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Analysis of Petrol Pumps Reachability in Anand District of Gujarat

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ABSTRACT
The problem of finding shortest path in a network has been studied by many researchers over the years. Most of the research works have proposed algorithms for finding the shortest route in a network. This work serves dual purpose; it not only aims to gain the high-level familiarity with availability of petrol pumps in the residential areas in Anand district, but also suggest the shortest route to reach a petrol pump from any location. The initial target areas for this analysis are the residential areas around Anand in Gujarat. Quantum GIS has been used to perform analysis of petrol pump reachability from a random place in Anand to a nearest located petrol pump and to identify the shortest path between the two locations. Results of comparison confirm the feasibility and robustness of proposed methodology which shows its potential application in real road networks.

Keywords
shortest path, reachability analysis, GIS, transportation, road networks

1. INTRODUCTION
Modes of transportation have added speed and efficiency to our daily life. Transportation plays a significant role in today's world by removing the distance barrier. It would not be boasting if transportation is said to be the lifeline of everyone. An efficient transport system helps in increasing productivity and in enhancing competitiveness of the economy of a country. In today's world where life has become very fast, people have become more dependent on the modes of transportation. Cars and bikes have not only become necessity, but also one of the items of luxury. We have become so much dependent on our vehicles for moving from one place to another that it happens at times that the petrol tank of our vehicles are almost dying of hunger and we do not realize that it needs refilling. At such occasions, everyone would be interested to know the nearest possible petrol pump to fulfill his immediate requirement.

India has one of the largest connectivity in terms of road networks in the world. Although the roads have been in existence since ancient times, the usage of these roads has recently been increased. The aim of this paper is to design a system which can be applied to any type of road network with the intention of providing globally optimal path from one location to another. It also has parallel processing ability by which the available paths are practically compared on the basis of their distance and the one with the shortest distance is displayed.

Geographic Information Systems (GIS) technology has recently seen development in the areas of network and transportation analysis and has become a preferred practice in many application areas. A fundamental problem in network analysis surrounds around computation of shortest paths between any two randomly chosen locations within a network. GIS has been used in past by many researchers in network analysis. Comber et al. analyzed green space access in an English city using a network analysis in GIS [4], Kyushik & Seunghyun [10] analyzed pedestrian accessibility to urban parks using the network analysis method of GIS. Dean [5] proposed to find optimal routes for networks of harvest site access roads using GIS-based techniques.

Pijanowski et al. [13] used a variety of social, political, and environmental factors to forecast land use changes using Land Transformation Model (LTM), which couples geographic information systems (GIS) with artificial neural networks (ANNs). Liu & Zhu [11] presented an integrated GIS approach to accessibility analysis, which provides a general framework for integrated use of GIS, travel impedance measurement tools and accessibility measures to support the accessibility analysis process. As far as finding shortest path is concerned, there are several algorithms to solve the shortest path problem by using genetic algorithms such as the Munemoto's algorithm [12], Inagaki's algorithm [9], and Chang's algorithm [1]. Munemoto uses variable length chromosomes and Inagaki uses fixed length chromosomes in their algorithms. Zhang et al. [16] proposed a parameter-free minimal resource neural network framework for solving a wide range of single-source shortest path problems for various graph types.

Guernic & Girard [3] have carried out algorithmic reachability analysis of continuous-time linear systems with constrained initial states and inputs. Lee et al. [14] identified to classify villages according to their spatial centralities, considering rural amenity resources, for integrated tourism management. Hong & Murray [7] compared vector and raster approaches for identifying obstacle-avoiding shortest paths/routes. Empirical assessment is carried out for a number of planning applications, highlighting representational issues, computational requirements and resulting path efficiency. In a similar work by Hong et al. [8] a spatial filtering method was presented to enhance Euclidean shortest path derivation in complex environments.

