Operations Research

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A new proposal to solve E-VRPTWRS

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1 Introduction

The Electric Vehicle Routing Problem with Time Windows and Recharging Stations (E-VRPTWRS) is a variant of the classical VRP. It adds some constraints to the availability of the nodes (time windows) and also includes a new parameter, called battery level, which forces to choose a set of recharching stations while delivering to customers along the route.

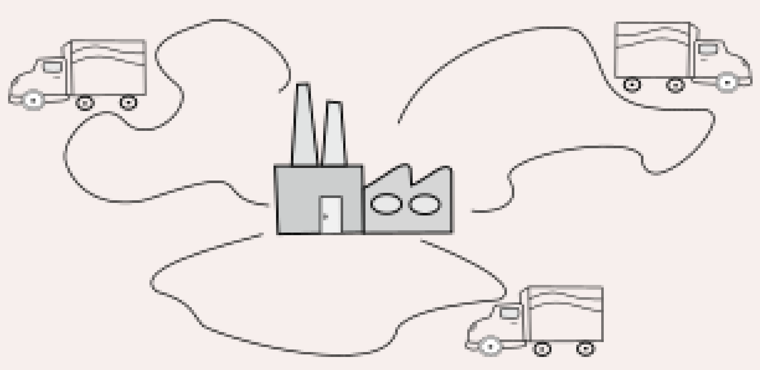

Figure 1: Vehicle Routing Problem.

Some algorithms found in literature that provide a solution to this problem are B&B (Branch and Bound) , heuristic and meta-heuristic methods. However, these that seek an approached solution are preferred over those that search the exact one, since the complexity and thus the computational cost is smaller.

2 Choquet Integral

Choquet Integral is a fundamental tool when dealing with multi-criteria optimization. In this problem, it has been used to select the best routes regarding a set of *criteria* (total traveled distance, node arrival date, battery level...). Firstly, it estimates a score for each route as an aggregation of these measured criteria; and then orders the routes by their scores. The dependencies/relations among these criteria (called *capacities*) play an important role: they dictate which are the most important criteria in order to find the optimal solution.

The integral can also be seen as an arithmetic mean of criteria being the capacities the weights of each measure.

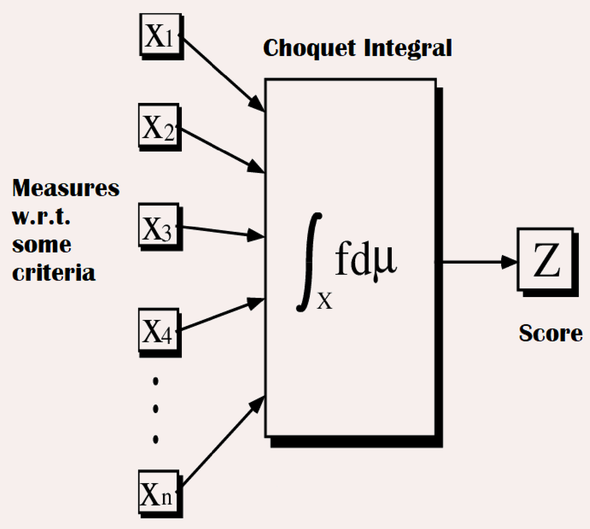

Figure 2: Choquet Integral Model.

3 Description of the algorithm

In this internship, the main objective was to improve a column generation method, which created all the possible routes and then combined them such that all clients were served. Routes can be seen as vehicles, and a combination of routes is indeed a fleet of vehicles. The constraint is that all clients must be served. We call the part which creates all the possible routes *subproblem*, and the one that combines them, *main problem*.

In the original algorithm, among all feasible combinations the one with least number of vehicles and shortest total traveled distance was chosen as solution. However, creating all the possible paths was, under some circumstances, hardly endless. So, in order to cut back the algorithm's complexity, Choquet Integral has been applied with the following criteria:

- Total Distance per number of clients served.
- Total Time per number of clients.
- Total Distance per number of nodes.

Furthermore, if we want to arrive to an optimal solution specifically for each instance (problem data), it is necessary to determine which criterion is most relevant in each case. That is where the capacities intervene. The optimal capacities are those ones who lead to a global optimal solution of the problem.

These optimal capacities are obtained by means of a meta-heuristic algorithm, in this problem a *simulated annealing* algorithm has been used.

