Double Genetic Algorithm for Vehicle Routing Problem

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Abstract. A Vehicle Routing Problem (VRP) is a combinatorial problem that seeks the optimal set of routes for a fleet of vehicles delivering a set of shipments to customers. This problem is very important for the logistics industry. Optimizing delivery routes can cut costs by up to 25%. The following paper proposes an algorithm that allows calculating routes that are close to the optimal ones for routes consisting of 100 destination points. The proposed algorithm is a combination of two genetic algorithms. The first part is an external algorithm to assign target points to each vehicle. Then, for each vehicle, an internal genetic algorithm is applied, which, within a single vehicle, determines the shortest route between the parcels to be delivered.

Keywords: Vehicle Routing Problem · Genetic Algorithm.

1 Introduction

One of the most frequently chosen optimization transport problems is the Vehicle Routing Problem (VRP) which uses more than one vehicle which has the beginning and the end of their route at the same point. For the first time, the solution algorithm of this problem was described by Dantzig and Ramser in 1959 [1].

This issue can easily be translated into a real problem which can be defined as a company that provides its customers a certain amount of homogeneous goods every day. The main company reason is to deliver the assumed amount of goods to each of the customers, meeting the following conditions: each customer receives exactly the amount of goods they need, the quantity of well-delivered by each vehicle may not exceed its capacity, each customer can be visited only once, the sum of the route costs of all vehicles used should be as low as possible [2].

This aim of the paper is to analyze the vehicle routing problem using a double genetic algorithm (internal and external) and to compare the results of changing the number of points and the number of goods to be collected from reloading points.

The paper is divided into 3 sections, each of which describes a different topic. After the introduction, in section 2 there is a description of the genetic algorithm implemented for VRP. The proposed algorithm is a combination of two genetic algorithms. The first part is an external algorithm to assign target points to each vehicle. Then, for each vehicle, an internal genetic algorithm is called, which determines the shortest route between the shipments to be delivered within a single vehicle. The most important is section 3, where there are described experiments and discussion of results..

2 Genetic Algorithm for Vehicle Routing Problem

Work on evolutionary systems, which genetic algorithms are part of, began in the 1950s. Based on evolution strategies, a group of researchers from the University of Michigan developed in the 1960s and 1970s the idea of genetic algorithms (GA) [3]. In contrast to research on evolutionary programming, the general idea was to explore adaptation based on nature observations and a way to incorporate that knowledge in machine processing.

Selection ensures that the strongest individuals understood as better solutions, have a larger probability to produce offspring [4]. Offspring, on the other hand, is generated by reproduction, which takes the form of crossing bits of one solution with bits of another one [6]. Finally, the randomized mutation is introduced, usually in form of swapping two bits, or negating just one of them in an individual in the whole population [5].

The classical approach to Genetic Algorithms is not valid for sequential problems such as Vehicle Routing Problem. The main problem is that a single solution cannot be represented as a set of bits. The proper encoding of a solution is a string of integer numbers, representing vertices of a problem-space graph [7].

We divide the issues of the VRP problem into the *external* algorithm were optimizing the placement of destination points for delivery vehicles and the *internal* algorithm was optimizing the route of the delivery vehicle.

The internal algorithm consists of three steps:

1. *Coding.* The adaptation of genomes of solutions to the VRP problem is being implemented as a list of delivery points for a given vehicle.
2. *Crossover.* Then the elite selection method is used with the adaptation function. Then the chosen ones are matched in pairs and crossed. At the very end, the process of mutation takes place.
3. *Function of adaptation.* The following rule applies here: the smaller the value of the fitness function, the less adaptation. It computes for everyone's destination point the distance between the next point on the list. Next, it is checked whether the current duration of the vendor's work is added to the distance covered in a given iteration. If the condition is true, the huge number is returned as an adaptation. After visiting all points on the road, you are returned is the value of the fitness function, which is the sum of the distance traveled from the starting point to the first point, distance traveled between all points and the distance from the last point to the starting point.

The external algorithm also consists of three steps:

1. *Coding.* The adaptation of genomes of solutions to the VRP problem creates a route list for a given vehicle.

2. *Crossover*. Then follows the elite selection method is used with an adaptation function. The selected route genomes are then paired and crossed. In the end, the process of mutating is realized.
3. *Function of adaptation*. The following rule applies here: the smaller the value of the fitness function, the less adaptation. In the beginning, a fleet of suppliers is created equal to the number of possible routes. Then it is checked whether any of the vehicles have failed contain loads exceeding the vehicle's capacity by weight. If such a case does not occur, the internal algorithm described is triggered above. Otherwise, the fleet returns a large number indicative of poor adjustment.

