Design and Development of a Genetic Algorithm for the Distance Constrained Vehicle Routing Problem with Environmental Issues

[Extended Abstract]

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ABSTRACT

Within the vehicle routing problem literature, the distance constrained vehicle routing problem (DCVRP) has its is importance due to its practical relevance of logistics operation. However, the DCVRP with the objective of minimizing the total traveling distance fails to meet the recent concerns about the environmental issues related to green logistics. This work tries to focus on DCVRP from its environmental perspective and proposes a Genetic Algorithm (GA) to solve it. A real world application related to DCVRP is presented and used to test our approach.

Categories and Subject Descriptors

F.2.2 [**Artificial intelligence**]: Problem Solving, Control Methods, and Search—*Heuristic methods*
; H.4.2 [**INFORMATION SYSTEMS APPLICATIONS**]: Types of Systems—*Logistics*

Keywords

Green logistics ; Environmental influence ; Routing ; Heuristic ; Vehicle Routing Problem

1. INTRODUCTION

Recently and due to global environmental deterioration, reaching sustainability has becoming a vital issue for humans in both economic and societal dimensions.

On the other hand, the vehicle routing problem (VRP) have been extensively studied in the literature [3]. The basic objective of VRP is to deliver a set of goods to a set of geographically dispersed customers while minimizing the transportation costs.

GECCO'15 Companion, July 11-15, 2015, Madrid, Spain

ACM ISBN 978-1-4503-3488-4/15/07.
DOI: http://dx.doi.org/10.1145/2739482.2764893

Among the different extensions of VRPs, distance constrained vehicle routing problem (DCVRP) is one of the less studied problems in the literature [1]. The DCVRP is a VRP problem where distance constraints are imposed on its routes. However as kara state [2], the literature related to this problem is still scarce. Classic DCVRP is designed with the economic objective of minimizing the total travel cost. Nevertheless, one could put a special focus on studying DCVRP while considering its related environmental dimension.

In this research, we focus on the DCVRP while considering CO2 emissions. In contrast to the classical DCVRP, the objective of our studied problem is to find the optimal solution with minimum environmental impact in terms of minimizing CO2 emissions. This latter represents a new search directive and an interesting problem to study and enrich existent works as the literature on DCVRP is still scarce [2].

The contribution of this work is twofold. First, we introduced a distance constrained vehicle routing model taking into account of the environmental aspect of the problem. The environmental aspect in our model is presented in terms of the emission of CO2. Second, a genetic algorithm (GA) is proposed as an effective and efficient solution approach to solve the proposed problem.

The rest of this paper is organized as follows. We propose the model formulation of our problem in Section 2. Our developed GA is proposed in Section 3 . In Section 4, we present the preliminaries computational results of our algorithm. Finally, the conclusions and further work are drawn in section 5.

2. PROBLEM MODELING

DCVRP is normally modeled on a graph, which comprises a set of nodes and the associative edges. In our work, the scenario of single depot and asymmetric network is adopted, which means all the vehicles depart from and return to the same depot and the route between any two nodes contains different directional information. In detail, node $i = 0$ is the depot, and the other nodes $i = \{1, 2, ..., n\}$ represent customers. The distance between node i and node j is represented as $d_{ij}(i, j \in V, i \neq j)$, and the asymmetric network indicates that the distance $d_{ij} \neq d_{ji}$. Vehicles with same maximum allowable distance Δ are available initially in the depot. The traveling cost between two customers i and j is illustrated as c_{ij}. $c_{ij} = \alpha d_{ij}$. α represents the proportion between the traveling distance and the economic cost. This formulation allows as to model a DCVRP with the objective of minimizing the total traveling distance.

2.1 Environmental issues for DCVRP

The critical issue in our research is to measure the amount of CO2 emission. In this research, we use γ_{ij} to denote the amount of CO2 emission when a vehicle travels from customer i to customer j. The objective of the treated problem is to find the optimal routes with the least CO2 emissions. In our work, we consider that CO2 emissions are caused by the fuel 'consumption of vehicles. We consider that the fuel consumption (FC) is determined by the traveling distance and the load of vehicles. In order to calculate the carbon emissions, we adapt a linear expression between the FC ,the traveled distance and the weight of vehicle, and integrate it into our model.

$\gamma_i j$ = emission rate $*$((fuel consumption while traveling empty between i and j)+ ((Max fuel consumption$-$ fuel consumption while traveling empty between i and j) /Load of vehicle)) $*d_{ij}$.

This function ensures that the carbon emissions are related to the weight as well as the distance of the traveled trips.

3. GA AS A SOLUTION APPROACH

We use a typical GA to solve the problem. Different features need to be defined when developing a GA. Among these feature one could consider solution representation, fitness function, crossover and mutation operator, etc. As solution representation, we used a simple permutation representation in which a solution is represented by an array of customers to visit in order. As an evaluation function, we used the Split function of Prins used initially for evaluating permutations for the CVRP. We adapted this function in order to determine the best routing solution adapted to our problem starting from a given permutation. More details about this function could be found in [6]. As for crossover operator, we used the one-point crossover where a single randomly chosen cross point is chosen and customers before the crosspoint are copied from the first parents to the offspring and customers after the crosspoint are copied from the second parent. As for mutation operator, we choose to adapt the insertion mutation operator where a randomly selected customer is selected and inserted in a new randomly selected position.

4. COMPUTATIONAL RESULTS

In order to test our algorithm for the minimization of environmental issue in DCVRP, we adapted a recent developed application of DCVRP for routing electric vehicles in urban context to serve a set of passengers' requests. The problem was studied by Mrad and Hidri [5] and Mrad et al [4]. This problem aims to reduce the total distance traveled by a set of electrical vehicle under battery constraints. The battery constraints represent the maximum allowable distance for the DCVRP. We adapt to our context this problem as it represents a real case application of DCVRP and a very recent problem to deal with. We should note that we used this real case application of DCVRP as there is available data related to carbon emission in this system [1]. We used an adapted real use case from the literature available in [7] to generate a set of 12 instances. The size of the instances was considered to be 100 customers to serve. We used this use case as it represents a real world application of our problem.To evaluate the obtained results, we used the GAP metric expressed as the percentage of deviation of the obtained solution by GA relative to a specific lower bound computed using a linear relaxation of a valid mathematical formulation [5] and the computational time in seconds. For the total tested instances, we obtained an average GAP of 6.86% in 1.72 seconds. This latter represents a very promising results. We should note that for the different instances the smallest gap was below 4.22% which is considered as good result. Another important feature could be turned to the computational time as it was below 2 seconds. This feature makes our GA a very powerful tool to solve real world application of DCVRP in small computational time.

5. CONCLUSIONS AND FUTURE WORKS

This research examines the DCVRP from an environmental perspective and proposes a new model of minimizing the carbon emissions in the context of VRP. In this research, a GA was adopted to solve this problem. Numerical experiments proved that our GA finds good solutions in small computational time. Further research should be conducted in at least two directions. We could develop a more enhanced meta-heuristics such as bee colony, ant colony, and particle swarm optimization to solve our problem and find better solutions. We could apply also this new model into another practical case of DCVRP such as in logistics or military operations.

6. REFERENCES

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