A Solution to Multi Capacitated Depot Vehicle Routing Problem with Pickup and Delivery Customers and Soft Time Window using Genetic Algorithm

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Abstract: *This paper presents a genetic algorithm for multi capacitated depot vehicle routing problem with pickup and delivery customers and soft time window (MCD-VRPPD-STW). MCD-VRPPD-STW is an expansion of VRP problems. In this problem routes are constructed in a way that vehicles gather the requests and deliver them to the customer as no customer remains without providing service. Routes are serviced by homogeneous vehicles in a way that all transportation demands are gathered and delivered to the customers. What makes this problem special is the capacity that is considered for each depot. Each depot has a capacity and the capacities of depots are not same as each other. In the scheduling process, problem constraints (soft time window constraint, capacity constraint of depots and capacity constraints of vehicles) are satisfied. A Genetic Algorithm is provided to solve the proposed problem with new constraints. The algorithm is then implemented by MATLAB and the calculation results are presented.*

Keywords: Multi Depot Vehicle Routing Problem; Vehicle Routing Problem with Pickup and Delivery; Multi Capacitated Depot Vehicle Routing Problem with Pickup and Delivery and Soft Time Window; MCD-VRPPD-STW.

1. Introduction

There are different variations of vehicle routing problems (VRP). This article is comprised from two important types of the VRP "multi depot vehicle routing problem and vehicle routing problem with pickup and delivery" with some other limitations. Every request by pickup customers are gathered and stored in depots and then delivered to delivery customers, satisfying the precedence. The real case of this problem and its new limitation is "POST" functionality.

This paper proposes a genetic algorithm for solving the MCD-VRPPDSTW. In this paper, the capacity of all vehicles is considered identical. Each Depot in this problem has a specific capacity. This assumption has not been considered in previous studies. Customers can't be Pickups and Deliveries simultaneously. This means that at a given time a customer can just only deliver a product or Pick up a product. The cost function in this problem is looking for minimizing four kinds of costs: traveling costs, the fixed costs of using depots, the fixed cost of using vehicles and finally the penalty cost of passing the time window. The main goal is minimizing the traveling costs.

As stated, MCD-VRPPDSTW is a combination of other VRP problems. Since MCD-VRPPDSTW is NP-hard (as MDVRP and VRPPD are NP-hard), it is too difficult to solve it using exact methods, so a heuristic method and heuristic techniques are chosen to solve this problem [2], [3], [4], [5], [7], [8] and [9].

Although this problem is a combination of other VRP problems, but because of considering the real limitation of having a specified capacity for each depot, this special combination has not been solved till now. Some instances of other versions of this problem which have been solved before are (without depot capacity limitation): E. Ben Alaïa , I. Harbaoui Dridi, H. Bouchriha and P.Borne in [10] propose a Genetic algorithm for optimization of the multi depot and multi vehicle pickup and delivery problem with time windows. In this article simultaneous pickup and delivery has been studied. Pandhapon Sombuntham and Voratas Kachitvichayanukul in [11] propose a particle swarm optimization algorithm for multi depot vehicle routing problem with pickup and delivery requests. Gábor Nagy and Saïd Salhi in [6] have provided a research on heuristic algorithms for single and multiple depot vehicle routing problems with pickups and deliveries. Some other studies have been made on VRPs that none of them have the "capacitated depot" limitation [12], [13] and [14].

This paper proposes a method to design a solution for the new problem of "MCD-VRPPDSTW" using genetic algorithm. A set of feasible solutions to minimize total distance is provided in this method.

2. Definition

Based on graph theory, this problem is defined as follows: Assume that G=(V,E) is a complete graph, which V={0,….,m,m+1,…,m+n} are its vertices and E are its edges. The $V \in \{0,..m\}$ vertices are the depots and $V \in \{m+1,..m+n\}$ vertices are the customers. For each vehicle

k, D_k depot is that vehicle's residence. Assume that for all of the edges of $e \in E$, I_e is the distance between the two vertices of that edge. For each customer i, d_i is the request for the delivered goods to that customer and p_i is that customer's received goods. In addition, P_i is the receiving vertex of the delivered goods to i and D_i is the delivery vertex for the received goods in i. Finally, for each customer i, the time window is $[a_i,b_i]$ and S_i is the service time. Now, the problem is finding a set of K simple cycles, so that:

- Each cycle traversed by vehicle K meets its corresponding depot vertex DK
- Each customer is met exactly by one cycle
- The vehicle's load must be always non-negative and never exceed vehicle's capacity C
- For each customer i, Pi must belong to the same cycle which i belongs to, and it must be met before i
- For each customer i, Di must belong to the same cycle which i belongs to, but it must be met after i
- For each customer i the service begins at the [ai,bi] time window

The objective function here is to minimize traveling costs, constant cost of using depots, constant cost of using vehicles and penalty of passing the time window. Minimizing the travelling costs is the most important of them. This problem is NP-hard, since it is a generalization of the CVRP problem [2].