Consider a situation when somebody is going on a long drive and it is discovered that the fuel tank is near the empty mark. Most of the times such situation occurs on unknown places and it becomes worst if he is standing far away from the town. Most of the time one would want to find the nearest fuel pump. With the methodology suggested in this paper, it would not be a problem anymore. The methodology will allow finding the nearest petrol pumps in Anand district. The system is featured with a dashboard with various options available. One can find the nearest petrol pump by either entering the current location and displaying the address of nearest petrol pump or locating the nearest pump on map. A search facility will enable to find the nearby petrol pumps. It also displays the distance and time required to travel from current location to desired petrol pump. The paper is organized as follows: Section 2 introduces methodology adopted to carry out the intended experiments along with the emphasis on performing network analysis for the roads of Anand. Section 3 discusses the experimental results obtained based on optimal conditions utilizing the QGIS plugin considering various scenarios. Section 4, the concluding section seeks to highlight the strengths and weaknesses of the method discussed and indicate the scope for further research.

2. METHODOLOGY

Calculating the shortest distance between two points in a network is one of the most common problems on a road network which are addressed recently by many researchers [2, 5, 9, 13, 15]. The strength of the suggested methodology lies in the fact that it does not depend on any constrained parameters to find the shortest path. It can be practically applied to any road within any network to find the shortest path among two randomly chosen points.

The Road Graph plugin of QGIS has been used to as a tool to define the shortest path based on distance by calculating cumulative cost length, between two points in a network. The data of petrol pumps is considered as point shape file while that of Anand roads as polyline shape file. The experiments have been conducted on vector data which initiates by importing the shape files in QGIS environment. Two points on any polyline layer over the road network can be considered to calculate shortest path between them supposing one as source and other as destination. The optimization on the path can be performed based on length or on travel time. Some of the important parameters which are required to be set are listed in Table 1.

Table 1. Units and Values set for Experimentation

Sr. No.	Parameter	Units and Values
1.	Time	Hour
2.	Distance	Kilometer
3.	Topology Tolerance	10 meter
4.	Direction	default
5.	Speed Limit	40 km/hr. and 60 km/hr.

Topology tolerance is set to 10m with an assumption that if there is a gap between two roads they can be treated to be continuous. The direction field is also set as default as there is no specific direction to move from one place to other. It can be easily verified from the output obtained that if the speed limit is kept same for all types of roads, shortest distance is the same route for length and time cost. On the other hand, if different speed limits are set for different segments of roads depending on their type, then there is difference between the shortest path for length cost as compared to shortest path way for time cost.

Anand district map has been taken and Geo-referenced to get the clear boundaries of the area and within the marked boundary, all talukas have been located.

Figure 1a: Geo-referenced Map of Anand District

Figure 1b: Anand District with Talukas

Anand Geo-referenced Map is then overlapped with point shape file of petrol pumps and lines shape file of roads showing connectivity of these petrol pumps along with adjoining Talukas of Anand.

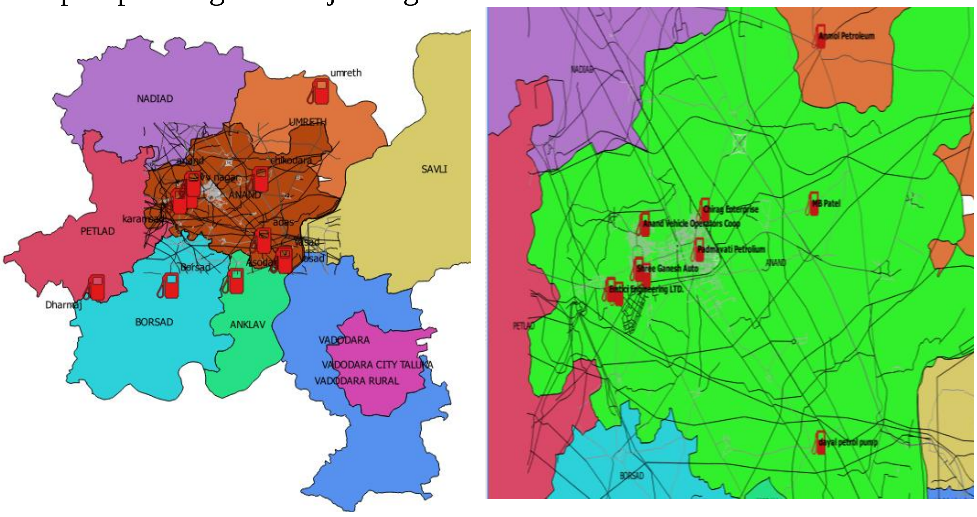

Figure 2: Road Network of Anand District with Petrol Pump Locations

In real time, following scenarios may take place for a resident of Anand.

