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Analysis and Application of Shortest Path Algorithms on Urban Road Networks

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Abstract
The shortest way to cover a distance between source and destination point is referred to as the shortest path. The shortest path algorithm has its applications in the area of emergency services, image segmentation, robotics, navigation, game AI, telecommunication, network routing, social network, robotic, logistic and transport. The variants of the shortest path algorithm include single-source-single destination (one to one), single-source all destination (one to many), single destination shortest path (many to one) and all pairs shortest path problem (many to many). The importance of shortest path is to minimize total distance travelled, total cost of a sequence of activities and total time of activities.
Keywords: Destination point, shortest path, shortest path algorithm, total distance travel

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I. Introduction

Computation of shortest paths between different locations on a network is a challenge in network and transportation analysis. Most times, the need for shortest distance arises in real time. For instance, Emergency response time to accident scene and movements of the accident victims to health facilities is critical in saving life. However, the increase in the number of road users in urban cities around the world has made road traffic congestion common phenomenon which affects emergency response time, which is also common feature of urban area and cities in Nigeria.

Apart from road accident, other emergency cases that usually require the use of shortest route to get to their destinations include: fire fighters, sick/pregnant mothers, courier service organization and security agents. Considering the fact that most of these call for the use of shortest routes has to do with our response to emergency related cases, computation of shortest paths between different locations on a road network and transportation analysis becomes inevitable if we are to save life or make economic gain. However, when large real road networks are involved in considering shortest distance application, shortest path determination on such large network can be computationally rigorous [1]. This is because the application involves answers in real time fashion.

This research work leveraged on advanced data structures, graph growth algorithms, shortest path algorithms and Dijkstra's algorithms, optimization models in directing cars in emergency responds etc. Today, the determination of fastest route to dispatch a vehicle in the case of emergency could be achieved using GIS. This is possible because links on real road network in a city tends to possess different levels of congestion at different times of the day.

II. Statement of the Problem

In the present society, there is a lot of problems in emergency response, logistics and transportation section. The Nigerian urban road network has evolved. Increased traffic congestion issues, poor route planning and bad roads infrastructure, respectively. In spite of increased research interest in the area of transportation decision analysis within a GIS environment. The need for effective and efficient timely response for emergency agencies like fire service, courier service firms, from source to destination, and on a reduced cost is optimal. Hospitals have equally faced challenges with route management issues at the time of medical emergencies. There is need to develop an improved shortest path algorithm approach to tackle these anomalies.

1. Aim

The aim of this study is analysis and application of Shortest Path Algorithms on Urban Road Networks.

2. Network Routing

The optimal paths between the network nodes so that routing cost is minimized is determined by shortest path. Shortest path algorithms are applied in graph theory, road network, logistics and operation research. Shortest path algorithms are also very important for computer networks, like the Internet. Any software that helps to choose a route engaged some form of a shortest path algorithm. Advantages of shortest path in road network includes; reduction in fuel consumption. direct approach path on the map. However, it may not consider traffic congestion or road conditions. It is good when traffic is light and road condition is good.

Finding shortest paths is important for solving problems in many different types of networks. For example, shortest paths can improve the efficiency of city planning. The all-pairs shortest paths (APSP) is a fundamental graph problem with many applications in urban planning and simulation [2], metric nearness problem [3], traffic routing and data centre network design [4]. In fact, APSP and the decrease-only metric nearness problem are equivalent.

III. Navigation

Shortest path algorithms can be used to find the quickest route between two locations on a map, taking into account factors such as traffic conditions and the type of transportation being used

IV. IMAGE SEGMENTATION

Segmentation task plays an important role in image processing. Finding the shortest path from one node (source) to multiple other nodes on an image is a relevant task in computer vision. Focusing on biomedical applications, the usage of shortest paths from density peaks improved the segmentation of non-convex cells in fluorescence microscopy images [5].

