Multi-Condition Vehicle Routing Algorithm and its Development

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Abstract. With the continuous improvement of roads in China, the number of vehicles, complexity of traffic and personalized needs of vehicle owners are also increasing gradually, which makes the routing planning particularly important. As a result, it is more and more important to develop appropriate routing planning algorithms to meet the needs of vehicles. However, most of the existing algorithms only solve the problem for a certain condition, rather than meeting the multiple conditions. In view of the above-mentioned problems, this paper describes the multi-condition vehicle routing planning algorithm and the current development status quo in detail by referring to the materials, analyzes the process of each algorithm and points out its advantages and disadvantages. Finally, the future trend of the vehicle routing planning algorithm under multiple conditions is predicted.

1. Introduction
The vehicle routing problem was first proposed by Dantzig and Ramser in 1959 [1]. It refers to that certain customers who have different demands for goods, the distribution center provides customers with the goods, and a motorcade is responsible for distributing the goods and organizing the appropriate route with the goal of satisfying the needs of customers as well as meeting some other requirements, such as the shortest distance, the lowest cost, the least time and so on.

When choosing a routing, we usually just consider one condition for optimizing, but the choice of routing is not that simple in real life. A variety of conditions should be discussed at the same time in order to find the optimal vehicle routing. Therefore, a single condition has been unable to meet the needs of vehicle routing planning. A better combination with the reality is of greater research significance and value. With the continuous development and progress of the times, logistics, transportation and green environment protection have been so close to people's lives. It is imperative to choose vehicle routings under multiple conditions, which has also become a research focus in recent years. In this paper, the algorithms for the vehicle routing problem under multiple conditions are summarized, and the research prospect is predicted.

Algorithms for the vehicle routing planning problem under multiple conditions can be generally divided into precise algorithms and heuristic algorithms.
2. Accurate Algorithm for Vehicle Routing
"Accurate solution" is the standard "optimization method", regarding the vehicle distribution problem, the solution can be found through the rigorous mathematical model or computer data structure planning, together with the use of mathematical rules or data structure search method. The precise algorithms cover the branch-and-bound method, cut-plane method, dynamic programming algorithm, set-covering method and so on.

2.1. Improved Branch-and-Bound Method
The branch-and-bound method can find the optimization of vehicle routing by searching and iterating, but it has a certain limit, beyond which the branch-and-bound method cannot be carried out any more, which brings a great trouble to the routing planning.

Laporte et al. [2] have taken advantage of the relations between the vehicle routing planning and multiple traveling salesmen to turn the vehicle planning problem into a traveling salesman’s problem, then the optimal solution is obtained by using the branch-and-bound method. Christofides et al. [3] have first turned this problem into a "K-degree center tree" and then used the branch-and-bound method to solve it. Chen Xin et al. [4] have combined it with other algorithms, used the Johnson algorithm to organize and model the problems. On the basis of finding several upper bounds and lower bounds, a number of accurate algorithms for the vehicle routing problem under multiple conditions are given.

2.2. Improved cut-Plane Method
With the help of Benders' decomposition algorithm [5-7], most of the problems of certificate planning can be solved effectively, the core of which is the cutting plane method.

If we use the interior point cut plane method to solve the routing planning problem, the algorithm has many iteration times and low computation speed, which may even cause the algorithm not to converge. While using the cutting plane method, sometimes the real number solution is cut off, and sometimes the integer solution is cut off. However, it is not so easy for both of the methods to solve the vehicle routing problem. Therefore, Liu Zhenhang and Yang Mingge et al. [8-9] have improved the cutting plane method and found the Gomory constraint, made some new pole in the feasible part reach the optimal point, and written down the corresponding row constraints, then the row constraints are decomposed, plus the conditions are forced to obtain inequalities greater than 0, thus different algorithms can be formed.

Sun Jinghao has established the variable model by analyzing both the integer linear programming model and polyhedron analysis, thus proved the dimension of polyhedron and maximal inductive inequality and gave two kinds of time-dependent, highly effective inequalities, and then added these inequalities to the algorithm as cut planes dynamically. This method can also be applied to the routing planning problem under multiple conditions.

