Public Transportation algorithm for an Intelligent Routing System

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Routing systems are composed by connected nodes, each one with its own properties, which have to be linked with routes fulfilling certain objectives and not violating certain constraints. Different systems have different objectives and constraints, leading to several different problems.

The objective in Vehicle Routing Problems (VRP) [1] is to minimize the number of tours required to visit all the nodes, named customers in VRP, of the system. The system presented in this paper belongs to a different category, where due to certain constraints not all customers can be visited.

The root problem this category is based on, is known as Orienteering Problem (OP) [2]. In the OP, several locations with an associated score have to be visited in order to obtain a total trip score. Each player can visit each attraction only once. The objective is to obtain a total trip score as high as possible without violating a time restriction.

Its generalization to multiple players is known as the Team Orienteering Problem (TOP). When locations have an associated time window, the problem is called TOP with Time Windows (TOPTW) [3]. The Time Dependent OP (TDO) [4] is an extension of the OP where the time needed to travel from a location *i* to a location *j* depends on the leaving time from location *i*.

The time dependent paths, where the time needed to travel from a location *i* to a location *j* depends on the leaving time from location *i,* were introduced by Miller et al. [5] (1960) in the Time Dependent

TSP (TDTSP) and by Malandraki and Daskin [6] in the Time Dependent Vehicle Routing Problem (TDVRP).

Formin and Lingas [7] approached theoretically approximation algorithms for the Time Dependent Orienteering (TDO). Broden et al. [8] presented an approximation algorithm for the orienteering problem with edge costs one and two. Albiach et al. [9] dealed with an extended version of the Asymmetric Traveling Salesman Problem with Time Windows (ATSPTW) that considers time-dependent travel times and costs.

This paper proposes the Multi Path TOPTW (MPTOPTW), which extends the previous algorithms including multiple paths to go from one location to another. The duration of at least one of these paths is dependent on the departure time. MPTOPTW is valid to simulate public transportation.

The MPTOPTW has several applications. The most relevant for the authors is the enhancements of routing solutions when it is possible to travel using different means of transportations, including public transportation. For example, this would be the case of a delivery shop where depending on the location of customers, the average speed of the traffic at a concrete hour of the day, and the availability of public transportation at concrete moment, the traveling time to reach customers varies.

The application scenario we are interested in is related to tourism. Personalised Electronic Tourist Guides (PET)[10][11], are mobile devices supporting tourist while they are on destination. Among others, a PET should provide an integrated solution for route planning that adapts to new circumstances, helping tourists to move within an unknown area. As this solution has to be provided in near real time (around a maximum threshold of 5 seconds), efficient algorithms are required to solve the associated routing problem.

Transportation information was identified as one of the most appreciated functionalities of a PET [12], [13], [14]. However, besides the application of the latest OR algorithms, one of the functionalities that actual PETs are lacking is the inclusion of public transportation.

In the field of public transport, there are some algorithms able to calculate the best route between locations. For example, an algorithm to calculate optimum itineraries in an urban public transport system has been proposed, including a stop at an intermediate point [15]. In Hong-Kong, a similar system was tested using a different approach [16]. These solutions, along with the ones available at different public transportation operators, have been designed as standalone solutions.

Thus, they are not suitable to be used within a wider algorithm required to solve the MPTOPTW, which has to calculate several times the best way to move from one place to another. If they were used to solve the MPTOPTW , the total calculation time would exceed the maximum time a tourists accepts to wait to obtain a route, which is approximately 5 seconds.

The main characteristics of MPTOPTW are:

- The collected score obtained visiting locations have to be maximized
- Not all locations can be visited due to certain constraints

- The time required to move from one location to the next one varies according to the departure time
- There are multiple paths to move between locations

MPTOPTW requires the following input data: a list of locations (ID, position, customized value for each day, opening and visiting times, cost); information about the public transportation network; routing preferences; starting and ending locations; and the constraints. Based on this information, the algorithm creates a personalised route with an ordered list of locations to visit, including the details to move from one location to the following one.

The algorithm to solve the MPTOPTW applies Iterated Local Search (ILS) [17]. ILS is a metaheuristic method based on iteratively building sequences of solutions generated by an embedded heuristic called local search. This leads to much better solutions than repeating random trials of the same heuristic. The solution found by the local search is perturbed to create a new solution. Then, the best solution is taken as the new starting solution for the local search. The process is repeated until a termination criteria is met.

To calculate the cost of going from one location to the next one, the algorithm chooses the fastest mean between public transportation and going on foot. The walking time only depends on the position of the locations. However, when using the public transportation, there is a walking time to and from the nearest stops, a waiting time till the transport arrives and a traveling time (including possible transfers).

Knowing the leaving time from the departure location and the details of the public transportation network (starting time of the services, frequencies, positions of the stops, traveling times between stops), it is possible to calculate all the traveling times and to choose the best option. This operation has to be done several times each time a location is inserted or removed.

The system is going to be validated during the summer of 2009 at San Sebastian. San Sebastian is a beautiful city located at the North of Spain, just 20 kilometers away from France. Regarding the public transportation, contacting the local public transportation company has granted access to updated information about different lines, stops, frequencies and travelling times.

The system presented in this paper can also be applied to multimodal freight transportation systems. Other OR algorithms have already been applied. For example, Yamada et al. [18] applied a genetic algorithm based heuristic to model the strategic level of multimodal transport planning, particularly in freight terminal development and freight transport network design.

In the context of multimodal freight transportation, each transportation destination would be equivalent to a tourist attraction, having an opening and closing time. It would always be possible to transport goods directly by road. Another possibility would be to use the existing multimodal transportation network (train, ship). Nodes of this multimodal network would be equivalent to the public transportation network, with several service frequencies and costs. A simple change should be done to the algorithm to change the main objective of the system from maximizing the global value to minimizing the total time or total cost required to go from the start to the end location.

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