1. If someone runs out of petrol while going to office for a meeting or a student going to attend class at his college. At this point, he needs to reach the nearest petrol pump.

   Let us call a random location considered as source at (72.9072, 22.5536) as point A. Experiments have been conducted to take into account different cases. This calculates the shortest path between the two points and also shows the time to reach from source to destination which is also least from all the possible paths. Both time and distance have been calculated using Google maps which show almost same time and distance when compared with the calculation results. There is noticeable variation in the values due to the fact that Google maps do not always show the shortest path between two points. The following cases are studied and the roads have been highlighted to understand the shortest path suggested.

   Case 1: Time taken to travel from point A to Bakrol Petrol Pump with Longitude and Latitude pair of (72.9248, 22.548) at speed of 60 km/hr. is shown in figure 3a:

Figure 3a: Time and Distance to Travel from Point A to Bakrol, V.V. Nagar Petrol Pump

Time and distance as calculated using Google maps is shown in figure 3b.

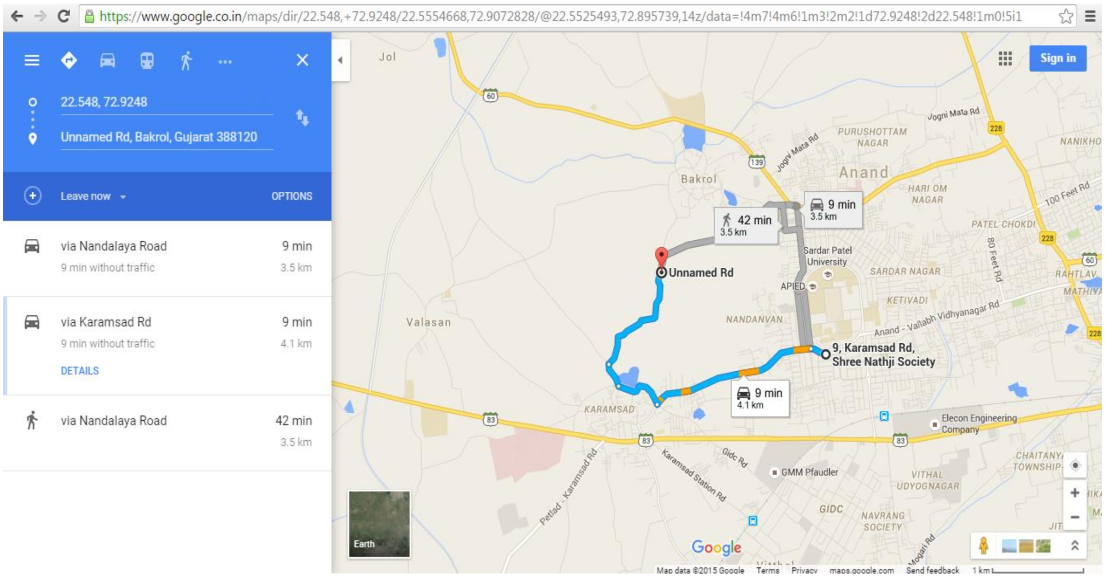

Figure 3b: Time and Distance to Travel from Point A to Bakrol, V.V. Nagar Petrol Pump using Google Maps

Case 2: Time taken to travel from point A to Karamsad Petrol Pump with Longitude and Latitude pair of (72.9091, 22.5399) at speed of 60 km/hr. is shown in figure 4a:

Figure 4a: Time and Distance to Travel from Point A to Karamsad Petrol Pump

Time and distance as calculated using Google maps is shown in figure 4b.

