A Randomized Multi-start Genetic Algorithm for the One-Commodity Pickup-and-Delivery Traveling Salesman Problem

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Abstract. The One-Commodity Pickup-and-Delivery Traveling Salesman Problem (1-PDTSP) is a generalization of the standard travelling salesman problem. 1-PDTSP is to design an optimal tour that minimizes the overall travelled distance through the depot and a set of customers. Each customer requires either a pickup service or a delivery service. We propose a Randomized Multi-start Genetic Algorithm (RM-GA) to solve the 1-PDTSP. Experimental investigations show that the proposed algorithm is competitive against state-of-the-art methods.

Keywords: One-commodity pickup-and-delivery TSP · Randomized multi-start optimization · Genetic algorithm

1 Introduction

The traveling salesman problem (TSP) is one of the most challenging NP-hard optimization problem. TSP has been widely studied in the fields of combinatorial mathematics [6], operational research [7] and artificial intelligence [1] due to its theoretical and practical significance. A more general extension of the TSP, called the One-commodity Pickup-and-Delivery TSP (1-PDTSP), is the focus of this paper. This variant was firstly evoked by Hernández-Pérez & Salazar-González, 2004 [3]. The 1-PDTSP variant is about seeking the shortest possible route that visits each customer exactly once and returns to the origin customer. A vehicle must either pick up or deliver known amounts of a single commodity to a set of customers. The collected goods from the pickup customers can be supplied to the delivery customers.

Due to its NP-hardness, the 1-PDTSP requires efficient approximate approaches to find the near optimal solutions in a reasonable amount of time. Several meta-heuristics have been proposed for the 1-PDTSP in the last 10 years. Hernández-Pérez et al. [2] combined the GRASP and VND as a hybrid approach for solving the 1-PDTSP. In GRASP/VND, the local search phase of GRASP has been replaced by a VND with two neighborhood structures (2-opt and 3-opt operators). The results showed that the GRASP/VND for 1-PDTSP

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is robust in terms of quality and computational effort. In Zhao et al. [8], Genetic Algorithm (GA) has been applied for the first time to 1-PDTSP. To construct the offsprings, a new pheromone-based crossover operator is used in the proposed GA. Experimentations showed that GA outperformed almost all larger instances as well as new best solutions are reached. More recently, Mladenović et al. [4] developed a general variable neighborhood (GVND) that improved the best known solutions in all benchmark instances. GVND is proved to be slightly better than GRASP/VND.

The goal of this research is to present an effective solution approach to deal with a TSP with pickup and delivery. The experimental results shows that the developed genetic algorithm is effective and very competitive compared to the other state-of-the-art methods. The remainder of this paper is organized as follows. In section 2, our GA meta-heuristic is described by given some pseudocodes, followed by computational results in Section 3. Conclusions are presented in Section 4.

2 Randomized Multi-Start Genetic Algorithm for 1-PDTSP

Genetic algorithm (GA) is a global search meta-heuristic belonging to the class of evolutionary algorithms, it is based on the principles of natural biological evaluation. The basic concept consists in starting with an initial population of random individuals. Each individual is a single possible solution to the problem under consideration and the population is the search space of the solutions. In each generation, the fitness of each individual is evaluated, and a the best individuals are then selected to be in the next population. Some other operators are considered in GA such as the crossover and mutation which are used where the individuals in the current population generate the offsprings. The selection, crossover and mutation is looped until a termination criterion is reached which is evaluated for each member of this population.

To improve the efficiency of GA for 1-PDTSP, in this paper, we proposed a randomized multi-start GA (RM-GA), which combines the advantages of GA in the search convergence and the randomized multi-start hill climbing strategy in escaping local optimality. The pseudo-code of RM-GA is depicted in algorithm 1.

3 Experimental Results

In this experiments, a benchmark dataset is used for evaluating the proposed RM-GA for 1-PDTSP. This tested instances have been obtained with a random generator similar to the Mosheiov [5] benchmark. The solution approach was built in Java and ran on a personal computer with 2.4 GHz $Intel^{®}$ $Core^{TM}$ processor, 4 GB RAM and Windows 7 as an operating system. This section experimentally evaluates the performance of the proposed RM-GA compared to Hybrid GRASP/VND approach of Hernández-Pérez et al. [2]. The GRASP/VND