2.3. Dynamic Programming Algorithm
Dynamic programming algorithm is to divide the problem, define the relationship between the problem state and the state, making the problem solved in a recursive (or divide-and-conquer) way.

The dynamic programming algorithm for deterministic vehicle planning was first proposed by Eilon [11]. However, their dynamic programming methods need to take a large number of states into consideration, so they can only solve the problems with a very small scale accurately. Christofides et al. [12] have reduced the number of states substantially by using state space relaxation technology, which significantly improves the performance of dynamic programming algorithm. Zhang Aihua et al. [13-14] have used the dynamic programming algorithm as a mathematical method to solve the optimal value.

But the recurrence relation of dynamic programming must be transformed from little problems to bigger ones, so it must be realized by recursion. Meanwhile, it can reduce the duplication of calculation. With the dynamic programming algorithm, the vehicle routing planning can be regarded independent with each other. Any condition encountered in the routing planning can be turned into parts of the dynamic programming, which can be combined with its core ideas to find solutions, as...
well. Under multiple conditions, we only need to list all the conditions one by one to solve the vehicle routing planning problem.

3. Heuristic Algorithm
The heuristic solution includes the conservation method, simulated annealing method, deterministic annealing method, tabu search method, gene algorithm, neural network, ant algorithm and so on.

3.1. Improved Conservation Method
The conservation method is the most famous heuristic algorithm used to solve the problems when the number of vehicles is uncertain. Parallel and serial modes can be used to optimize the driving distance. The idea is simple, clear, easy to implement, and very effective [15-17], but under multiple conditions, it does not show the flexibility. First of all, the conservation method mainly emphasizes on saving the distance, but does not consider the time factor. If the road is congested, although the distance is saved, the time is also wasted. Secondly, the vehicle routing planning cannot be tackled flexibly at any time. This shows that although the conservation method is simple and convenient, it also has great shortcomings.

Therefore, Tai Xiaohong and Li Lu et al. have added the customer's time constraint factor and put forward the improved conservation method to solve the vehicle routing problem under multiple conditions, so that the planning routing can meet a series of requirements in an orderly way and finally reach the destination.

3.2. Simulated Annealing
Simulated annealing algorithm [19-20] is a stochastic search algorithm based on the thermodynamic annealing principle. It has the characteristics of fast convergence and global search, so it is good for enriching the search content and easy to jump out of the trap of total extreme value. At present, it is widely used in the vehicle routing problem. However, in terms of the traditional simulated annealing method, the routing optimization is rather difficult, the time of finding solutions increases exponentially, causing such a long time in the final routing planning. Zhou Jun et al.[21] have improved the algorithm by turning it into a multi-segment mapping problem according to the vehicle routing problem and solving the traditional simulated annealing algorithm once and for all, thus shortening the time and improving the speed of the algorithm.

3.3. Tabu Search
Tabu search method is an overall, step-by-step optimization algorithm. By introducing a flexible storage structure and the corresponding tabu criteria to avoid circuitous search, the vehicle routing problem under multiple conditions is finally solved. Ye Chao et al. [22-23] have used other algorithms to do the initial calculation, so as to find a better initial value, and then improve the algorithm quality and efficiency to complete the vehicle routing planning under multiple conditions.

3.4. Neural Networks
Neural network is a computational intelligence theory that simulates the function of human brain neurons. It has the ability to learn from experience. However, the convergence rate of neural network routing planning algorithm is relatively slow, a traditional neural network cannot be used in the vehicle routing planning system. Therefore, an improved neural network [24-25] should be used for vehicle routing planning.

If the routing point is outside the obstacle, or it is inside the obstacle, then moves to the direction of reducing the routing distance once it is removed, it will not move to the direction away from the obstacle anymore, so that the routing can quickly converge to the shortest non-collision routing [26-27]. Zhang Yaofeng et al.[28] have improved the neural network, which enables the improved fast neural network to gain the self-learning ability, and increase the linear reinforcement algorithm. Based on the neural network algorithm, a four-layer network structure is adopted to design the energy function as the evaluation function of the network. By finding the extreme value of the energy function, the vehicle can complete the routing planning task.
3.5. Improved Ant Colony Algorithm

Ant Colony Algorithm [29] is a probabilistic algorithm used to find the optimal routing. It was proposed by Marco Dorigo in his doctoral thesis in 1992. The inspiration comes from the behavior of ants in finding routings to food.