Thus, some examples of solutions to our problem are presented. In the plot, it is possible to see the set of nodes visited by the vehicle during one journey. Blue nodes represent the clients, red ones represent the recharging stations and the yellow time frames constitute the travel time between two nodes. Also, red line shows the battery level during the day for each vehicle.

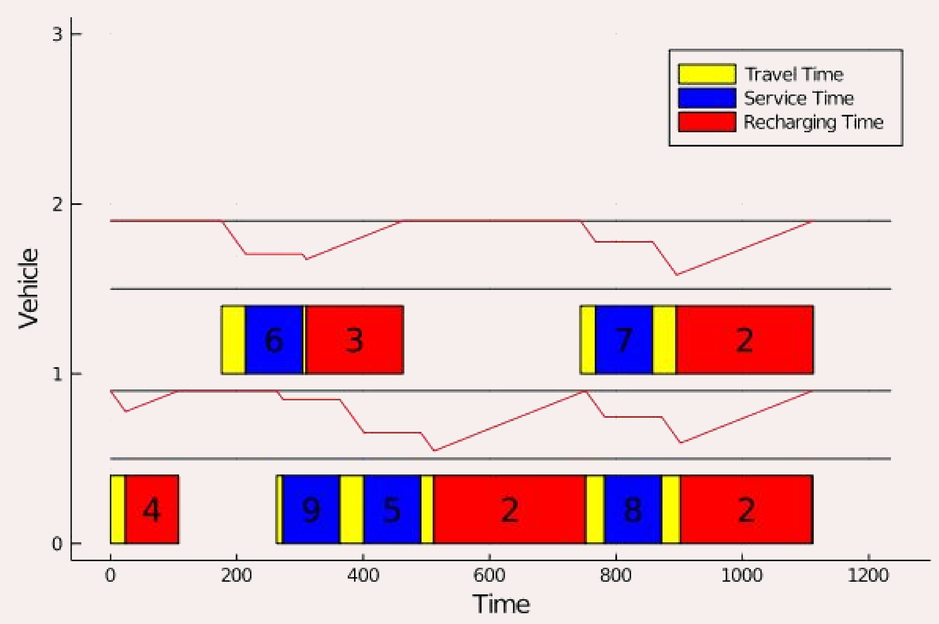

Figure 3: E-VRPTWRS Solution Example 1.

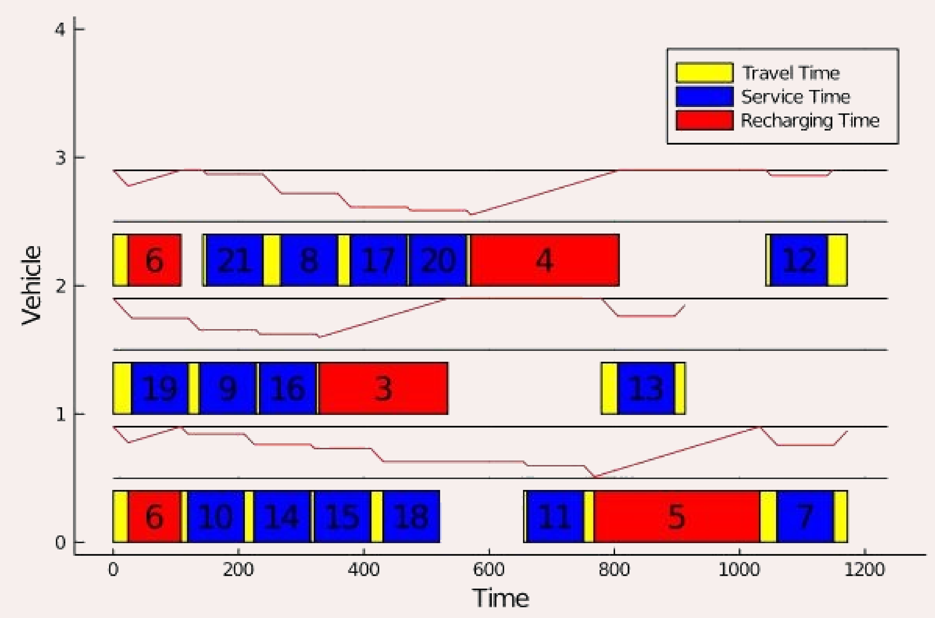

Figure 4: E-VRPTWRS Solution Example 2.

If you want to learn more about this project, about how to apply Choquet Integral or the E-VRPTWRS, you can consult the internship report by scanning this QR code: