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A Survey of Recent Applications of Improved Dijkstra's Shortest Path Algorithm

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Abstract - *The shortest path problem exists in variety of areas. There are many algorithms to solve the shortest path problems. Dijkstra's algorithm is the most popular algorithm among that. It is an optimal and efficient algorithm till date and follows the label-setting paradigm. Dijkstra's algorithm finds the optimum shortest-path and so it is a type of greedy algorithm. Many algorithms are modified and improved based on this algorithm. This paper presents a survey of improved algorithms based on Dijkstra's algorithm that are applied in different application areas.*

Key Words: Shortest path problem, Dijkstra's algorithm, label, path optimaization, weight, graph, complexity

1. INTRODUCTION

The shortest path problem is about finding a path between two vertices in a graph such that the total sum of the edges weights is minimum. There are many shortest path algorithms or path planning algorithms have been proposed, like Bellman-Ford algorithm, Dijkstra's Algorithm ,Topological sort, Floyd-Warshall algorithm, Johnson's algorithm , A* algorithm, Aggressive Heuristic Search (AHS) , Jump Point search (JPS), D* algorithm, Lifelong Planning A* (LPA*), D* Lite, Adaptive A* (AA*), Path-Adaptive A* (Path-AA*) , Tree Adaptive A* (Tree-AA*) ,Value iteration, Q-learning to count a few[6]. Among these, Dijkstra's "label algorithm" which was conceived by computer scientist Edsger W. Dijkstra in 1956 and published three years later is one of the best shortest path algorithms.

Dijkstra's Algorithm is an algorithm for computing the shortest path between two vertices of a graph where all edges have nonnegative weight. It is based on repeatedly expanding the closest vertex which has not yet been reached. Dijkstra is optimal and efficient and follows the label-setting paradigm, as opposed to the label correcting paradigm. Originally Dijkstra's algorithm [1] is the single source shortest-path (SSSP) algorithm. Dijkstra's algorithm is best suited for directed graphs with non-negative weights. The algorithm identifies and maintains two types of vertices sets : Solved vertices set and Unsolved vertices set . Initially the source vertex is assumed as a solved vertex and checks all the other edges (through unsolved vertices) connected to the source vertex for shortest-paths to the destination. Once the algorithm identifies the shortest edge, it adds the corresponding vertex to the set of solved vertices. The algorithm iterates until all vertices are solved.The time complexity of Dijkstra's algorithm $O(n^2)$. One advantage of the algorithm is that it does not need to investigate all edges. This is particularly useful when the weights on some of the edges are expensive. The disadvantage is that the algorithm deals only with non-negative weighted edges. Also, it is applicabel to static graphs only[1-3].

There are many applications of Dijkstra's Algorithm. It is is mostly used in routing and other network connected protocols, the robot pathfinder, route navigation, game design[5,6]. Also Dijkstra's Algorithm is used to solve many shortest path problems in the process of production, organization and management. In this paper some of the applications of Dijkstra's Algorithm are discussed.

2. Applications of Dijkstra's Algorithm: A Literature Survey

2.1 Robot Path Planning

Path planning [6] is a very general problem in computer science and artificial intelligence and has many application areas such as robotics, computer games and artificial systems. Robot path planning is an important area of research.

Wang, Langfang ,and Yuan developed an application in the robot path planning using Dijkstra's algorithm where the robot is a maze robot. They built environment model where the robot's working space is a two-dimensional structure of space. The intersection method is used to pass the obstacles. From the simulation results the authors conclude that, the Dijkstra algorithm can be effectively used to solve the robot path planning problem which is correct and effective[5].

On 2D eight-neighbor grid map many times we need to control many robots to move to a goal position from different initial positions. With respect to this in Ref [6] the authors analyze a property on 2D eight-neighbor grid map and introduces an Improved Dijkstra's Algorithm (IDA) to solve the problem. According to their reaserch, each position only needs to calculate once to get the shortest distance to the goal position in IDA, so it is saving much time with respect to the original Dijkstra's algorithm. The IDA proposed by authors is very useful for finding the shortest path in many recent robotic applications.