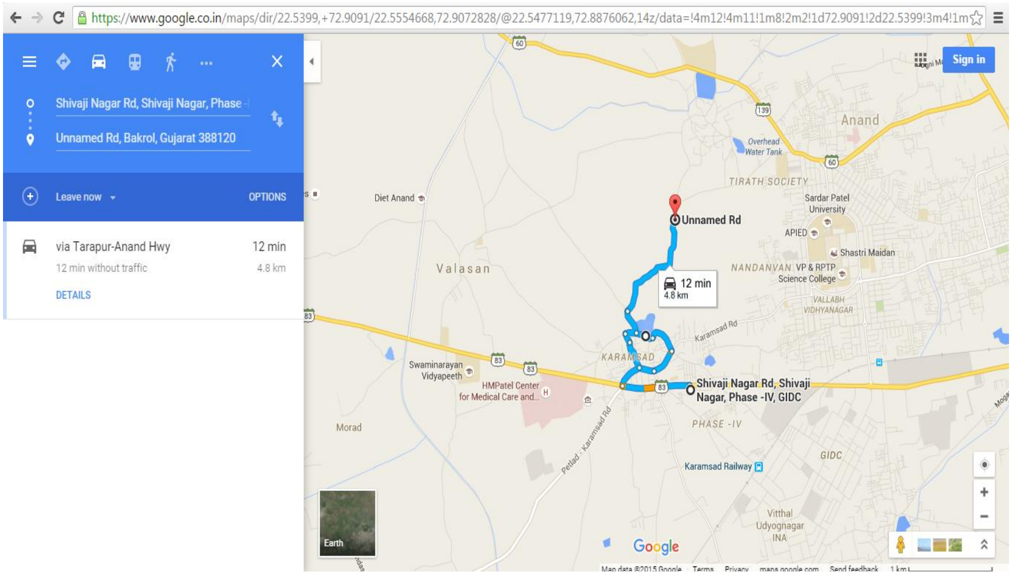

Figure 4b: Time and Distance to Travel from Point A to Karamsad Petrol Pump using Google Maps

Case 3: Time taken to travel from point A to Anand Petrol Pump with Longitude and Latitude pair of (72.9278, 22.5638) at speed of 60 km/hr. is shown in figure 5a:

Figure 5a: Time and Distance to Travel from Point A to Anand Petrol Pump

Time and distance as calculated using Google maps is shown in figure 5b.

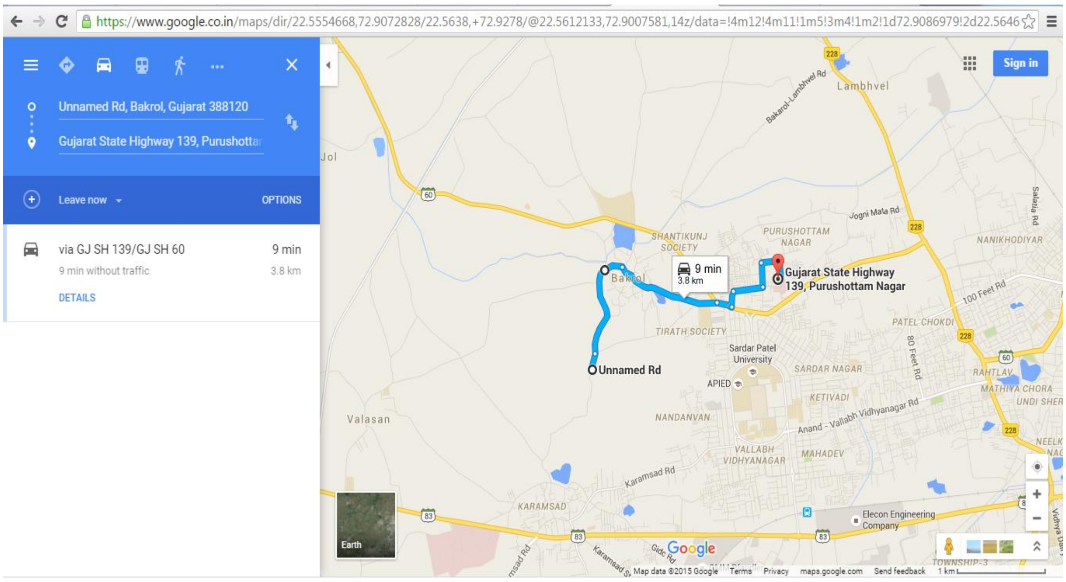

Figure 5b: Time and Distance to Travel from Point A to Anand Petrol Pump using Google Maps

These calculations are summarized in Table 2 to show the shortest path from source to nearby petrol pumps.