Images conveniently capture the result of physical processes, representing rich source of information for data driven medicine, engineering, and science. The modeling of an image as a graph allows the application of graph-based algorithms for content analysis. Amongst these, one of the most used is the Dijkstra Single Source Shortest Path algorithm (DSSSP), which computes the path with minimal cost from one starting node to all the other nodes of the graph. However, the results of DSSSP remains unknown for nodes until they are explored. Moreover, DSSSP execution is associated to frequent jumps between distant locations in the graph, which results in non-optimal memory access, reduced parallelization, and finally increased execution time.

On light-microscopy images, Uhlman *et al*. developed a plugin for Image J (Diverse Paths J) to identify the skeleton of worms, following the shortest path from the head to the tail [6]. Instead, Ghidoni and colleagues reported a shortest path-based descriptor to analyze and classify medical images [7].

If you have different places connected by road networks and the time required to travel these roads. The path from one place to another is determined. The times are not directly proportioned to the distances as a result of the different factors such as gravity of road traffic level using the road as cost. The particularities of each road are put into consideration, many algorithms have been used.

V. Algorithm for Locating Shortest Path

Dijkstra's algorithm

Dijkstra’s algorithm finds the shortest path tree from a single-source node by building a group of nodes that have the closest distance from the source or the origin. Because of that, it is used in finding the shortest possible distance and directions between two geographical locations – such as in Google Maps, Waze, Maps.me, GPS Navigation, etc.

Another example would be that the firefighter department wants to develop a system that finds the shortest route between the closest firefighter department and the location of the fire, to avoid any potential delays. The same scheme works on ambulance systems for finding the closest path to the hospitals in cases of emergency. Or when logistics companies and delivery services want to develop a system that finds the shortest route between the warehouse and destinations for their delivery.

It is also used when routing data in networking and telecommunication domains to minimize the delay occurring in transmissions. If we imagine a city as a graph, the vertices represent the switching stations, and the edges represent the transmission lines. Social networking applications can also be considered using the shortest path between users by measuring the number of connections between two users. Many social networking applications are based on six degrees of separation (as in the average number of a person’s friends is six), and it can be mentioned as the distance measured in the number of connections between any two users of the network field. Even if the average number of friends for users is not big, the problem of finding the shortest paths between users is very compound from the view of this algorithm complexity. Moreover, this algorithm can be used even in-flight agenda – in a database with all airports, flights, routes, arrival time, departure time, passenger information and more.

Wherever you encounter the necessity for shortest path solutions: be it in robotics, engineering, transportation, embedded systems, factory or production plants to detect faults, errors or more – essentially, you can use this algorithm for any situation that requires discovery of the shortest path to solve the problem.

Bellman-Ford algorithm

It computes single-source shortest paths in a weighted digraph (where some of the edge weights may be negative). Dijkstra's algorithm accomplishes an equivalent problem with a lower running time but requires edge weights to be non-negative. This suggests that Bellman-Ford's algorithm is typically used only when there are negative edge weights on the nodes.

This algorithm finds the shortest path between a given source vertex and all other vertices in the graph, a bit like Dijkstra's – except it can be used on both weighted and unweighted graphs and it's much easier to implement into a selected field for research.

On the Web, there are many protocols that use this algorithm. The best example is the basic network routing information protocol. This is one of the oldest Internet protocols, from its early beginning, and it prevents loops by limiting the number of hops a packet can make on its way to the destination. A second example is the interior gateway routing protocol. This protected protocol is used to help machines exchange routing data within a system.

The Floyd-Warshall algorithm

It is also an algorithm for finding the shortest paths in a weighted graph, with positive or negative edge weights but with no negative cycles. A single execution of the algorithm will find the distances of shortest paths between all pairs of vertices. Although this algorithm does not return details of the paths themselves, it is possible to reconstruct the paths with simple changes within the algorithm.

It is usually used to find all pairs of shortest path problems from a given weighted graph. As a result of this algorithm, it will generate a matrix, which will represent the minimum distance from any node to all other nodes in the graph.