2.2 To find the Maximum Load Path for Road Consignments

Finding the shortest path and finding the maximum load path are nearly same problems. We can include finding the maximum load path problem in path optimization problems. In road network, path optimization is especially useful for improving road consignment or road freight efficiency. The need about improvement in efficiency of road consignment is impending because it is an important factor in the profitability of trade between countries due to fast growth of e-commerceas as well as road freight. Normally the vehicle has strict load restrictions on the road, once it enters the restricted road section, it does not only break the rules and needs to pay a fine, but it may also pose a safety risk. Therefore, before the vehicle goes on the road, it is necessary to plan the route first and select a path that can satisfy the limitation of the road weight limit and maximize the load capacity of the vehicle, so that the travel is more intelligent and safe.

Kaicong Wei, Ying Gao, Wei Zhang, Sheng Lin modified Dijkstra's algorithm for solving the problem of finding the maximum load path. They considered road map that indicates the road load limit between each pair of adjacent road intersections, to find a path to maximize the load capacity of the vehicle according to the starting and destination locations. They modeled this problem as a directed graph. G = (V, E), where V is the set of nodes in G, representing the intersection of roads, and E is the set of links in G, representing every road. The original Dijkstra's algorithm cannot effectively solve the problem of finding the maximum load path, although the problem of finding the maximum load path is similar to the problem of finding the shortest path. According to the resuls achieved by authors the modified Dijkstra's algorithm takes O((n+m)logn) time. And hence modified Dijkstra's algorithm is giving excellent results to find the maximum load path for road consignment or road freight [7].

2.3 Finding a Shortest Path In An Optical Networks

Dijkstra shortest-path algorithm can efficiently use for finding a shortest path in an optical networks.[8] It can be used in both a wavelength-division multiplexed network(WDM) and an elastic optical network (EON). In the wavelength-division multiplexed network, the problem is called the routing and wavelength assignment (RWA) problem, and in the elastic optical network (EON), it is called the routing and spectrum assignment (RSA) problem, or the routing, modulation, and spectrum assignment (RMSA) problem. There are main two versions of the RWA, RSA, and RMSA problems, Static and dynamic. In Future optical networks should handle dynamic traffic, where connections are frequently changing, and are of short duration as opposed to the quasi-static WDM connections that are characteristic of traditional networks. If the increasing deployment of optical networks, network densification, softwarization of the network control are given, the ever increasing need for bandwidth and agility, further increased by content-oriented services, network and service orchestration, and the next-generation wireless network requirements, a shortest optical path should be found fast.

In Ref. [8], the authors propose a generic Dijkstra algorithm that enables real-time control of future optical networks that efficiently solves the dynamic RWA, RSA, and RMSA problems. It is the generalization of the Dijkstra shortest-path algorithm. In generic Dijkstra algorithm the authors reformulate labels, iterations and edge relaxation with respect to above stated optical networks problems. Their simulation study shows that the generic Dijkstra algorithm is better and faster than other frequently used routing algorithms. The new proposed algorithm can be applicabel to have quick control in the routing over multilayer and wireless networks. The algorithm could be used to solve efficiently the contiguous frequency and time resource allocation in the wireless orthogonal frequency-multiplexed wireless networks.

2.4 The Improved Dijkstra algorithm with Resolved Issues

In ref. [9] the authors found and resolved three issues with Dijkstra algorithm. First issue: Its exiting mechanism is effective to undigraph but ineffective to digraph, or even gets into an infinite loop; Second issue: It hasn't addressed the problem of adjacent vertices in shortest path; Third issue: It hasn't considered the possibility that many vertices may obtain the "p-label" simultaneously. The improved algorithm can solve the shortest path problem of undigraph and digraph both. The improved algorithm is better than the original algorithm with respect to above stated issues : 1. In the improved algorithm the exit mechanism is improved so that the algorithm could not fall into an infinite loop. 2. The improved algorithm can get adjacent vertices (with respect to the previous vertices) in the shortest path. 3. The improved algorithm solved the problem of more than one vertices obtain "p-label" at the same time. This improved Dijkstra algorithm can be used in many applications like the robot pathfinder, game design.text file.

2.5 Dijkstra's Algorithm in GIS Application

A geographic information system (GIS) is a computer-based tool which are used in planning, administration and analyzing in different countries. GIS is widely used in government agencies, transportation agencies, emergency systems. A shortest path is critical problem in GIS. In many GIS applications, on the shortest path analysis of real-time requirements are also higher, such as 111, 108 fire and medical care system [9]. In Ref. [10] authors compare dijkstra algorithm and Bellman-Ford algorithm used in GIS application. In terms of time and space complexity, they observed that running time of Bellman Ford algorithm is more than Dijkstra algorithm. Also bellman ford algorithm takes more space than dijkstra algorithm. So Dijkstra algorithm is very fast, and suitable for GIS application. In

Ref.[11] also, authors conclude that Dijkstra algorithm showed better performance in finding the shortest path, for GIS based application in finding the best route.