The above algorithms work in loops with a given number of iterations. In the end, the adaptation of the best supplier fleet is returned.

3 Experiments

The experiments were performed in the study, to determine the optimal algorithm parameter values. It was tested on and verified on Solomon benchmark data sets: population size of the external algorithm and population size of the internal algorithm.

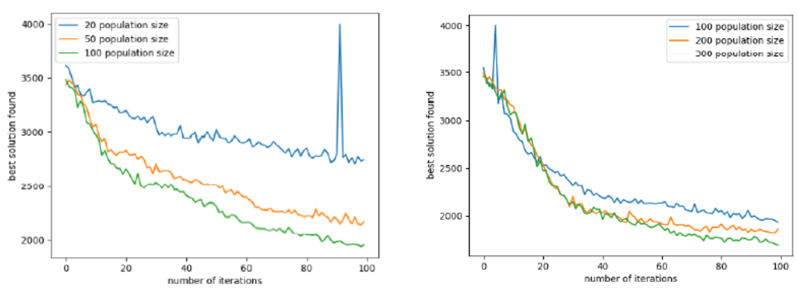

Fig. 1. Effect of the *external* algorithm's population size on the result.

There was a clear correlation between the size of the population and the quality of the results (Fig. 1). However, this parameter is also linearly correlated with the execution time algorithm. To optimize the execution time, the algorithm was determined at a value of 200 for the external algorithm population because above these values, only a slight increase in the quality of the results was observed.

There was a clear correlation between the population size of the internal algorithm with the quality of the results, however, this parameter is also linearly correlated with the execution time of the algorithm (Fig. 2). The above-mentioned correlation was also found parameter to the maximum achievable result. This relationship is because the higher population of the internal algorithm allows for finding optimal solutions for cars with a larger number of assignments points.

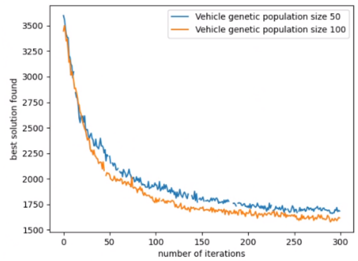

Fig. 2. Influence of the *internal* algorithm's population size on the result.

4 Summary

In experiments there were found the suitable parameters' values for *external* and *interneal* genetic algorithm. The results showed that the optimal parameters for the presented algorithm are: external algorithm population is equal to 200, internal algorithm population is equal to 100. Next, these values were used to check the correctness of results of benchmark data – the result are promising and worth further research. These experiments showed that the double genetic algorithm can be used to solve the VRP problem.

References

1. Dantzig, G.B., Ramser, J.H.: The Truck Dispatching Problem, Management Science **6(1)**, (1959)
2. Ji, X., Yong, X.: Application of Genetic Algorithm in Logistics Path Optimization. Academic Journal of Computing & Information Science, **2**, pp. 155-161 (2019)
3. Mitchell M.: An Introduction to Genetic Algorithms, MIT Press (1998)
4. Ochelska-Mierzejewska, J., Poniszewska-Marańda, A., Marańda, W.: Selected Genetic Algorithms for Vehicle Routing Problem Solving. Electronics **10(24)**:3147 (2021) https://doi.org/10.3390/electronics10243147
5. Ochelska-Mierzejewska, J., Zakrzewski, P.: Comparison the Genetic Algorithm and Selected Heuristics for the Vehicle Routing Problem with Capacity Limitation. In: Kryvinska N., Poniszewska-Marańda A. (eds) Developments in Information & Knowledge Management for Business Applications. Studies in Systems, Decision and Control, **377**, Springer, Cham (2022) https://doi.org/10.1007/978-3-030-77916-0_10
6. Saxena, R., Jain, M., Malhotra, K., Vasa, K.D.: An Optimized OpenMP-Based Genetic Algorithm Solution to Vehicle Routing Problem. In: Elci, A., Sa, P., Modi, C., Olague, G., Sahoo, M., Bakshi, S. (Eds.): Smart Computing Paradigms: New Progresses and Challenges. Advances in Intelligent Systems and Computing, **767**, Springer (2020)
7. Toth, P., Vigo, D.: The Vehicle Routing Problem. Monographs on Discrete Mathematics and Applications, SIAM, Philadelphia (2001)