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Review Article

Survey of Multiple Destination Route Discovery Protocols

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Abstract:

Route discovery protocols for multiple destinations are one of the most interesting research topics since it is applied for real-world applications and is needed in smart city services such as delivery services. The inclusion of artificial intelligence can improve the performance of multiple destination route discovery protocols. In this paper, we studied and analyzed multiple destination route discovery protocols based on different search strategies, especially artificial intelligence methods. The survey compares multiple destination route discovery protocols related to their applications and implementation tools. Important parameters are considered regarding route planning such as the mapping models of multiple destinations and different artificial intelligence search strategies. In this survey route discovery protocols for multiple destinations consider their different goals related to travel time and cost deadlines, moving obstacles, real-time traffic conditions in the city, customer satisfaction, and optimal route. In conclusion, using artificial intelligence can enhance route discovery protocols for multiple destinations compared to traditional search methods.

1. Introduction

Transportation costs many resources such as water, oil, and truck maintenance. Therefore, cost optimization in transportation is extremely necessary for providing the best price. For multiple destination route discovery, routing optimization will offer good service when the time and cost are minimized for service especially when competing with E-commerce logistics [1-6].

Smart transportation is linked with the smart environment to have a smart city [1]. Multiple destination route discovery protocols are important in a smart city to discover a route when many destinations are available. Figure 1, shows an example of multiple destination route discovery using Google Maps to visit three cities in Kurdistan Region and North of Iraq where the source is Erbil city and the destinations are Mosul, Duhok and Sulaymaniyah cities. Many smart city applications need multiple destination route discovery protocols such as searching different places in the city to visit, goods distributor drivers for multiple destinations, and delivery service for markets and restaurants to serve many customers [2, 3].

The main contribution of this work is as follows:

- Study and compare different protocols related to multiple destination route discovery.
- Analyse multiple destination route discovery protocols relate to artificial intelligence strategies.

The remainder of this paper is organized as follows: a description of the background of multiple destination route discovery protocols will be presented in section (II); then, an analysis of multiple

destination for route discovery protocols is explained in section (III). Finally, the conclusion and future work are explained in section (IV).

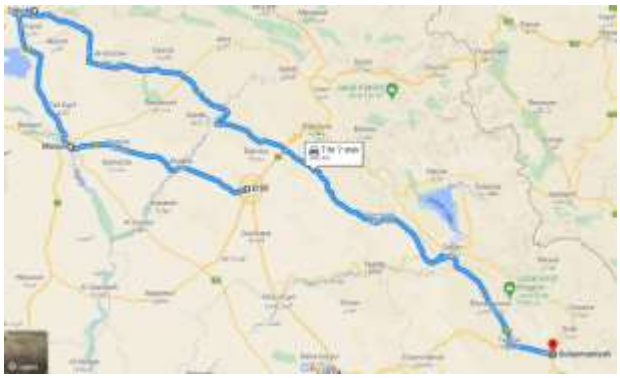

Figure 1. *Multiple destination route discovery using Google Maps to visit three cities in Kurdistan Region of Iraq*

2. Background and Related Works

In the literature, limited researches focus on multiple destination compared to single destination route discovery protocols that has wide publications. Figure 2 shows the multiple destination routing protocols approaches. The early studies of multiple destination route discovery protocols had implemented using search algorithms while the recent researches apply artificial intelligence algorithms.

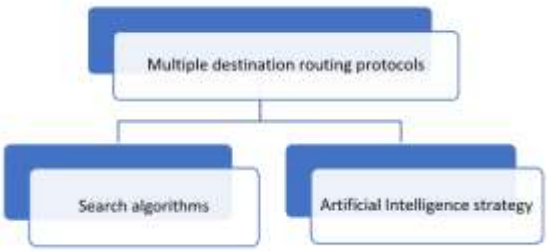

Figure 2. *Multiple destination routing protocols approaches*

Reem et al., [4] implemented Ant Colony Optimization (ACO) algorithm for multiple destination route planning to optimize the route for Google Map application when it is used to visit multiple cities. The proposed algorithm suggested the visited order of cities with shortest path for the citizen in Erbil city.

Timothy et al., [5] proposed an Improved Particle Swarm Optimization (IPSO) algorithm to find shortest overall path when the robot moves between moving obstacles.

Ky Phuc et al., [6] solved multiple pickup and multiple delivery vehicle routing problem with time window and heterogeneous fleets using (ACO) algorithm and proposed a mathematical model to represent the system.

Huang et al., [7] proposed an efficient optimizing algorithm for multi-destination route. In this proposal the customer can specify the time and the cost to travel via the optimal route and the algorithm will be performed according to customer requirements and deadlines.

Zhuang et al., [8] used search algorithm with probability for the mobile robot movement to find the optimal path when visiting multiple destinations. The proposed algorithm will minimize the obstacles when the mobile robot moves in the environment.

