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ROUTE OPTIMIZATION FOR A BEER DELIVER DECISION SUPPORT SYSTEM

OPTIMIZACIÓN DE RUTA PARA UN SISTEMA DE APOYO A LA TOMA DE DECISIONES EN LA DISTRIBUCIÓN DE CERVEZA

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Abstract: In this paper we present a brief literature review on routing problems and decision support systems for fleet management. Problems such as the Travelling Salesman Problem and the Vehicle Routing problem are presented along with their most common solution methods. We also propose a decision support system prototype for the fleet management of a beer delivery organization.

Keywords: travelling salesman problem; vehicle routing problem; decision support systems.

Resumen: En este artículo se presenta un breve repaso de la literatura sobre problemas de enrutamiento y sistemas de apoyo a la toma de decisiones en la gestión de flotas. Se presentan problemas como el Problema del Vendedor Viajero y el Problema de Enrutamiento de Vehículos junto con sus métodos de solución más comunes. También proponemos un prototipo de sistema de apoyo a la toma de decisión para la gestión de flotas de una organización de reparto de cerveza.

Palabras clave: problema del vendedor viajero, problema de enrutamiento de vehículos, sistema de apoyo a la decisión.

1 Introduction

Nowadays, the fleet management systems incorporate a wide variety of integrated technologies to potentiate an extensive set of functionalities, such as, operations planning, routing, scheduling, tracking, diagnosis, management and many others. The response to transportation requests made by a fleet of vehicles are wellknown problems in the literature. These kind of problems usually fit in one of two large groups: Vehicle Routing Problem (VRP) and Arc Routing Problem (ARP). The first group, VRP, represents the problems of traversing a set of specific points, which means that the demand is spread along the nodes of a graph [12]. The second, ARP, represents the problem of traversing several arcs of a graph [12]. In this paper we will focus our study on the Travelling Salesman Problem (TSP) and VRP. We will also present a Decision Support System prototype to the fleet management of a beer delivery organization.

The VRP was first introduced in the literature under the name Truck Dispatching Problem by Dantzig and Ramser (1959) [3] in the context of the optimization of the gasoline delivery, made by a fleet of homogeneous trucks, between a terminal and several service stations. In that paper, the problem was presented as a generalization of the classical TSP, therefore it makes part of the NP-Hard problems, in terms of computational complexity. In the past 50 years enterprises and academy gave an increasing attention to these kind of problems. A lot of effort was made to approximate the theoretical concepts to the real world problems, resulting in a wide range of solution methods applied to a lot of variations of the original VRP. The following sections of this article are organized in the following way: A brief review of the TSP and

Multiple Travelling-Salesman problem (mTSP); the VRP; Decision support system prototype architecture, usability and results.

2 Routing Problems

2.1 Travelling salesman problem

Conceptually, the TSP is the problem of finding the shortest route that visits once, and only once, a set of cities, given the distance between each pair of cities and returns to the origin city [7]. It was first formulated in 1800 by the mathematician William Rowan Hamilton in the context of the Hamiltonian cycle a cycle in a graph that visits each vertex exactly once. The general TSP mathematical formulation was first presented in 1930 by Merrill Flood on his work to solve the school bus routing problem. A mathematical formulation for the TSP is presented on equation 1. Cities are identified with the numbers 1, …, n where x_{ij} is the path from a city i to city j if x_{ij} = 1 and c_{ij} > 0 is the distance from city i to city j.

$$\begin{aligned} \text{Minimize} \quad & \sum\nolimits_{i \neq j} c_{ij} x_{ij} \\ \text{subject to} \quad & \sum\nolimits_{j=1} x_{ij} = 1 \quad i = 1, \ldots, n \\ & \sum\nolimits_{i=1}^{n} x_{ij} = 1 \quad j = 1, \ldots, n \\ & \sum\nolimits_{i,j \in S}^{n} x_{ij} \leq |S| - 1, \\ & S \subset V,\ 2 \leq |S| \leq 2 - n, \\ & xij \in \{0, 1\}, \\ & i, j = 1, \ldots, n,\ i \neq j \end{aligned} \tag{1}$$

The mTSP is a generalization of the TSP problem and is defined by Bektas [2] as follows: Given a set of nodes and m salesmen located at a single depot, mTSP consists of finding tours for all m salesmen, who all start and end at the depot, such that each node is visited exactly once. This generalization makes the problem more similar to the VRP. A mathematical formulation for the mTSP is presented on equation 2.

