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A hybrid approach to the problem of journey planning with the use of mathematical programming and modern techniques

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Abstract

In the last decades, products and services concerning the transportation of individuals have made the world more interconnected than ever before. Although this fact has enabled people to perform travel-related activities more effectively, neglecting the ecological footprint of those transports has created environmental problems, and as a consequence, for our societies. This study introduces a novel approach for the multi-modal journey planning problem (MMJP) and specifically proposes a hybrid solution algorithm that solves the problem of Environmental MMJP, based both on heuristic and exact algorithms. The algorithm delivers as solutions multi-modal paths that a person can follow and produce the minimum Greenhouse Gas Emissions (GHG) from the different modes of transport that he or she will use while travelling. Given a set of public transport operation schedules, emission calculation models and public network data, a mixed-integer linear programming (MILP) model was developed for the problem, which is solved in combination with the Dijkstra's algorithm in order to deliver the optimal journey. The research is still ongoing for the improvement of the algorithm and the goal is to integrate it in an online platform.

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1. Introduction

In order to define journey planning, one could say that it is the computation of an optimal, feasible and personalized journey from a starting point A to an ending point B. Over the years, many solution approaches have been proposed for the journey planning problem, with the one that is most well-established being the modeling of transportation networks as graphs, interconnecting them into a super-network and calculating optimal routes by solving the Shortest Path Problem (SPP) on those graphs. SPPs are solved by using shortest path algorithms which are either exact or heuristic algorithms. Exact algorithms evaluate every candidate solution in the solution space and return the optimal every time. On the contrary, heuristic algorithms make use of empirical rules and principles that give direction to the search and contribute to getting a solution faster than an exact approach, but do not guarantee that the solution returned is optimal. Although hybrid approaches are not very common in the literature for the solution of the MMJP, this paper

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introduces such a hybrid algorithm. Hybrid approaches are a combination of exact and heuristic, and use modern speed-up techniques without compromising the quality of solution that an exact approach has to offer. In both cases, no matter their attributes, the important task that the algorithms perform is to calculate the path from a point A to another point B, such that the total distance travelled from A to B will be the minimum.

The mostly known SPP algorithm is Dijkstra's algorithm (Dijkstra, 1959) , which is a label setting algorithm. Since its publication, many studies have been made in order to make it more efficient (Bast, et al., 2014). A large category of these studies is "Goal-Directed Techniques", which contains methods such as "A* Search", "Geometric Containers", "Arc Flags", "Precomputed Cluster Distances" and "Compressed Path Databases". A second category is "Hierarchical Techniques", such as "Contraction Hierarchy" and "Reach". A third one is "Separator-Based Techniques", such as "Vertex Separators" and "Arc Separators". "Bounded-Hop Techniques" is one more category of methods accelerating Dijkstra's algorithm, which contains "Labelling Algorithms", "Transit Node Routing" and "Pruned Highway Labelling". Moreover, combinations of the aforementioned techniques lead to even higher acceleration of Dijkstra's original algorithm, with the most common combination being the "Goal-Directed" with the "Hierarchical Techniques".

All these methods are quite efficient in solving the SPP. However, SPP is the typical problem concerning road networks, where a person travels by private vehicle (car, bicycle or even on foot). When dealing with public transportation networks, journey planning, although conceptually similar, is a significantly harder problem due to its inherent time-dependent and multicriteria nature. The multi-modal journey planning problem (MMJP), which seeks journeys combining schedule-based transportation (buses, trains) with unrestricted modes (walking, driving), is even harder.

Although up to now research has focused on road networks and the SSP, when it comes to public transit networks there is a variety of problem formulations in the literature. The simplest variants is the *Earliest Arrival Problem (EAP)*, in which, given a source stop A, a target stop B and a departure time T, the problem asks for a journey that departs from A, no earlier than T, and arrives at B as early as possible. Also, there is the *Range Problem (RP)*, which, instead of taking as input a departure time, it takes a time range (e.g. 6-9am) and asks for the journey with the least travel time that depart within that range. Another variant worth mentioning is the *Multi-Criteria Problem (MCP)*, which asks for Pareto sets of journeys with respect to the optimization criteria. Such criteria might be the minimization of the number of transfers or of the total journey cost, while the minimum travel time is still required. The most important characteristic of these journeys that make up a Pareto set is that they are non-dominating journeys. A journey J1 is said to dominate another journey J2 if J1 is better or equal to J2 in all criteria.

The goal of this study is to address the *Environmental Multi-Modal Journey Planning (EMMJP)*, which proposes a journey that is the most environmental friendly. This problem is a *Multi-Criteria Problem (MCP)*, because it asks for the minimum environmental impact, besides maintaining the earliest arrival criterion.

Although user convenience is important, neglecting factors such as the environmental impact is an important issue, especially since transportation is the human activity that burns out most of the fossil fuels that are extracted from Earth. As a consequence, its contribution to the effect of global warming is huge. Carbon dioxide that vehicles emit does not only ruin the environment, but also has a negative impact on human health. Earth's air quality has decreased a lot in recent years, while humans have to deal with health issues.

All of the mentioned factors point out that the contribution of solution algorithms, which could provide guidance and navigation when it comes to people's everyday commute, would be crucial. Being implemented as an internet platform, which could be accessed by anyone, it could save up tons of gas emissions.

With all that in mind, Section 2 presents algorithms that approach the multi modal journey planning problem, focusing on those who can either support multi-criteria optimization or their structure seems friendly towards a multi-criteria approach. Section 3 presents the hybrid approach proposed by the current study that uses Dijkstra's algorithm and a Mixed Integer Linear Program (MILP). Section 4 concludes the paper with some remarks for future work.

2. Literature Review

In this section, previous approaches that deal with the multicriteria multi-modal journey planning problem in public transportation networks are mainly presented, as this is the category which includes the Environmental Multi-Modal