Table 2: Time Taken to Travel Specified Destinations

Sr. No.	Source	Destination	Distance	Time Taken with speed 40km/hr.	Time Taken with speed 60km/hr.
1.	(72.9072, 22.5536)	V.V.Nagar Petrol Pump (72.9248, 22.548)	3.81648 km	5.986614 mins	3.81648 mins
2.	(72.9072, 22.5536)	Karamsad Petrol Pump (72.9091, 22.5399)	2.36807 km	3.752604 mins	2.368074 mins
3.	(72.9072, 22.5536)	Anand Petrol Pump (72.9278, 22.5638)	3.61323 km	5.357046 mins	3.61323 mins

2. Another scenario may take place when a person reaches a petrol pump at location X, but on reaching there he discovers long waiting queues or comes to know that the petrol pump is not functional. There are other petrol pumps at locations Y and Z which he can choose as alternative destinations. Obviously, he will be interested to go to a petrol pump which is relatively nearby and takes him less time to reach by covering least distance. Considering the same locations, following cases are studied:

   Case 1: Time taken to travel from V.V.Nagar Petrol Pump at (72.9248, 22.5476) to Karamsad Petrol Pump with Longitude and Latitude pair of (72.9091, 22.5399) at speed of 60 km/hr. is shown in figure 6:

Figure 6: Time and Distance to Travel from V.V.Nagar Petrol Pump to Karamsad Petrol Pump

Case 2: Time taken to travel from V.V.Nagar Petrol Pump at (72.9248, 22.5476) to Anand Petrol Pump with Longitude and Latitude pair of (72.9278, 22.5638) at speed of 60 km/hr. is shown in figure 7:

Figure 7: Time and Distance to Travel from V.V.Nagar Petrol Pump to Anand Petrol Pump

These calculations are summarized in Table 3 to show the shortest path from one petrol pump to nearby petrol pumps:

Table 3: Time Taken to Travel from Fixed Source to Different Destinations

Sr. No.	Source	Destination	Distance	Time Taken (60 km/hr.)	Time Taken (40 km/hr.)
1.	V.V.Nagar (72.9248, 22.5476)	Karamsad (72.9091, 22.5399)	2.51038 km	0.0418397 hr.	0.064332 hr.
2.	V.V.Nagar (72.9248, 22.5476)	Anand (72.929, 22.5642)	2.30406 km	0.038401 hr.	0.0573263 hr.

3. EXPERIMENTAL RESULTS

In order to provide solution to the basic queries discussed in above sections, the paper first systematically examines some of the key scenarios which show requirement of petrol pumps. It then attempts to explore the need of more petrol pumps in the district due to unavailability of sufficient number existing in that area. These requirements are supported by some practical indicators to characterize the serving capability of existing petrol pumps in Anand district. Figure 8 depicts the road network to show the connectivity of Anand district. QGIS Road Graph plugin is used to find the shortest distance between two points on the road network. The relationship between road type and speed limit are studied in an effort to better understand their dependence on time calculation. Finally, some general noteworthy insights are drawn from the research contained in the paper.