Minimize

$$\sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}x_{ij}$$

subject to:

$$\sum_{j=2}^{n} x_{1j} = m, \tag{2}$$

$$\sum_{j=2}^{n} x_{j1} = m,$$

$$\sum_{i=1}^{n} x_{ij} = 1, \quad j = 2, \ldots, n$$

$$\sum_{i=1}^{n} x_{ij} = 1, \quad i = 2, \ldots, n$$

+ subtour elimination constraints,

$$x_{ij} \in \{0, 1\}, \forall (i, j) \in A,$$

Given the importance and the complexity of the problem, the TSP was the target for an enormous number of different solution methods over the past 60 years. These methods can be classified as exact methods and heuristic methods. The exact methods lead to the optimal solution, but are more expensive in terms of time and computational resources, on the other hand, the heuristic methods (non-exact) are solution methods that lead to a sub-optimal solution but require less time and computational resources. It is important to remember that the TSP is an NP-Hard problem where the number of possible solutions has the order of $n!$ (where n is the number of cities) so, for a large number n, the computation of all possible solutions is practically impossible. Exact methods:

– Brute-Force: Consists on the computation and evaluation of all the possible solutions for the problem. It has a running time of $O(n!)$, so if we have 20 cities, we will have to evaluate approximately $2.4329\ 10^{18}$ solutions, which turns out to be almost impractical.
– Dynamic programming: The Held-Karp method [5] decreases the running time to $O(n^2.2^n)$. Considering the exponential part of the previous expression, the computation of all the solutions will turn out to be impractical for $n = 50$ there will be $2.814\ 10^{18}$ solutions.
– Branch-and-bound, Cutting-plane and branch and cut methods: these are, by far, the best methods to solve the TSP. A branch-and-cut method was able to solve an instance with 85,900 cities Applegate et al. [1].

Heuristics and Meta-heuristics:

- Simple heuristics: The number of simple heuristics, usually based on the concept of greedy algorithms, are found in the literature. Examples are the heuristic for the Nearest Neighbor heuristics, Insertion heuristics and the Christian Nilsson heuristic [9];
- Tabu search: A largely used meta-heuristic applied to the TSP [11];
- Ant colony optimization: A meta-heuristic based on a cooperative learning method presented by Dorigo [4] in the context of the TSP and lately used by a large number of researchers to solve a large variety of problems. Is able to give fast and good solutions, if implemented correctly.

2.2 The Vehicle Routing Problem

VRP is an important problem in the fields of transportation, distribution and logistics. The VRP can be described as the problem of finding a plan for the following task: Determine a set of vehicle routes to perform all (or some) transportation requests with the given vehicle fleet at minimum cost; in particular, decide which vehicle handles which requests in which sequence so that all vehicle routes can be feasibly executed [12]. A way to formulate, mathematically, the one of the variants of VRP is depicted on equation 3. In this formulation c_{ij} represents the cost of going from node i to node j, x_{ij} is a binary variable that has value 1 if the arc going from i to j is considered as part of the solution and 0 otherwise, K is the number of available vehicles and $r(S)$ corresponds to the minimum number of vehicles needed to serve set S. Finally 0 represents the depot node.

$$\text{Minimize } \sum_{(i,j)\in A}^{n} c_{ij} x_{ij}$$

Subject to

$$\sum_{j\in \delta+(i)}^{n} x_{ij} = 1, \quad \forall_i \in N,$$

$$\sum_{j\in \delta-(j)}^{n} x_{ij} = 1, \quad \forall_j \in N,$$

$$\sum_{j\in \delta-(0)}^{n} x_{0j} = |K|,$$
$$\sum_{j\in \delta-(0)}^{n} x_{ij} \geq r(S), \quad \forall_{S} \subseteq N, S \neq \emptyset$$
$$x_{ij} \in \{0,1\}, \forall (i,j) \in A$$

Given the potential of the problem to real world applications, several variants of the problem emerged on the literature over the past 50 years [6, 10, 13] to fit better in the real problems specific constraints. Some of those constraints are:

- Capacity constraints: The total packages demand of the locations cannot exceed the vehicles carrying capacity;
- Time/distance constraints: the duration/length of each route cannot have a fixed bound;
- Maximum number of locations that each vehicle can visit;
- Time windows: each location must be serviced within a time window and waiting times are allowed;
- Precedence relations between pairs of locations: for example, location *j* cannot be visited before location *i*.

