An Algorithm for the Electric Vehicle Routing Problem with Nonlinear Charging Process

Mhand Hifi$^1$, Shohre Sadeghsa$^1$, Labib Yousef$^1$

Unité de Recherche EPROAD, Université de Picardie Jules Verne
7 rue du Moulin Neuf - 80000 Amiens, France
{surname.name}@u-picardie.fr

Mots-clés : Electric vehicle routing, heuristics, variable neighborhood

1 Introduction

Electrical vehicles are the new generation of the transportation after conventional gas or diesel powered vehicles. Since the majority of the existed cars on the road belong to companies, their transportation fleets may have the most environmental impact. Recently, several companies (Unilever, Ikea, Germany’s Deutsche Post DHL Group ...) are committed to shift their transportation fleet from gas and diesel-powered transportation to electric vehicles. Other companies have also planned such a passage for the next years (Fairley [1]).

Although the use of electrical vehicles is increasing due to their functionalities, technical construction of electrical vehicles is still hampered. Evident technical limitations of electric vehicles are limited battery capacity, charging times and short driving ranges. For this reason and also as other optimization problems inspired by practical applications, the operations research community recently started to study such a family of vehicle routing problems; that is the so-called electric VRPs (noted E-VRPs) (Montoya et al. [2]).

Herein, we propose a Variable Neighborhood Search (VNS) based meta-heuristic for solving the E-VRP with nonlinear charging function. Such a problem has been already studied in Montoya et al. [2], where the authors considered the nonlinear behavior of the charging process using the piecewise approximation function.

2 The problem studied – electric vehicle routing problem

An instance of E-VRP is characterized by a complete directed graph $G(N, E)$, where $N$ denotes the set of nodes which includes customers, available charging stations and depot(s). Each customer has a service time $P_{ij}$ and the charging time in the charging stations which is a decision variable. Each charging station can serve unlimited number of electric vehicles (noted EVs) simultaneously. Let $E = \{(i, j) : i, j \in N, i \neq j\}$ be the set of edges, where each edge connects two nodes and has both specific time and energy consumption. There are unlimited homogenous EVs and the number of EVs are also considered as a decision variable. Each EV has a battery capacity of $Q$ with limited travel time of maximum time $T_{\text{max}}$. It is assumed that each EV will leave the depot with fully battery charge and can return to the depot with zero battery. In a feasible solution all the customers are visited exactly once and each vehicle starts and ends at the depot. Hence, the objective is to minimize both travel and charging times that respect the maximum travel time and, the maximum battery capacity for each vehicle.

The charging process is related to the infrastructure of all charging stations; that is associated with the charging rate and thus the slope of the charging function. Each charging station has different charging function, which in our study we assumed it to be with slow, moderate or fast slope. Let’s define $Q_i$ as the battery level when the vehicle arrives at the time $S_i$ whereas $O_i$ the battery level of vehicle when it leaves the station at time $D_i$. Then, the charging process is consists of two parts. The first part is with the linear segment and the second part with the concave segment. In piecewise linear approximation function the function of the charging
process is approximated with the set of the break points. Break points are defined with the correspond time and charging level. Piecewise linear approximation function divides the function of charging in different segments. Each segment starts and ends with a breakpoint which is connected with a straight line. Therefore the slope of each segment will be constant.

3 Solution method

Both VRP and E-VRP are NP-hard and their resolution is very complex, especially when their resolution are tackled with exact methods. Therefore, we propose to approximately solve E-VRP by using a meta-heuristic which combines three stages : - Starting solution : GRASP (Feo and Resende [3]), used a the first stage of the method, which serves to build a random solution with respect to the maximum travel time $T_{\text{max}}$. In this case, the tour only respects the maximum time and doesn’t visit any station.
- Feasibility procedure : the aim of the second stage is to build feasible solutions by introducing the travel time limit. Indeed, it tries to insert stations into each sub-tour with respect to the maximum travel time limit, in order to induce the energy feasible solution.
- Enhancing procedure : Once a feasible solution is obtained, the third stage is applied in order to intensify / diversify the search process. We do it by applying six well-known neighbors operators, like 2-opt, exchange, etc.

Note that, on the one hand, the first three neighbors operators (of the last stage) try to insert and remove nodes in the single tour as follows : (i) remove and insert a single node in a single tour, (ii) reverse the order of the visited nodes in a single tour and, (iii) remove and insert a group of nodes in a single tour. On the other hand, the rest three neighbor operators insert and remove nodes in multiple tours as follows : (i) remove a node from a tour and insert it in another one, (ii) swap a node from a tour with a node from another tour and, (iii) swap a group of nodes from a tour with a group of nodes from another tour.

4 Preliminary experimental part

This part was conducted on a set of instances extracted from Montoya et al. [2]. The purpose of this section is two-fold : (i) to show how to determine a good trade-off between the quality of the obtained bounds when using the six neighbor operators and (ii) to evaluate the effectiveness of the proposed method when its achieved results are compared to those reached by one of the best available method in the literature.

For this preliminary experiment, the proposed method matches all bounds of the literature by consuming a less average runtime. Hence, we intend to extend the diversification strategy in order to better explore the space search related to both feasible and unfeasible solutions.

5 Conclusion

A first version of the variable neighborhood search was proposed for approximately solving the electric vehicle routing problem, where the method exploits some specific properties of the electric cars. In the preliminary computational results, the proposed method (on several tested instances) showed that its achieved bounds matched several better available bounds and is able to provide new other bounds.

Références

