitude	Fire Station Name	Type	Address
1	95º20´52.39"E	20º52´09.04"N	Station 1	District Fire Station	Between the streets 3 and 4 ; North of PyiTharyar Quarter
2	95º18´53.44"E	20º51´06.25"N	Station 2	Township Fire Station	The east of Market Quarter, The First Road
3	95º23´16.56"E	20º52´20.55"N	Station 3	Area Fire Station	AungZeyar, The old high way road of Ygn-mdy
4	95º20´52.24"E	20º52´34.92"N	Station 3	Area Fire Station	AungSan Quarter, beside Meiktila-KyaukPadaung high way road
5	95º21´15.06"E	20º52´38.15"N	Station 3	Area Fire Station	TheeGyone highway road, and Beside Ygn-Mdy high way road
6	95º20´50.65"E	20º52´53.10"N	Station 4	Fire Station	Big Market, beside the old high way road of Ygn-Mdy
7	95º20´41.02"E	20º52´40.8"N	Station 4	Fire Station	3 rd street of meiktila Industrial zone, beside Ygn-Mdy highway road

Figure 4. Fire stations information

4.2. Geo referencing of Toposheet

Geo referencing process allows registration of the digitized Toposheet on the earth surface [10]. This is very critical stage as the accuracy of the map depends upon geo referencing.

4.3. Digitization

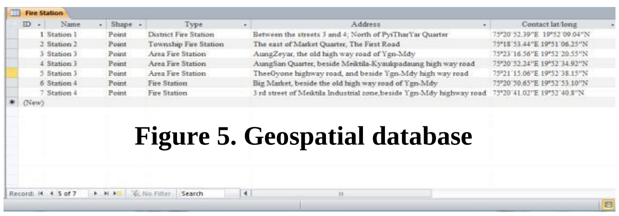
Digitizing converts paper map features into digital format. In this step road network is extract from Toposhet.

4.4. Mapping of Fire Station

In this step the coordinates of the Fire Station is taken by doing field survey. And based upon that coordinates the Fire stations are placed on the map as a point feature.

4.5. Creation of Personal Geo database

Geo-database has been created by integrating actual positions of Fire Station with the Fire Station data collected as shows in Figure (5).



Fire Station

ID	Name	Shape	Type	Address	Contact lat/long
1	Station 1	Point	District Fire Station	Between the streets 3 and 4; North of PyiTharYar Quarter	75°20´52.39"E 19°52´09.04"N
2	Station 2	Point	Township Fire Station	The east of Market Quarter, The First Road	75°18´53.44"E 19°51´06.25"N
3	Station 3	Point	Area Fire Station	AungZeyar, the old high way road of Ygn-Mdy	75°23´16.56"E 19°52´20.55"N
4	Station 3	Point	Area Fire Station	AungSan Quarter, beside Meiktila-Kyaukpadaung high way road	75°20´52.24"E 19°52´34.92"N
5	Station 3	Point	Area Fire Station	TheeGyone highway road, and beside Ygn-Mdy high way road	75°21´15.06"E 19°52´38.15"N
6	Station 4	Point	Fire Station	Big Market, beside the old high way road of Ygn-Mdy	75°20´50.65"E 19°52´53.10"N
7	Station 4	Point	Fire Station	3 rd street of Meiktila Industrial zone,beside Ygn-Mdy highway road	75°20´41.02"E 19°52´40.8"N
(New)					

Record: 5 of 7 No Filter Search

Figure 5. Geospatial database

5. Experiment

In this paper, the proposed system is tested on Meiktila down town region, road network. After the data collection it is important to locate it in the map. The Fire Station location is carried out using the ArcGIS tool. After Fire Station location is done it is important to draw a road map. It is also using the ArcGIS. The Fig (3) shows the Toposheet of the Meiktila city. When creating a network routing system, specific spatial data were collected for the accurate completion of the network. For example, a complete road network, where all the roads within the network are connected, is significant because it allows connection throughout the system.

5.1. Network Analysis

ArcGIS network Analysis is a powerful extension of ArcGIS that provides network-based spatial analysis including routing, travel directions, closest facility, and service area analysis. ArcGIS network Analyst enable users to dynamically model realistic network conditions including turn restrictions, speed limits, height restrictions, and traffic conditions at different times of the day. For the Network analysis and finding shortest path we use the A* algorithm. ArcGIS Network Analyst allows you to solve common network problems, such as finding the best route across a city, finding the closed Fire Station or facility, identifying a service area around a location, or choosing the best facilities to open or close.

A* algorithm is a graph search algorithm that solves the single source shortest path problem for a graph with non-negative edge path costs, producing a shortest path tree. This algorithm is often used in routing and as a subroutine in other graph algorithms. For a given source vertex in the graph, the algorithm finds the path with lowest cost between that vertex and every other vertex.

