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Hybrid ant colony optimization algorithm for two echelon vehicle routing problem

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Abstract

A hybrid heuristic ant colony algorithm is proposed and applied to solving the two echelon vehicle routing problem, which combines three heuristic or meta-heuristics. The problem is divided into m+1 CVRP by a separation strategy (distance-based cluster). Then better feasible solutions are built by an improve ant colony optimization with multiple neighborhood descent (IACO_MND), which is taken as the initial solution of the threshold-based local search procedure, two different neighborhood structures, i.e., threshold-based insert and threshold-based swap are successively used. Computational results on the 22 benchmark problems with the size ranging from 20 to 50 show that the proposed hybrid algorithm can find the best known solution for some problems in short time, which indicates that the proposed method outperforms other algorithm in literature.

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1. Introduction

Proposed by Dantzig and Ramser [1] in 1959, VRP has made a lot of research achievement in decades. But the researches about the problem more concentrated in single-level scheduling system, and the researches about the multi-level system, such as ME-VRP, are very small. Crainic et al. [2] apply the multi-level system to the practice first time for a City Logistics instance in 2004. Feliu et al. [3,4] integrated the multi-level system into the VRP first time and build the mathematical model for it, they call it Multi-Echelon Vehicle Routing Problem (ME-VRP). With the model and complexity of logistics increase, more and more researchers began to study and discuss the issue. Since VRP is a NP hard problem, so ME-VRP is NP hard, and more complex than the basic VRP. Therefore, the method for solving such problem mainly focused in heuristic and meta-heuristic which can fine the better solution in a relatively short time. And it has achieved some results. Such as Feliu et al. [3,4] use Base-Math heuristic algorithm for solving a number of public instance about 2E-VRP. Crainic et al. [5] proposed a

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Clustering-based Heuristic algorithm. Then they simple improved their algorithm, and proposed Multi-Start Heuristic Algorithm [6], it asked that the local search will continue until the object value is not be improved. Crainic et al. [7] analyzed the relationship of the distribution of customers, the system layout and the cost, and compared the multi-level system with the traditional single-level VRP in performance and efficiency, which can shows the feasibility and effectiveness of the Multi-Echelon VRP. Perboli et al. [8,9] derived new families of valid inequalities for the two-echelon vehicle routing problem, in order to more efficiently obtain better strength feasible solution. Therefore, this paper proposed a hybrid ant colony optimization algorithm for 2E-VRP.

2. Problem definition

Defined the central depot set V0={v0}, a set Vs of intermediate depots called satellite and customer set Vc, wherein each customer $i \in Vc$ has a positive demand di associated, the problem consists in minimizing the total transportation costs, calculated by considering arc costs cij for shopping goods from one point to the other of the transportation network, while satisfying the demand of all the customers with a limited fleet of vehicles. Differing the classical VRP, the freight stored in V0 must transit through intermediate depots, called satellites, and then be delivered to the customers. The demand of each customer has to be satisfied by only one satellite, and there are on thresholds on minimum and maximum number of customers served by a single satellite. This assumption induces, for each 2E-VRP feasible solution, a partition of Vc set in, at most, |Vs| subsets, each one referring to a different satellite. Customer-satellite assignments are not known in advance, not allowing to solve the problem by decomposition into |Vs| +1VRPs. Two distinct fleet of vehicles m1 and m2, with different capacity size K1 and K2, are available to serve first and second network level, respectively.

3. Hybrid ACO Algorithm

Our method (Hybrid ant colony optimization algorithm) has three phases. First phase, we apply throughout a separation strategy (distance-based cluster) splitting the problem into m+1 routing sub-problems (CVRP). Second phase, we proposed Improved Ant Colony Optimization with Multiple Neighborhood Descent (IACO_MND) to solve the m+1 sub-problem. This phase can obtain better feasible solution. Last phase, we proposed Threshold-Based Local Search (TLS) to improve the better feasible solution. Follow our paper will introduce the three phases detail.

The initial clustering is based on the direct shipment criterion, which assigns a customer to its nearest satellite in Euclidean distance. It can build the correspondence between satellite and customer. Other words, one customer only belong to one satellite, but one satellite can include multiple customers. Moreover, the assignment must be feasible with respect to the satellite's capacity constraints. If the assignment is not feasible, the customer is assigned to the second nearest satellite, and so on until a feasible assignment is found. It will split the problem into m+1 CVRP.

This phase, a hybrid heuristic algorithm IACO_MND is proposed and applied to solving the capacitated vehicle routing problem, which combines two meta-heuristics, i.e., Ant Colony Optimization [10-13] and Multiple Neighborhood Descent [14]. Several feasible solutions are built by an insertion based IACO solution construction method, which is taken as the initial solution of the MND procedure. During the MND procedure, three different neighborhood structures, i.e., insertion, swap and 2-opt are successively used.

First, we use the distance-based greedy algorithm to construct a better feasible solution s0. And setting initial pheromone according to equation $\tau_0 = f\left(s_0\right)/n$, where n is number of the customers.

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