Solving modular electric vehicle routing problems by a decomposition technique and a genetic algorithm

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1 Introduction

This paper aims at promoting the use of electric vehicles for urban freight distribution. More precisely the light duty vehicles considered in this study are modular as an alternate and promising new mode of goods transportation. They can be split into several modules that can be left at specific locations for charging purposes or to gain agility. The aim of this work is to prove that managing a fleet of such modular electric vehicles for urban goods delivery brings added-value as compared with the management of a fleet of equivalent capacitated light duty vehicles. It is a completely new challenging problem which does not exist in the literature [1] and combines both the complexity of a classical VRP with the constraints related to the use of electric and modular vehicles in urban environment. Formally, the problem can be stated as follows: given a set of customers with demands for pick-up and delivery of their commodities, and a set of at most a given number N of modular electric vehicles departing from a localised depot, the problem is to design at most N routes ending at this depot, such that all requests are satisfied and the payload of each vehicle as well as the overall capacity of the fleet is respected. The objective is to minimize the overall transportation costs both economic and environmental. Solutions have to satisfy constraints such as time windows when visiting customers, the possibility for a vehicle to release a payload module at a charging terminal and the ability for another vehicle to collect it before returning to the depot, benefiting from the additional recharged battery.

2 Combining a decomposition approach with metaheuristics

The main contribution of this paper is concerned with metaheuristic approaches. More precisely, the solving procedure consists in decomposing the problem into two subproblems that are solved using hybrid genetic algorithms as illustrated in the figure below.

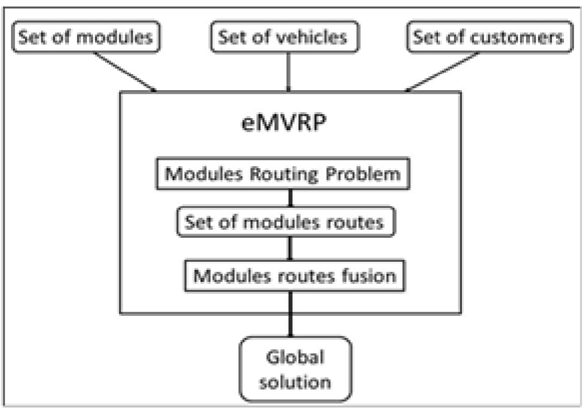

Figure: Decomposition technique for modular electric vehicle routing problems

Modules Routing Problem

The first solving step consists in allowing the customers to be serviced by the modules. This step can be considered as a reduction of the initial problem to a classical VRPTW which is called MRP for modular routing problem. The MRP is solved using an ad hoc genetic algorithm including a brand new and efficient modelization of the solution. In most of the metaheuristics used in the literature for solving VRPTW, a solution is represented by a set of lists of customers, each list being a vehicle route which starts and ends by the depot. In this work, the solution is retrieved via the parameters which were used at each iteration by the insertion heuristic that constructs the solution.

Modules Routes Fusion

In a second phase, the problem is to fusion the resulting modules' routes to allocate the modules to the different vehicles. This leads to design the vehicles' routes, which consists in a MRF for Modules Routes Fusion. An iterative procedure based on a genetic algorithm has been then used for this second solution phase. A taboo search method is used for the mutation operations. At each iteration corresponding to a time t included in a given time window, an assignment of candidate vehicles which run between two customers is decided. The set of the decisions which have been taken at each iteration constitutes the solution to the problem.

The assessment of the iterative algorithm used for this second step calculation is based on its ability to exploit the modular structure of the vehicles. This ability can be measured by comparing the results obtained with electric modular vehicles with the ones of a standard VRP with time windows. To enable these comparisons, the tests on the VRP with time windows are performed with vehicles which have three times the capacity of a module. Indeed, the electric modular vehicle considered in this study can carry up to three modules.

Benchmark		**VRPTW**		**VRP-eM**	
Name	***Number of customers***	***Number of vehicles***	***Total distance***	***Number of vehicles***	***Total distance***
C101	100	10	878,36	8	884,86
C105	100	10	828,7	7	991,36
C109	100	10	832,7	7	976,88
RC101	100	15	1787,39	10	1827,4
RC109	100	13	1381,31	11	1392,2
C1_2_1	200	20	3503,84	15	3740,15
C1_2_2	200	27	4531,8	20	4699,22
C1_2_3	200	23	3902,48	16	4037,54
C1_2_5	200	20	3525,93	15	3642,31
C1_4_1	400	40	9693,75	29	9878,41
C1_4_3	400	49	12127,06	36	12519,94

The results obtained with the iterative algorithm on benchmark instances [2] spread from 100 customers to 400 customers are promising. Indeed, the number of modular vehicles needed to perform the deliveries decreases in average by 43 % as compared with classical vehicles, which can lead to huge cost savings. These results clearly shows that to perform daily deliveries, less electric modular vehicles are needed than classical light duty vehicles which can cost lower when taken individually but cost more when dealing with a bigger fleet of operating vehicles.

References

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