Asaduzzaman et al., [9] used modified Dijkstra algorithm for multiple destinations. Dijkstra algorithm is used to find the shortest path from single source to single destination. The modified Dijkstra algorithm is improved to be implemented many times till all destinations are visited. The paper cconsidered the indoor environment in warehouses or libraries for customers to find the shortest path when searching for multiple items.

Abeer A. et al., [10] proposed an algorithm with minimum time for the driver to travel to serve multiple destination in the city. Two important parameters are considered to find the route in the proposal which are: free parking places around the city and the real-time traffic conditions.

Shushang et al., [11] used Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) to optimize the path of unmanned express vehicles to achieve the shortest logistics path in multiple destinations.

Yu et al., [12] used search algorithm to find the multiple destinations with deadlines and cost constraints.

Eric et al., [13] used Cluster-Based Approximation strategy. In this strategy all the destinations are clustered into several destination clusters. Each cluster will have different visiting destinations and the proposed algorithm will find the optimal path inside each cluster.

Table 1 is an overview and it gives a compare between related works for multiple destination route discovery protocols. Different parameters are considered to compare between different multiple destination routing protocols, including:

- Mapping model, this model is needed to represent the search space for the source and multiple destinations.
- Artificial intelligence concepts and search technique, the process for implementing the route discovery over different researches use simple search techniques such as A* search algorithm or Dijkstra algorithm and some researches use artificial intelligence concept such as ACO or PSO.

Table 1. *Overview and compares between related works for multiple destination route discovery protocols*

No.	Authors	Application of Research	Mapping Model	AI / Search Technique	Consider Optimal Route Yes/ No	Simulation and Tools
1	Reem et al., [4] 2022	Improve Google Map application with artificial decision to develop the route discovery for multiple-destination for the citizen in Erbil city, Iraq	2D graph	Ant colony optimization (ACO) algorithm	Yes	MATLAB software
2	Timothy et al., [5] 2022	Consider moving obstacles avoidance in the environment when the robot moves and find shortest overall path length for each waypoint to waypoint	Graph- based map	Improved Particle Swarm Optimization (IPSO) algorithm	Yes	Pseudo code
3	Ky Phuc et al., [6] 2021	Solve multiple pickup and multiple delivery vehicle routing problem with time window and heterogeneous fleets	Mathematical model	Ant colony optimization (ACO) algorithm	Yes	Pseudo code
4	Huang et al.,[7] 2021	Satisfy user multiple requirements relate to cost and time with deadlines	Multi-weight dynamic directed graph	Best-first search algorithm	No	JDK1.8
5	Zhuang et al.,[8] 2021	Consider obstacles in the environment when the mobile robot finds the optimal path	2D graph	Simulated annealing strategy	Yes	MATLAB software

		of multiple destinations				
6	Asaduzzaman et al.,[9] 2021	Consider indoor environment to find the shortest path for multiple destination like in warehouses or libraries when a customer needs multiple items to search	A bi-directional graph	Dijkstra algorithm	Yes	Pseudo code
7	Abeer et al.,[10] 2019	Consider real-time traffic conditions in the city and free parking places for drivers	Weight directed graph method	A* search algorithm	Yes	Pseudo code
8	Shushang et al., [11] 2019	Optimize the path of unmanned express vehicles to achieve the shortest logistics path in multiple destinations	2D graph	Particle swarm optimization (PSO) and genetic algorithm (GA)	Yes	MATLAB software
9	Yu. et al., [12] 2017	Multi destinations route planning with deadlines and cost constraints	Weight directed graph method	A* search algorithm	Yes	Java JDK 1.8
10	Eric et al., [13] 2011	Use cluster strategy to cluster the destinations into several destination clusters	Tree structure	Data mining: Cluster-Based Approximation Strategy (CBAS)	Yes	Java JDK 1.5

- Consider optimal route, the main goal of researches is to find the shortest path form source to visit multiple destination.
- Simulation experiment and tools are needed to implement the proposed protocol.

3. Analyse Multiple Destination Route Discovery Protocols

The route discovery protocols need mapping model and route planning algorithm to find the optimal route form source to visit multiple destination. This section will give a description about different mapping models and different artificial intelligence algorithms that are used in the multiple destination route discovery protocols.

First: Mapping Model

Mapping model represents the search space for the source and multiple destinations. The graph is used to represent the source and multiple destination. In the literature, two-dimensional graph and weight graph are the most used model to map the location

of the nodes. Data structure such as tree structure is used in early research [13]. The following section will describe the three most used mapping models.

A. 2D and 2D Grid graph

Two-dimension (2D) graph model is represented as x and y coordinate for each node to have the location of source and multiple destination [4, 5, 8, 11]. The 2D grid graph is used to represent the location of the nodes according to their distance between each pair of nodes, [7].