3 Decision Support System for Beer Delivery

Decision Support Systems (DSS) related to routing problems provide enormous gains to the companies, reducing transportation costs and increasing profitability. There are several examples of such systems in the literature, namely the ASICAM developed in the context of the forest wood transportation and the DSS developed by Weintraub, Andres [14] to solve the general VRP.

In this Section we present our DSS prototype proposal for the fleet management of a beer delivery organization.

3.1 Application Architecture

Beer deliver decision support system (DeliBEERy) was built with Django, a high-level Python free and open source Web application framework. DeliBEERy provides a friendly user interface, where its possible to create, save and optimize routes with vehicles capacity restriction. To execute this operations, is important to manage the users and routes saved in the database with back-office platform. This platforms (Front-office/Back-office) communicate with SQLite database through python.

It was configured an open-source JavaScript library for mobile-friendly interactive maps in Front-Office platform and also configured with Gurobi, an optimization engine. This engine will provide DeliBEERy with the best optimized route to deliver their beer. To proceed to the optimization route calculation method, Gurobi needs the distance matrix data. DeliBEERy communicates via javascript with an open source routing machine (OSRM) providing the distance matrix data to Gurobi. After computing the routes, the solution is sent to OSRM in json format. OSRM will respond with the drawn map solution. For a best understanding of the process, see the Figure 1.

3.2 Usability

The first thing to start using DeliBEERy is authenticate in the application. When logged in, the application redirect the user to the home page, represented in Figure 2. There are several options in the left menu where each one has is specific function.

Start with **Save Instance**, after click in it, will save the distance matrix provided by OSRM in the database along with the attributes tables. **Calculate Route** will ask to first indicate the capacity of vehicles needed if the respective field is empty, then Gurobi will optimize the route using the vehicles capacity and the distance matrix provided by OSRM for the given set of clients. The VRP is often defined under capacity and route length restrictions, when capacity constraints are present, as in this case, the problem is denoted as Capacitated vehicle routing problem (CVRP). For our problem resolution we will follow the approach by Maes [8].

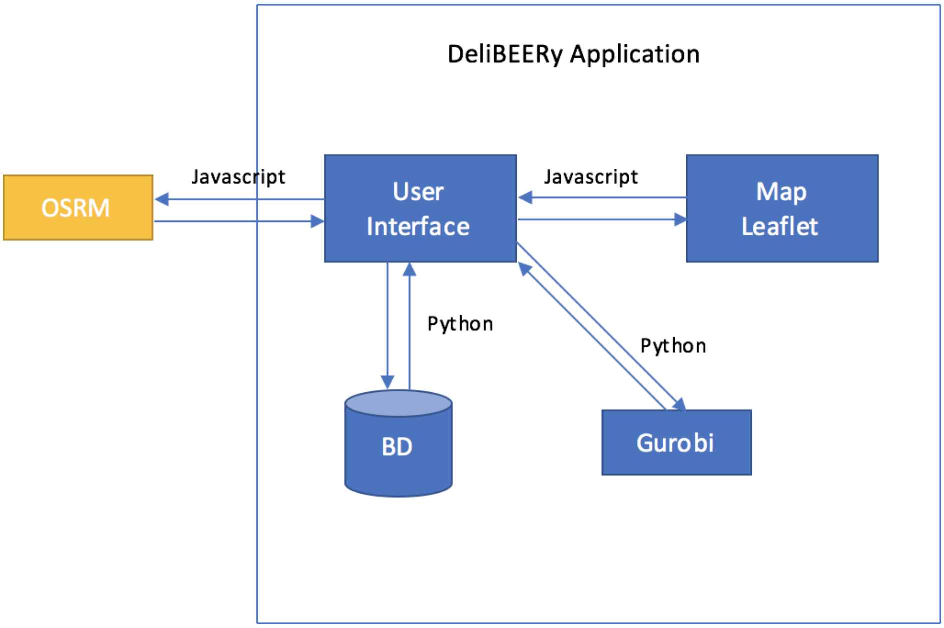

Fig. 1. Decision support system architecture.