2.6 In automated guided vehicle (AGV) systems

Automated guided vehicle (AGV) systems have been widely used for various applications, such as intelligent warehouses and smart manufacturing systems. In the AGV systems, optimal path planning to find appropriate paths for AGVs to complete given tasks is an important issue. The AGVs are used as a main component in automated manufacturing systems, for transferring loads. The automated manufacturing systems should strictly follow the environmental policy on CO2 emissions, so it required energy-efficient solutions. It also demand for low energy cost. Reduction of the energy consumption in the AGVs is very important to improve the energy efficiency of manufacturing system. In Ref.[12], The authors designed an operational environments of an AGV as shown in figure 1. In the graph the various slopes and distances are given to edges between vertices. The authors assume that the AGV operates on the graph.

The AGV carries loads composed of the different weights as many as the number of graph vertices and the loads must be delivered to each designated vertex in the graph. To calculate the energy consumption , a tractive force model for the AGV is established so that the weight representing the energy consumption between a pair of vertices can be calculated according to varying weights and ground conditions of the AGV, whenever each load is placed. here, using the Dijkstra algorithm based on the weights of the graph that changes, whenever the load is dropped, the optimal path and order of visiting each vertex to place each load are determined.

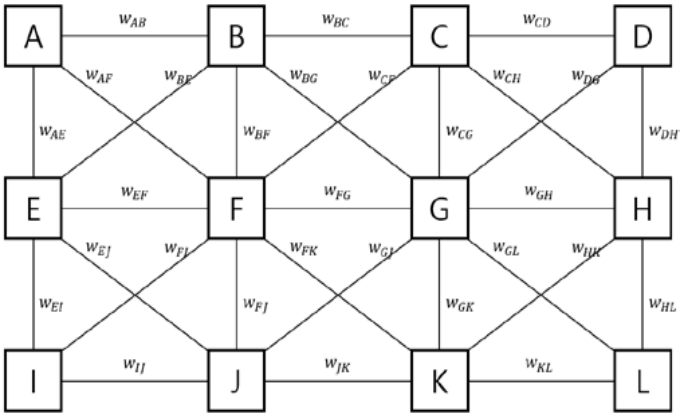

Fig -1: Operational environment of an AGV

In this application the modified Dijkstra algorithm used as the path planning algorithm for AGV. The new algorithm is systematically generating the optimal solutions for tasks of AGV of transferring each load to a designated location with minimum energy consumption.

2.7 Some Other Applications

A new path-value function proposed by the authors in Ref.[13] can be used to guide the design of new operators based on the image foresting transform. Such results ensure the correct behavior of the Dijkstra algorithms and are beneficial to image processing. To solve the classical k Shortest Paths (KSP) problem, which identifies the k shortest paths in a directed graph the Dijkstra's algorithm can be used as a baseline algorithm.[14]

3. ANALYSİS

Shortest Path algorithms mainly classified in two categories such as static, where the external environment remains constant and dynamic, where the external environment is changing. Basically the Dijkstra's algorithm is static shortest path algorithm. But with improvement it can produce desired results in changing environment like dynamic shortest Path algorithms. After surveying different application, the Dijkstra algorithm if use with modification or clubing together with other shortest path algorithms according to type of application areas, it can work better in terms of time and space complexity and enhance the performance.

4. DİSSCUSSİON

There are many shortest path algorithms or path planning algorithms have been proposed. Dijkstra's algorithm is giving best results till date with some modifications. The limitations of Dijkstra's algorithm like falling into infinite loop or negative weight can be overcome by improvement. According to Sniedovich, M, [16] the Dijkstra's algorithm was inspired by Bellman's Principle of Optimality and so technically it should be viewed as a dynamic programming successive approximation procedure. Therefore, Dijkstra's algorithm can applied to solve dynamic programming problem with modification at some extent.

5. CONCLUSİON

Dijkstra's algorithm which is popular in reaserchers is static shortest path algorithm. In this papers some applictions of improved Dijkstra's algorithm are discussed. Dijkstra algorithm with modifications and combing with other shortest path algorithms can work efficiently in almost all application areas to find shortest path.

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