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Memetic algorithm for computing shortest paths in multimodal transportation networks

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Abstract

Route planning in multimodal transportation networks is gaining more and more importance. Travelers ask for efficient routing methods allowing them to reach their destinations through the intricate multimodal transportation scheme. In this paper, we propose a new approach for computing multi-modal shortest paths. We only consider railway, bus and pedestrian networks. The travel time is the only metric in our cost function. Our proposed approach is a combination of two meta-heuristics: Genetic Algorithm (GA) and Variable Neighborhood Search (VNS). We compare our approach with the exact shortest path algorithm Dijikstra that has been modified to work in a multimodal environment, as well as, with a pure GA. Results have shown that the success rate of our approach in terms of converging to optimum/near optimum solutions is highly better than a pure GA. Moreover, in contrast to traditional algorithms like Dijkstra, our approach is fast enough for practical routing applications.

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1. Introduction

A Multimodal Transportation System (MTS) is the combination of all traveler modes and kinds of transportation systems operated through various systems (Bielli et al., 2006). That is, a set of choices of modes of transport that travelers can use simultaneously in order to reach their destinations. Nowadays, the human mobility within urban areas usually happens in a multimodal context (Liu, 2011). People are more prone to use more than one mode of transport during their travels. However, the transport system has become more and more complex. Users usually find themselves more confused with having several possibilities to go from one place to another. Consequently, for

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the sake of helping people efficiently to find optimal or near optimal routes through the complex transportation scheme, route planning in MTS has gained significant importance.

Generally, we can distinguish between private and public route planners. The formers usually consider private transport modes, which are qualified as continuous modes such as cars, bicycle and walking. On the other hand, public route planners are only dedicated to public transportation modes such as bus, subway, tram which work according to predefined timetables.

Nowadays, there exist several solutions to solve the conventional route planning in transportation systems. These solutions come in the form of free or paid software and applications such as Google and Bing Maps. Most of such routing tools support more than one transportation mode. However, few could provide a free combination of travel modes. In practice, travelers usually ask for an integrated solution that compute optimal or near optimal routes with combining all available transportation modes whether they are private or public.

In this paper, we introduce a new multi-modal routing approach. We focus our research on two public modes (Bus and railway) and one private mode (walking) that people can use to access transportation means, as well as, to make transfer between modes.

The remainder of this paper is organized as follows. We introduce some related works in Section 2. Section 3 describes the multi-modal Shortest Path Problem (SPP). We present in section 4 our modeling approach. Section 5 is devoted to present our novel approach. Experimental results and some discussions are shown in Section 6 and 7. Finally, we conclude this paper in section 8, as well as, we propose some future works.

2. Related work

Several approaches have been developed in order to represent the intricate multimodal transportation network. Some models are based on the hypergraph theory such as in (Nguyen et Pallottino, 1988), (Febbraro et Sacone, 1995), (Lozano et Storchi, 2002). Other models are based on the space-time-network (Pallottino et al., 1998) or on the multi-label networks (Ziliaskopoulos et Wardell, 2000). Using hyper-graph networks eliminates usually some arcs used for changing between transportation modes. As a result, the search space for the routing algorithms is usually less in comparison with other modeling approaches. However, the other models are more efficient when it comes to handle additional problem constraints.

Several algorithms have been proposed since 1956 for routing in static networks, such as (Dijkstra, 1959) Although such algorithms compute shortest paths in polynomial times, they become too slow to process real world data sets like continental networks, even on today's computers.

Researches have therefore focused on accelerating traditional algorithms using speed up techniques (Schultes, 2008). For more details about speed up techniques in static networks refer to (Delling, 2009 and Bast et al., 2014).

While routing in static networks has become quite easy, routing in dynamic networks turns out to be more difficult. Public transit networks such as bus and railway are inherently time-dependent. The travel time from one station to another is not static; it depends on the arrival time of the user at the departure station. Cooke and Halsey (1966) showed that standard algorithms like Dijkstra could be augmented to cope with the time dependency aspect of public transportation modes. However, that would be at the expense of additional computational efforts, especially when the size of the network becomes very important (Delling, 2009). Extensive works have therefore been investigated to augment speed up techniques used in static networks to accommodate for the new variant of SPP raised when dealing with time-dependent networks. For more details about accelerating techniques in dynamic networks, the reader can refer to (Bauer et al., 2011).

Although, speed up techniques are efficient and fast enough to compute shortest paths, they become less performant or even inapplicable when additional constraints are added to the SPP such as stochasticity and multi-criteria paths optimization. Therefore, there has been an application need to develop new routing approaches that provide optimal or near optimal routes in reasonable computational time in large-scale multimodal networks, as well as, that cope with additional problem constraints such as stochastic arcs' weights, multi-criteria optimization etc. We believe that meta-heuristics such as Genetic Algorithms, Local Search Procedures are efficient candidates to handle such requirements.

Metaheuristics have been used to solve several routing issues. For instance, Abeysundara et al. (2005) used a Genetic Algorithm to solve the routing issue in road networks. Yu et al. (2012) proposed an improved Genetic Algorithm to solve the route-planning problem in a multimodal transportation network. Davies et al. (2003) introduced a new genetic approach for rerouting in dynamic and stochastic networks. Other metaheuristics have been used to solve routing issue such as in (Mohemmed et al., 2007). Although such approaches are very interesting,