Still in the left menu there is a table with information about the markers location. With the buttons **New Attribute** and **Remove attribute** the user can add or remove attributes to the table. It is listed also in another table, the historical of the saved set of clients location by date. To view a specific set of clients location, the user click in the required date indicated in the row, then DeliBEERy will load the saved set of clients location. To remove a specific saved set of clients locations, the user need to make the same procedure but clicking instead in the **X** in the required row.

Show Route, it will open a new window with the route solution showed in Figure 3. Where it's possible to visualize the solution drawn by OSRM.

4 Results

As showed in Figure 3 the results allows to obtain optimized routes minimizing the number of vehicles used and the costs associated to the beer delivery. Its possible to have a general view about the transportation planning, the route for each associated vehicle and also the client characteristics.

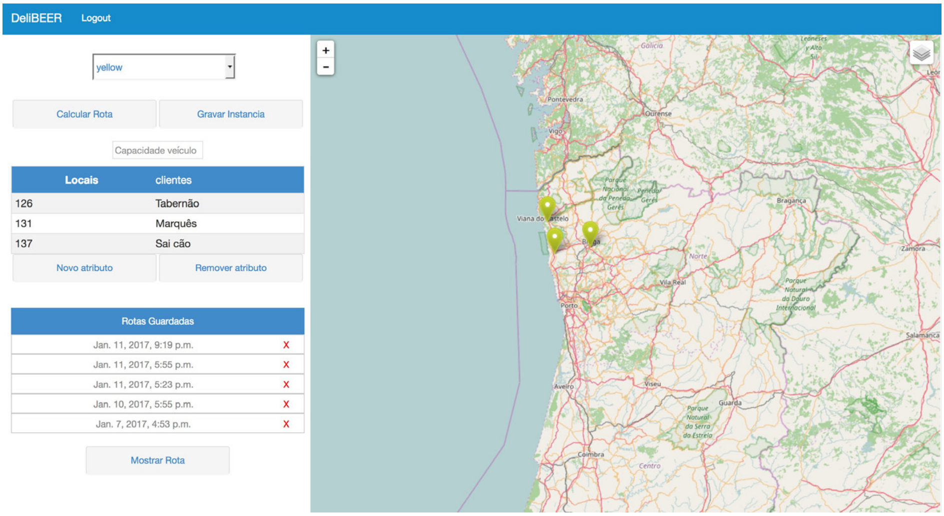

Fig. 2. DeliBERRy home page.

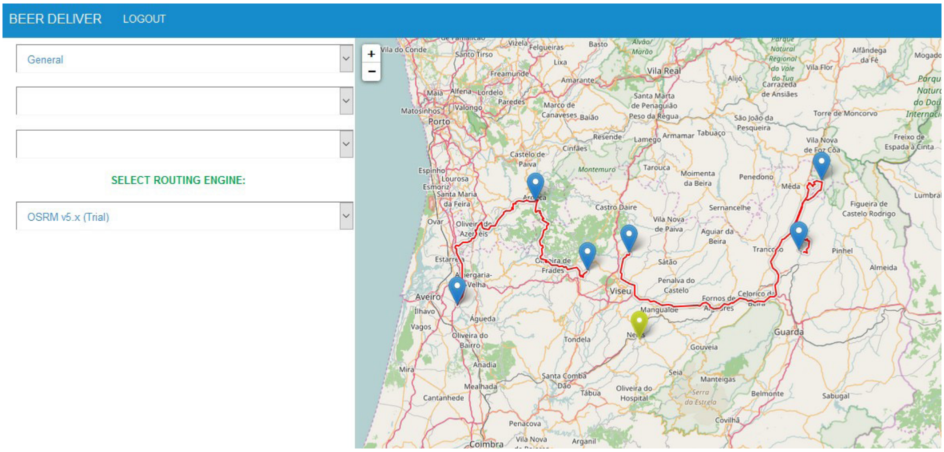

Fig. 3. DeliBERRy route solution page.

5 Conclusions

This work results from a thorough and broad review of literature, concerning Optimization routing problems. Over the past 60 years a lot of research was made in the definition of problems such as TSP, VRP and their variants, to incorporate the specific features of the real world problems. There are a wide variety of solution methods that encompass exact and non-exact approaches that are capable of solving the TSP and VRP for significantly large instances. In this paper was presented a quickly and simple solution to an CVRP approach with the help of open source tools. Regardless of the scientific improvements, a lot of work is still necessary to develop Decision Support Systems that fit the majority of the users' requirements.

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