Algorithm 1. Randomized Multi-start Genetic algorithm for the 1-PDTSP

Input: $cmd \leftarrow list\ of\ customers$
$C \leftarrow capacity$
Find the initial solution x
$x* \leftarrow x$
while terminate criterion t **do**
  $p \leftarrow$ Construct random population $(x*)$
  for $i < p_{size}$ **do**
    Select A_i as father individual and B_i as mother individual from p
    Crossover $x' \leftarrow A_i$ and B_i
    if x' is feasible and improves the best solution $x*$ **then**
      $x* \leftarrow x'$
    end if
  end for
  Mutate $x*$
end while
Output: Best tour

Table 1. Results on the benchmark instances; $n = 20$ and $Q \in \{10, 15, 20\}$

$Q = 10$			$Q = 15$			$Q = 20$		
Inst	H-best	RM-GA	Inst	H-best	RM-GA	Inst	H-best	RM-GA
A	4963	**4963**	*A*	-	4085	*A*	3816	**3816**
B	4976	**4976**	*B*	-	4309	*B*	4224	**4224**
C	6333	**6333**	*C*	-	5121	*C*	4492	**4492**
D	6280	**6280**	*D*	-	5470	*D*	4706	**4706**
E	6415	**6415**	*E*	-	5658	*E*	4673	**4673**
F	4805	**4805**	*F*	-	4352	*F*	4118	**4118**
G	5119	**5119**	*G*	-	4538	*G*	4369	**4369**
H	5594	**5594**	*H*	-	4564	*H*	4159	**4159**
I	5130	**5130**	*I*	-	4117	*I*	4116	**4116**
J	4410	**4410**	*J*	-	3977	*J*	3700	3703

results are directly extracted from the original paper. Tables 1, 2 and 3 report the minimum total cost obtained for our proposed RM-GA with comparison to the state-of-the-art algorithm. In all tables, the columns n, $Inst$, q and H-best represent respectively, number of customers, name of instance, capacity of vehicle and GRASP/VND solution.

For the first subset of instances, shown in table 1, we reached the best solution found in Hernández-Pérez et al. [2] for almost all instances where $Q = 10$ and $Q = 20$. Table 2 show that we found the H-best in 67% of cases. From table 3, we can conclude that our approach performs better for the large scaled instances. In table 3, we reached H-best in 90% of instances.

Table 2. Results on the benchmark instances; $n = 20$ and $Q \in \{25, 30, 35\}$

$Q = 25$			$Q = 30$			$Q = 35$		
Inst	H-best	RM-GA	Inst	H-best	RM-GA	Inst	H-best	RM-GA
A	3816	**3816**	*A*	3816	**3816**	*A*	3816	**3816**
B	4224	**4224**	*B*	3942	3942	*B*	3942	3942
C	4492	**4492**	*C*	3989	3990	*C*	3897	3900
D	4706	**4706**	*D*	4112	4113	*D*	3743	**3743**
E	4673	**4673**	*E*	4381	44390	*E*	4299	**4299**
F	4118	**4118**	*F*	4118	**4118**	*F*	4118	**4118**
G	4369	4370	*G*	4248	**4248**	*G*	4248	**4248**
H	4159	4160	*H*	4007	**4007**	*H*	4007	**4007**
I	4116	4116	*I*	4026	**4026**	*I*	4026	**4026**
J	3700	3703	*J*	3678	**3678**	*J*	3678	**3678**

Table 3. Results on the benchmark instances; $n = 20$ and $Q \in \{40, 45, 1000\}$

$Q = 40$			$Q = 45$			$Q = 1000$		
Inst	H-best	RM-GA	Inst	H-best	RM-GA	Inst	H-best	RM-GA
A	3816	**3816**	*A*	3816	**3816**	*A*	3816	**3816**
B	3942	**3942**	*B*	3942	**3942**	*B*	3942	**3942**
C	3897	**3897**	*C*	3897	**3897**	*C*	3897	**3897**
D	3743	3744	*D*	3743	3744	*D*	3743	3744
E	4299	**4299**	*E*	4299	**4299**	*E*	4299	**4299**
F	4118	**4118**	*F*	4118	**4118**	*F*	4118	**4118**
G	4248	**4248**	*G*	4248	**4248**	*G*	4248	**4248**
H	4007	**4007**	*H*	4007	**4007**	*H*	4007	**4007**
I	4026	**4026**	*I*	4026	**4026**	*I*	4026	**4026**
J	3678	**3678**	*J*	3678	**3678**	*J*	3678	**3678**

4 Conclusion

In this paper, we addressed the 1-PDTSP which concerns with finding a feasible vehicle route with the optimal traveling cost, such that each customer requires either a pickup service or a delivery service. To handle the 1-PDTSP, we proposed a Randomized Multi-start Genetic Algorithm (RM-GA). The experimental results showed that RM-GA is competitive compared to the other existing method.

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