5.2. Creation of map for Fire Stations

Based upon the coordinates taken by using GPS Figure (6), locations of the Fire Stations are mapped accurately on map. Fig shows the map created using geodatabase and the location of the Fire Station.

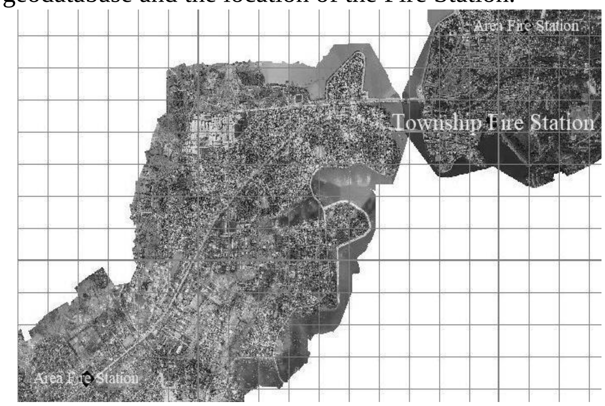


Figure 6. Map created using geo database

5.3. Creation Shortest path

Figure 7: Shortest path between two locations

System will generate the shortest path between two locations by calculating the distance based on road length. This will help the user to reduce the traveling time to reach particular Fire Stations. The shortest distance from area fire station is as shown in Figure (7).

5.4. Service Area Analysis

In our project the service area is created around the Fire Station point for finding that how many other facilities are present within 500 m area. So that in any case the particular Fire Station is closed user can immediately find out the other one within the accessible area. Service area analysis is as shown in Figure (8).

Figure 7. Service area analysis

6. Conclusion

This study finds the shortest path from the user location to Fire Station selected. It uses the ArcGIS and the A* algorithm for implementation. ArcGIS is used to digitize the map into road network. Network Analysis is carried out for all the network related problems. This will help the user to find the shortest path from their location to the Fire Stations. Also the user can able to find all the closest present within their area dynamically, which is helpful in terms of reducing their travel time and finding appropriate Fire Station immediately.

References

[1] Amrapali C. Dabhade, Dr. K. V. Kale, "GIS Based Health Care Information System for Aurangabad City", *International Journal of Engineering and Innovative Technology (IJEIT)* Volume 4, Issue 1, July 2014.

[2] Kang-Tsungchang, Introduction to Geographic information system (Fourth Edition), Tata MCGraw Hill Private Limited.

[3] Ajay D. Nagne, Dr. BhartiW.Gawali, "Transportation Network Analysis By Using Remote Sensing And Gis A Review", *International Journal of Engineering Research and Applications (IJERA)* ISSN: 2248-9622, Vol. 3, Issue 3, PP.070-076, May-Jun 2013.

[4] Usman Ado Kibon and M. Ahmed "Distribution of Primary Health Care Facilities in Kano Metropolis Using GIS (Geographic Information System)", *Research Journal of Environmental and Earth Sciences*, Volume 5 Issue 4, 2013, pp.167-176

[5] LELLA Wilfred Kouassi Camille, LIU Fujiang, N‟gottaN‟guessan, WANG Shun,"Applied GIS in location of petrol station in Abidjan city, Cote divoire", IEEE, 2010

[6] Aurangabad, Maharashtra, Sited on Jan 2014 http://en.wikipedia.org/wiki/Aurangabad,_Maharashtr.

[7] MohamadTaufikLokhman, Abdul Rauf Abdul Rasam, AbdMalekMohd Noor, "Reforming Health Care Facility Using Geographical Information System", IEEE Control and System Graduate Research Colloquium (lCSGRC), 2012.

[8] Tao Peng and Xiaowen Wang, "A Mobile-based Navigation Web Application: Finding the Shortest-time Path based on Factor Analysis", June 2012.

[9] Ke Huang, MingqingYou , "GIS-Based Environmental Health Management Information System", 2nd Conference on Environmental Science and Information Application Technology, 2010.

[10] Holia, Mehfuza, V. K. Thakar, "Image Registration for Recovering Affine Transformation Using Nelder Mead Simplex Method For Optimization", *International Journal of Image Processing (IJIP)* 3.5: 218, 2005.

[11] Cho-L.L, Tun-W.P,Chun-T.C and Chang-M.H. "Path-Planning Algorithms for Public Transportation Systems" , 4th international IEEE conference on Intelligent Transportation System, USA ,August 2001.

[12] Abhishek-G, Prateek-M, Rishabh.L and Ms. N.S, "Path Finding A* or Dijkstra's?", IJITE, Vol.02 Issue 01, January, 2013.

[13] Human Samet, "Database and Geographical Information System (GIS)", University of Maryland, USA, 2002.