B. Weight directed graph and bi-directional graph

In graph theory, a directed graph (or digraph) is a graph that is made up of a set of vertices connected by directed edges, often called arcs. In [10, 12], Weight directed graph is used for multiple destination route discovery protocols.

A bi-directional graph is a graph in which each edge is given an independent orientation (or direction, or arrow) at each end [9, 14].

C. Tree structure

In [13], a tree structure is used with data mining and cluster strategy. A new proposal for tree network which is a three-dimensional tree structure is used in modern analysis for network [15]

Second: Route Planning for Multiple Destination using Artificial Intelligence and Search Algorithms

Artificial Intelligence is one of the hot topics for many applications and technologies affecting our life nowadays. It has developed and created many opportunities for problem-solving [16].

A. Ant colony optimization (ACO) algorithm

Ant colony optimization (ACO) is used to solve optimization problems; then, it is developed to be used for artificial intelligence applications. ACO is based on behavior of ants for finding food. During the ant walk, it deposits pheromone on the ground in order to mark the favorable path and the density of pheromone deposition increases when the ant returns back to the source point with food. In ACO algorithm many ants will travel on different paths at the same time and the optimal path will be found when it has the maximum pheromone deposition [17, 18]. In [4, 6], ACO is used in finding the optimal path when multiple destinations are available.

B. Particle swarm optimization (PSO)

Particle swarm optimization (PSO) algorithm is based on the natural behavioral observation of birds when they fly and travel as swarm. It uses an iterative methodology to optimize randomly initialized particles to define a path from the initial position to the goal [19, 20, 21]. In [5, 11] PSO is used in finding the optimal path when multiple destinations are available.

C. Genetic algorithm (GA)

Genetic Algorithm is a search-based optimization technique based on the principles of Genetics and Natural Selection. It is frequently used to find optimal or near-optimal solutions to difficult problems which otherwise would take a lifetime to solve. It is frequently used to solve optimization problems, in research, and in machine learning. A genetic algorithm is a search heuristic that is inspired by Charles Darwin's theory of natural evolution. This algorithm reflects the process of natural selection where the fittest individuals are selected for reproduction in order to produce offspring of the next generation [22]. In [11], GA is used with PSO to implement multiple destination route discovery.

D. Dijkstra algorithm

The Dijkstra's algorithm is an algorithm that finds shortest distance in a given path between the source point to the destination point. Dijkstra's algorithm is an iterative algorithm that choose the source node as the root of the tree, then the node selects one node, among all nodes not in the tree, which is closest to the root, and adds this to the tree. After this node is added to the tree, the cost of all other nodes not in the tree needs to be updated because the paths may have been changed [23, 24]. In [9], used modified Dijkstra algorithm for multiple destinations.

E. A* search algorithm

It is a searching algorithm that is used to find the shortest path between an initial and a final point in a graph. It will be used for the shortest path finding. It is an extension of Dijkstra's shortest path algorithm (Dijkstra's Algorithm) [24]. In [10, 12], they use A* algorithm.

F. Simulated annealing

Simulated annealing is a method for solving optimization problems. The method models the physical process of heating a material and then slowly lowering the temperature to decrease defects, thus minimizing the system energy. At each iteration of the simulated annealing algorithm, a new point is randomly generated. The distance of the new point from the current point, or the extent of the search, is based on a probability distribution with a scale

proportional to the temperature. The algorithm accepts all new points that lower the objective, but also, with a certain probability, points that raise the objective. By accepting points that raise the objective, the algorithm avoids being trapped in local minima, and is able to explore globally for more possible solutions. An annealing schedule is selected to systematically decrease the temperature as the algorithm proceeds. As the temperature decreases, the algorithm reduces the extent of its search to converge to a minimum [25-31]. In [8], they use this concept to find the shortest path with multiple destinations.

4. Conclusions and Future Works

In conclusion, most algorithms use artificial intelligence techniques or hybrid algorithms to improve the planning for multiple destination route discovery.

MATLAB software is the most simulation software that is used to implement the multiple destination route discovery protocols in addition to Java JDK.

In the study, each route discovery protocol for multiple destinations designs its goals in implementation such as travel time and cost deadlines, moving obstacles, real-time traffic conditions in the city, customer satisfaction, and optimal route. Recent studies use artificial intelligence strategies in route optimization such as using the Ant Colony Optimization (ACO) algorithm and Particle Swarm Optimization (PSO). Using artificial intelligence can enhance route discovery protocols for multiple destinations compared to traditional search methods that are previously used such as the Dijkstra algorithm and A* search algorithm.

To measure the efficiency of multiple destination route discovery protocols many metrics could be considered such as: the impact over variate numbers of destinations, the impact of average time interval and the impact of total distance.

The survey will give a good background to authors to work on new research for multiple destination route discovery protocols.

For future works, multiple destination route discovery protocols could be used to enhance the mobile applications used for GPS navigator or delivery service in smart city applications.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
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