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A multimodal transport network model and efficient algorithms for building advanced traveler information systems

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Abstract

Route planning in urban public transport systems constitutes a common decision problem faced by travelers. Therefore, building Advanced Traveler Information Systems (ATIS) that provide passengers with pre-trip information on navigating through the network has become a certain need. Since passengers do not only seek a short-time travel, but they endeavor to optimize other criteria such as cost and effort, an efficient routing system should incorporate a multiobjective analysis for both routes and transport modes. We propose in this paper a new formulation that adequately allows representing a public transit network, as well as, yielding correct results when applying routing algorithms. Based on this formulation, we develop a multicriteria routing algorithm to determine the entire set of nondominated solutions to solve an itinerary planning problem. We introduce also several enhancement strategies to accelerate the algorithm's search process. As transportation modes, we focus on Railway, bus, tram and pedestrian. As optimization criteria, we use travel time, number of transfers and the total walking time. Experimental results have been assessed by solving real life itinerary problems defined on the transport network of the city of Paris and its suburbs. Results indicate that test problems were solved within reasonable amount of time and the new approach is efficient enough to be integrated within a real world journey-planning system.

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1. Introduction

Online services for route planning in transportation networks have become a commodity used daily by millions of commuters. The problem of efficiently computing good journeys presents several modeling and algorithmic challenges, and has been an active area of research in recent years.

In fact, when dealing with transportation systems, we should not consider each transportation mode separately. Rather, we should look to them as one single system with relations and dynamics between its components. For this seek, we need a model reflecting the multimodal nature of the transportation system. This model should also adequately represent each component of the system (stops, routes, trips), as well as, yield correct results when applying routing algorithms.

Routing applications whether they arise in transportation area or other domains such as communication networks, energy and military usually refer for solving Shortest Path Problems (SPP). While solving some routing problems can be done in a straightforward manner, computing shortest paths under certain circumstances is not always an easy task. For instance, solving the one-to-one SPP in static networks can be easily accomplished by applying the well-known algorithm of Dijkstra. On the other side, computing multicriteria shortest paths appears to be more difficult especially in large-scale time-dependent networks

Computing itineraries w.r.t several criteria refers to the multicriteria or Multiobjective Shortest Path Problem (MOSP), a fundamental problem in the field of multiobjective optimization. More precisely, given two journeys j_1 and j_2 , we say that j_1 dominates j_2 if there is at least one criterion for which j_1 has a better value than j_2 and there is no criterion for which j_2 has a better value than j_1 . A journey j is then called Pareto-optimal if it is not dominated by any other journey. The ultimate goal in multiobjective analysis is therefore to find all Pareto-optimal solutions.

The difficulty in multiobjective optimization stems from the fact that, in many optimization problems, determining the entire set of nondominated solutions is a tedious task since one problem may have a huge number of nondominated solutions (even in case of two objectives). Additionally, and in contrast to single criteria search, one cannot abort the search after finding a first optimal solution. Even after finding all Pareto-optima, search algorithms require a substantial amount of time to guarantee that no further solution exists.

The main goal of this paper is to compute Pareto-paths in multimodal transportation networks. To do so, we propose a new modeling approach allowing efficiently computing multicriteria shortest paths. We then develop a routing algorithm to compute Pareto paths over the proposed modeling approach w.r.t some criteria. We finally introduce several efficient enhancement strategies to improve the performance of the proposed algorithm.

We assess the performance of our work by solving real life itinerary planning problems based on the real data of the French region Il-de-France that includes the city of Paris and its suburbs.

The rest of this paper is structured as follows: in next section, we present some related works. We introduce in Section 3 the new modeling approach and fix some notations. In Section 4 we introduce the multicriteria routing algorithm to solve the MOSP. Experimental results are presented in Section 5. Finally, Section 6 gives some comments and outlines future works.

2. RELATED WORKS

Routing is a widely researched topic in transport systems, mainly because of its relevance to real world applications. The major research effort on this problem relates to two things: modeling transport network and solving routing issues. While the former consists of defining how to represent a transport system, the latter deals with developing algorithms to support routing issues faced by travelers and transport operators.

In terms of modeling, Pyrga et al., (2007) and Delling et al., (2009) have done extensive works to incorporate the multimodality aspect into their models. Liu et al. (2009) proposed a switch point approach to model multimodal transport networks. Van Nes (2002) conducted several researches for designing multimodal transport networks. Ayed et al. (2008) proposed a transfer graph approach for multimodal transport problems. Zhang et al. (2011) introduced a generic method to construct a multimodal transport network representation by using transfer links, which is inspired by the so-called super-network concept. Pyrga et al. (2004) has also done relevant works to generalize a time-expanded model that deals with realistic transfers. Bast et al. (2010) also handled multimodal networks by incorporating predefined transfer arcs between nearby stations.

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