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An Adaptive Large Neighborhood Search for the Hierarchical Vehicle Routing Problem

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1 Introduction

The Vehicle Routing Problem (VRP) is one of the most studied problems in combinatorial optimization. Among VRP's variants, we are interested in a class so-called "Vehicle Routing Problem with Priority Assignment" (VRPPA) where customers who require service are divided into different groups of priorities according to their requests, locations, inventory levels, etc. In the VRPPA, we focus on a VRP of Panchamgam in the context of humanitarian relief [2] in which vulnerable people in disaster is assigned into several priority groups and demand satisfaction for priorities are controlled by different rules. We extend this problem so that it becomes more flexible and can be applied even in non-humanitarian relief situations and we name it Hierarchical VRP (HVRP).

2 Hierarchical Vehicle Routing Problem

The HVRP includes a set $K = \{1, \dots, k_{max}\}$ of heterogeneous vehicles with limited capacities and travel distances, moving on a symmetric graph $G = (N, E)$ where $N = \{0, \dots, n\}$ is a set of nodes and $E = \{(i, j) : i, j \in N, i \neq j\}$ is set of edges. In N , node 0 represents depot while nodes $i = 1, \dots, n$ represent customers. Customers are divided into p_{max} groups, each group has a service level that is represented by a priority $p \in P = \{1, \dots, p_{max}\}$ where priorities in P are sorted in descending order. The objective is to maximize the total demand and minimize the total service time while satisfying all constraints and rules. We inherited three rules from the original study but two rules below are the most important:

Definition 1 *d-relaxed rule is represented by value d - a control parameter to relax service levels of customer groups. Indeed, the rule allows a vehicle from a certain node with priority p to visit any node with priority $q < p + d + 1$ and all nodes with priority p must be serviced earlier than any node with priority $q \geq p + d + l \forall l \geq 1$.*

Definition 2 *Order of Demand Fulfilment (ODF) rule guarantees service for the most urgent nodes by requiring in a solution, all nodes with priorities p to be serviced if there is at least one node with priority $p + 1$ already serviced.*

Panchamgam presented a special case of the HVRP - the Hierarchical Travelling Salesman Problem (HTSP) in an article without tests[3]. Recently, a study proposed a hybrid meta-heuristic called GILS-RVND to solve the HTSP [1]. This method combines three popular

metaheuristic: Greedy Randomized Adaptive Search (GRASP), Iterated Local Search (ILS) and Random Variable Neighborhood Descent (VND). To our knowledge, the publications on the HVRP are quite and only on the HTSP case, long computation time and small instances. This motivates us to study the HVRP with a quick reponse algorithm and acceptable results on different instance scales simulated from several real situations. With the already obtained results, we believe the ALNS algorithm can provide a reasonable balance for such requirements.

3 Adaptive Large Neighborhood Search (ALNS) and instance generation

We propose a ALNS algorithm with three new operators and some operators adapted from the previous studies. We also propose several improvements to reduce the runtime and improve the quality of results by applying local search in ALNS with additional methods to deal with the rules in $O(1)$ time. To generate new instances, we use basic CVRP instances [4] as a library. For each basic instance, we generate 4 new instances simulated from 4 disaster situations (earthquake, storm, flood, tsunami) and 1 new instance simulated from 1 non-disaster situation (random). The method used in disaster simulations can assign priority groups based on some characteristics of the disasters. We use 4 instance sets. Set 1 is adapted from the literature [1] to compare ALNS with GILS-RVND algorithm in the HTSP case while set 2, 3 and 4 are generated as stated above. Set 2 includes 5 small instances (under 100 nodes) to compare ALNS with CPLEX. Set 3 includes 50 instances (from 108 to 1001 nodes) to test HVRP with homogeneous fleet and HVRP in a special case when it is transformed into the CVRP. Set 4 includes 50 instances (from 106 to 289 nodes) to test HVRP with heterogeneous fleet.

4 Results

The results show that ALNS can achieved very good results in the first and the second sets. For the third and the fourth sets, we only present the results with runtimes because CPLEX cannot solve instances in reasonable runtimes. In most of the tests, the runtimes in our ALNS outperforms algorithms of the literature.

5 Conclusions

In this study, we propose a flexible model for the HVRP and a high performance ALNS algorithm. Results on 4 instance sets prove our algorithm can solve large instances in very short time with reasonable results.

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