Wang Peidong [30] has proposed an improved ant colony algorithm with the capacity constraints in his paper. This algorithm stresses on the vehicle initialization and improves the possibility for vehicles to attain the optimal routing. This heuristic algorithm can give more convenience to the vehicles in plan the routing. It can also update the road information in real time, find the optimal routing anytime and anywhere, and prevent the algorithm from stopping running. At the same time, the search range can be enlarged by the exchange search and the insertion search. Besides, he has proposed an improved a routing planning algorithm under static environment, which uses the grid method to model. In the search process, the heuristic factor is composed of the target guidance function and the largest pheromone in a certain range, which shortens the distance between the starting point and the target point. Meanwhile, it can also move back and forth between two points to improve the speed of routing planning.

3.6. Improved Genetic Algorithm

Genetic Algorithms (GA) is an adaptive heuristic method based on population genetics, which has the characteristics of parallel search, strong robustness and global optimization. It is suitable for solving large-scale, complex problems. Therefore, GA is very popular in vehicle routing planning. However, the convergence speed of a single genetic algorithm is slow and the global search ability is poor, so it cannot plan the routings well under multiple conditions. Therefore, Wang S, Liu M et al. [31-32] have improved the traditional genetic algorithm and added a time window to it. By considering the correlation, the adaptive selection of individual concentration and individual fitness, crossover, mutation operator and other factors, the previous problems are solved.

3.7. Improved Particle Swarm Optimization

Genetic Algorithms (GA) is an adaptive heuristic method based on population genetics, which has the characteristics of parallel search, strong robustness and global optimization. It is suitable for solving large-scale, complex problems. Therefore, GA is very popular in vehicle routing planning. However, the convergence speed of a single genetic algorithm is slow and the global search ability is poor, so it cannot plan the routings well under multiple conditions. Therefore, Wang S, Liu M et al. [31-32] have improved the traditional genetic algorithm and added a time window to it. By considering the correlation, the adaptive selection of individual concentration and individual fitness, crossover, mutation operator and other factors, the previous problems are solved.

4. Summary and Prospect

In summary, the problem of vehicle routing planning under multiple conditions

- Can use some single algorithms for improvement and combine other algorithms to comprehensively improve the convergence of vehicle routing, so that the vehicle can be operated faster and better, and it will be more efficient to find a suitable method for vehicle routing under multiple conditions.
- Can use the improved algorithm to reduce the range of vehicle routing planning so as to improve its search speed.
- Can use the algorithm with memory function to remember, so that the vehicle can accurately find a more practical routing planning under the same conditions.
- In the two-dimensional and three-dimensional states, it can be improved by combining modeling with algorithm.

At present, there are still many problems in the routing planning of our country. Many algorithms cannot be used in different conditions. The routing planning should be applied to different vehicles under different conditions. For example, the refrigerated carriages should be biased towards the shortest possible distance. Vehicles for postal service should be biased towards the minimum number
of repetitive road sections; Artificial intelligence vehicles should be biased towards the road sections with fewer obstacles in a short distance.

In short, different vehicles should have algorithms suitable for themselves respectively, which requires us to improve different algorithms according to the needs of the vehicles. The future trend leads to the development of big data and artificial intelligence. The vehicle routing planning should be more biased towards the driverless cars under multi-conditions, which requires us to combine the algorithm with modelling, artificial intelligence and big data.

5. Conclusion
This paper analyses and summarizes the existing commonly used vehicle routing planning algorithm, analyses its advantages and disadvantages, finds a more suitable vehicle routing planning algorithm improvement under multiple conditions, classify its categories and makes a summary. Finally, according to the existing development trend, the development direction of vehicle routing planning under multiple conditions in the future is predicted. With the development of science and technology, vehicle routing planning under multiple conditions will make more and more progress, it will also be increasingly close to people's lives, and enters the big data era successfully.

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