3. Utilizing Genetic Algorithm for MCDVRPPDSTW Problem`s Optimization

For implementing the algorithm, the following steps are considered:
a) Generating the initial population: the nearest neighborhood method is used to generate the initial population from.
- Routing and checking constraints: problem's constraints must be considered in this part. This means that the nearest neighbor must not violate the problem's constraints. To this mean, a function named Capacity-Check(Per,Perd) is defined which takes a permutation of customers and a permutation of depots as input parameters, checks the constraints on them and returns the problem's routes as its output.

At the end of this step, the population of customers and depots are created. The created population will be a permutation of points. Routes show which routes are allocated to each depot. Fig – shows a sample of these permutations.

Figure 1: A Schema of Customers and Depots in the Proposed Algorithm

b) Evaluating routes: after determining the initial population, the cost of the selected population must be calculated in the main function (genetic algorithms function). This is performed by function Cost (PerC,PerD) which takes a permutation of customers and depots as input and calculates the value of their cost function. The cost of this function is equal to traveling costs, the constant cost of using depots, the constant cost of using the vehicle and the cost of passing the time window penalty. The most notable of these costs is the cost of minimizing the traveling costs.
c) Generating new population: this population is created by crossover and mutation operators. The crossover is applied on permutations. A simple one point crossover is applied for this approach. Reversion, insertion and swap are applied for mutation.

This algorithm stops when all of the customers are serviced.

4. Computational Results

The proposed algorithm for solving the MCDVRPPDSTW problem (the multi capacitated depot vehicle routing problem with pickup and delivery requests and soft time window) is implemented by MATLAB. It should be explained that the data sets used in this solution are created by ourselves and are compatible with the conditions of the problem. This data set includes 10, 20, 30, 40 and 50 customers. The algorithm is analyzed by this data set and the responses and their spent times are extracted.

The coordination of customer and depot nodes are generated by a discrete uniform random function, between 0 and 10. The amount of delivered and picked up goods for customers are generated by a discrete uniform random function, between 0 and 10. A node delivers or picks up a good by the probability of 0.5. The lower bound of reaching the node is generated by a discrete uniform random function, between 0 and 5 and its upper bound is generated by a discrete uniform random function, between 10 and 30. The cost of using the vehicle is considered 50 and the penalty of delay or being early is 20. The constant cost of depots is generated by a discrete uniform random function, between 100 and 120. The capacity of depots is generated by a discrete uniform random function, between 25 and 35. Also, the capacity of the vehicle is considered 25.

Due to complexity, a certain coding is used for the problem's name definition. For easier understanding, the problem names are considered as X.Y.Z1.Z2. In this naming, X indicates the number of customers; Y shows the number of potential depots. Z1 represents depot capacity's tightness (T) and looseness (L); Z2 is the indicator of tightness (T) or loosens (L) of the vehicle's capacity. It must be noted that tight capacities are considered 0.6 times of the initial capacities (more free).

The results of the performed analyses on the MCDVRPPDSTW problem's solution are shown in the following table.

Table 1: Computational Results

The Solving Time	Cost of the Method	Problem Name
5.1292	344.8415	10.5 .L.L
5.3341	398.7563	10.5 .L.T
5.2735	501.7121	10.5 .T.L
5.2997	499.0933	10.5.T.T
10.7918	679.2067	20.7 .L.L
10.0143	779.2164	20.7 .L.T
10.5304	927.6333	20.7 .T.L
10.7634	1030.9066	20.7.T.T
15.8877	851.7644	30.10 .L.L
16.9283	1032.6606	30.10 .L.T
15.2267	1182.8739	30.10 .T.L
24.2127	1198.9045	30.10.T.T
32.1712	1122.7518	40.12 .L.L
48.5146	1170.6035	40.12 .L.T
47.4446	1381.8011	40.12 .T.L
36.0284	1515.7470	40.12.T.T
57.1339	1368.8826	50.15 .L.L
65.3618	1635.8641	50.15 .L.T
32.3772	1865.2103	50.15 .T.L
32.8098	2027.2125	50.15.T.T
24.3616	1075.7821	Average

By MATLAB implementation, the average response of the problem is 1075, 7821 and 24, 3616 seconds by average is achieved. These results show that our algorithm is working well for solving the proposed problem.

5. Conclusion

This paper presented a genetic algorithm for solving the multi capacitated depot vehicle routing problem with pickup and delivery customers and soft time window (MCD-VRPPD-STW). Goods are gathered from the delivery customers and stored in depots. In the next step the pickup customers are identified and their requests are delivered to them. Each vehicle initially is in a specific depot; it starts moving from that depot, services the customer and again will return to the same depot. Each depot has its specific capacity and the sum of orders in routes related to a depot will not exceed its maximum capacity. The objective function is consisted of traveling costs, constant cost of using depots, constant cost of using vehicle and penalty of passing time window. To solve this problem, soft time window was used and the amount of its penalty was considered in the objective function. In addition, vehicles had specific capacities; maximum amount of orders in a route must not exceed the vehicle's capacity. This problem was implemented by MATLAB. In this research, pickups and deliveries do not occur simultaneously. As a future work, we tend to focus on simultaneous pickups and deliveries. Results showed that our algorithm is working optimally for the proposed algorithm.

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