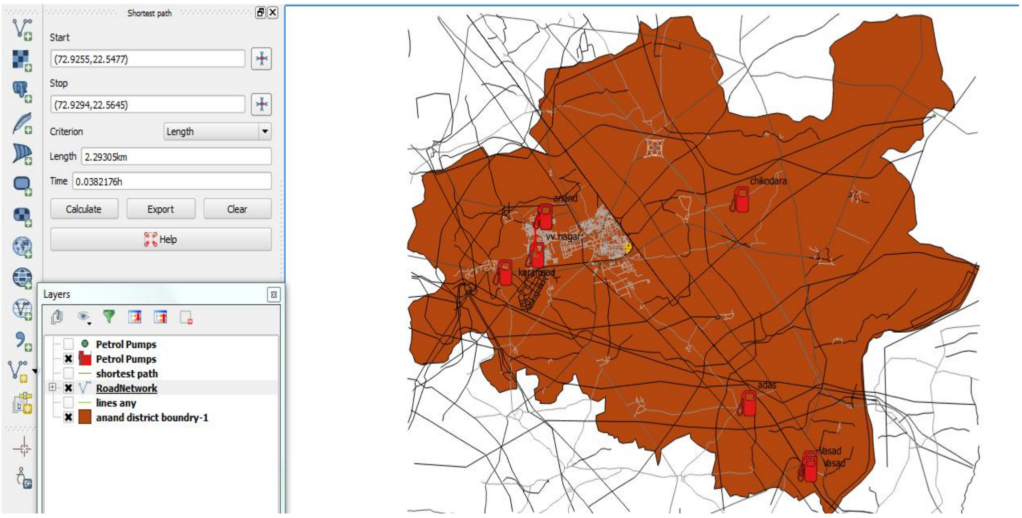

Figure 8: Road Network of Anand District

Some selection attribute queries were run over the road network to specify the speed limits on the attribute road_type as shown in figure 9. The roads are also classified in various categories based on the speed limit set for the vehicles moving on the respective roads.

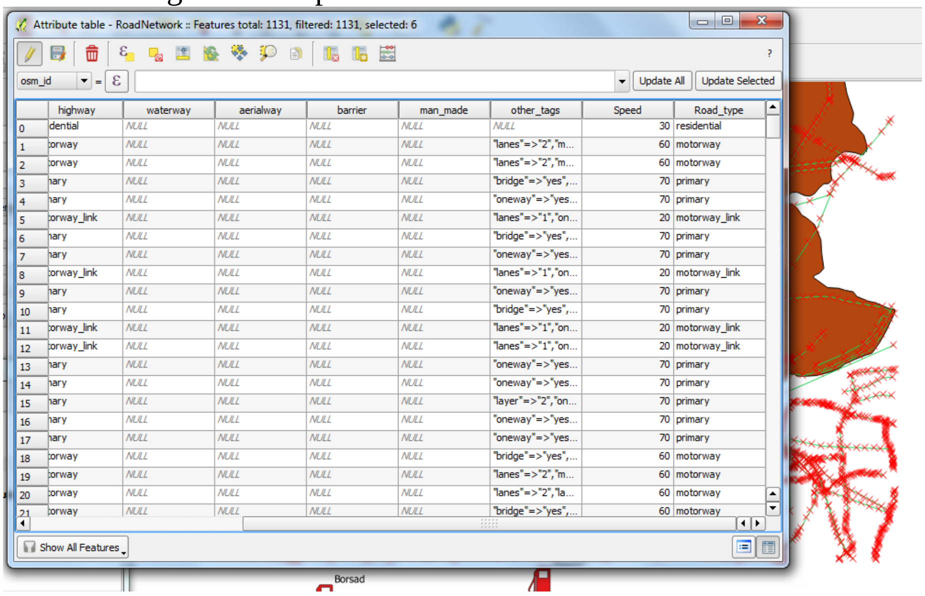

Figure 9: Speed Limits on road_type Attribute

Table 3 presents the summary of all possible road types along with their set speed limits. In actuality, in reaching a particular location, a person may have to take different types of roads. The significance of setting these speed limits is realized while calculating the time required to reach nearest petrol pump from specific location going via these roads.

Table 4: Speed Limits for Different Road Types

Road Type	Speed Limit
Trunk	80km/hr
Primary	70km/hr
Secondary	60km/hr
Motorway	60km/hr
Tertiary	40km/hr
Residential	30km/hr
Service	20km/hr
motorway_link	20km/hr

A comparative analysis is performed with the results shown by Google maps to point out the variation in shortest path calculated by proposed method as shown in table 5.