The biggest difference between Floyd's algorithm and Dijkstra's is that Floyd's algorithm finds the shortest path between all vertices. And Dijkstra's algorithm finds the shortest path between a single vertex and all other vertices.

Floyd-Warshall algorithm is used for: shortest paths in directed graphs; transitive closure of directed graphs; inversion of real matrices and optimal routing.

When it comes to optimal routing, one is interested in finding the path with the maximum flow between two vertices. This means that, rather than taking minima, one instead takes maxima. The edge weights represent fixed constraints on flow. Path weights represent bottlenecks, so the addition operation above is replaced by the minimum operation.

It can also be used in testing whether an undirected graph is bipartite, fast computation of Pathfinder networks and maximum bandwidth paths in flow networks.

Johnson's algorithm

It is more of a way to find the shortest paths between all pairs of vertices in an edge-weighted, directed graph. It allows some of the edge weights to be negative numbers, but no negative-weight cycles may exist.

It works by using the Bellman-Ford algorithm to compute a transformation of the input graph that removes all negative weights, allowing Dijkstra's algorithm to be used on the transformed graph. This algorithm is used in job sequences and scheduling. The Chinese Postman Theory is a famous route inspection problem that involves graph theory, a branch of mathematics and computer science. The issue of this theory is to find the shortest closed path or circuit that visits every edge of an undirected graph. When the graph has an Eulerian circuit, that circuit is an optimal solution. Otherwise, the optimization problem is to find the smallest number of graph edges to duplicate so that the resulting multigraph does have an Eulerian circuit. It can be solved in polynomials by an algorithm based on the concept of a T-join. The postman's job is to deliver all of the town's mail using the shortest route possible. In order to do so, he (or she) must pass each street once, not return, and then come back to the origin point.

VI. Related Works

Empirical researches have been carried out on shortest path algorithm. According to [8] an evaluation of the following shortest path algorithm was done: the graph growth algorithm which was implemented with two queues, Dijkstra's algorithm which implemented with approximate three buckets and Dijkstra's algorithm which was implemented with double bucket. The authors summarized them algorithms, and demonstrate the data structures and procedures related to the algorithm. In [9], an elaborate evaluation of shortest path algorithms was presented. The researchers evaluated a set of 17 different SPP algorithms. In their work c programming language was used in coding all their algorithms on a SUN sparc-10 workstation. The outcome of their studies proved that no one algorithms beats all others in all problem modules. The summarized that Dijkstra's algorithm is best when implemented with a double-bucket strategy for network with non-negative arc lengths. According to [10], an empirical evaluation of 17 and 15 algorithms on different real road network was studies. They are of the opinion that Dijkstra's algorithm incorporating approximate bucket and TWO-Q, DKD present the fastest result when evaluation was carried out on all the algorithms. This paper proposes a link-based shortest path algorithm to generate dissimilar paths for the travel information in real road network where exists turn prohibitions. The main merit of proposed model is to provide efficient alternative paths under consideration of overlaps among paths to alleviate the path similarity. Another merit is that it does not require extra nodes and links for expanding the network. Thus, it is possible to save the time of network modification and of computer running. The algorithm is tested with some example networks and then will be expanded to a dynamic case [11]. In [12], three set of shortest path algorithm that run fastest on real road network was examined. The algorithms are (a) the Dijkstra algorithm implemented with double buckets. (b) the Dijkstra algorithm implemented with approximate bucket and (c) The Gallo and Palloltino's graph growth algorithms implemented with two queues. A simple optimization strategy was proposed with consideration of the characteristics of scale-free complex network. The paper expressed that the classic Dijkstra's algorithm can be improved by simple modification. The entire result showed that the average running time of their algorithm is lower than Dijsktra's algorithm by a factor relating to the connection probability in a random network of ER model [13]. They stated that the performance of their own algorithm is better than Dijkstra's algorithms in scale free network generated by AB model. It was showed that the time complexity is reduced to about 0(n^2.4) in a scale free complex network.

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