Table 5: Distance Variation Calculated Vs. Actual

Sr. No.	Source	Destination	Calculated Distance	Actual Distance	Distance Variation
1	(72.9072, 22.5536)	V.V.Nagar (72.9248, 22.548)	3.81648 km	4.1 km	0.284 km
2	(72.9072, 22.5536)	Karamsad (72.9091, 22.5399)	2.36807 km	4.8 km	2.432 km
3	(72.9072, 22.5536)	Anand (72.9278, 22.5638)	3.61323 km	3.8 km	0.187 km

4. Conclusion

An efficient method for finding the shortest path is presented for suggesting the optimal distance and minimum time required to move from one location to another in a road graph network. The suggested method helps in locating the available petrol pumps in the given radius standing at a specific location and finding the shortest and the fastest way to get from that location to the nearest petrol pump in Anand district chosen as a sample. The same method can be applied to any location on the map.

REFERENCES

Ahn, C.W. and Ramakrishnal, R.S., A Genetic Algorithm for Shortest Path Routing Problem and the Sizing of Populations, IEEE Transactions on Evolutionary Computation, 2002, pp. 566-579.

Beardwood, J., Halton, J.H. and Hammersley, J.M., The shortest path through many points, Mathematical Proceedings of the Cambridge Philosophical Society, 55, 4, 2008, pp. 299–327.

Colas Le Guernic, Antoine Girard, Reachability analysis of linear systems using support functions, Nonlinear Analysis: Hybrid Systems, 4, 2, 2010, pp.250-262.

Comber A., Brunsdon C., Green E., Using a GIS-based network analysis to determine urban greenspace accessibility for different ethnic and religious groups, Landscape and Urban Planning, 86, 1, 2008, pp. 103-114.

Dean D.J., Finding optimal routes for networks of harvest site access roads using GIS-based techniques, Canadian Journal of Forest Research, 27, 1, 1997, pp. 11-22.

Goldberg A.V., Harrelson C., Computing the shortest path: A search meets graph theory, In Proceedings of the sixteenth annual ACM-SIAM symposium on Discrete algorithms, Society for Industrial and Applied Mathematics, Philadelphia, PA, USA, 2005, pp. 156-165.

Hong, I. and Murray, A. T., Assessing Raster GIS Approximation for Euclidean Shortest Path Routing, Trans. in GIS, 20, 2016, pp. 570–584.

Hong, I., Murray, A. T. and Wolf, L. J., Spatial Filtering for Identifying a Shortest Path Around Obstacles, Geogr Anal, 48, 2016, pp. 176–190.

Inagaki J., Haseyama M. and Kitajima H., A genetic algorithm for determining multiple routes and its applications, Proc. IEEE International Symposium on Circuits and Systems, 6, 1999, pp. 137-140.

Kyushik Oh, Seunghyun J., Assessing the spatial distribution of urban parks using GIS, Landscape and Urban Planning, 82(1–2), 2007, pp. 25-32.

Liu, S. and Zhu, X., An Integrated GIS Approach to Accessibility Analysis. Transactions in GIS, 8, 2004, pp. 45–62.

Munemoto M., Takai Y. and Sato, Y., A migration scheme for the genetic adaptive routing algorithm", Proc. IEEE Int. Symp. Circuits and Systems, 1999, pp. 137-140.

Pijanowski B.C., Brown D.G., Shellito B.A., Manik G.A., Using neural networks and GIS to forecast land use changes: a Land Transformation Model, Computers, Environment and Urban Systems, 26, 6, 2002, pp. 553-575.

Sang-Hyun Lee, Jin-Yong Choi, Seung-Hwan Yoo, Yun-Gyeong Oh, Evaluating spatial centrality for integrated tourism management in rural areas using GIS and network analysis, Tourism Management, 34, 2013, pp. 14-24.

Zhan B.F., Charles E. N., Shortest Path Algorithms: An Evaluation Using Real Road Networks, Transportation Science, 32, 1, 1998, pp. 65-73.

Zhang J., Zhao X. and He X., A Minimum Resource Neural Network Framework for Solving Multi-constraint Shortest Path Problems, Neural Networks and Learning Systems IEEE Transactions on, 25, 2014, pp. 1566-1582.

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