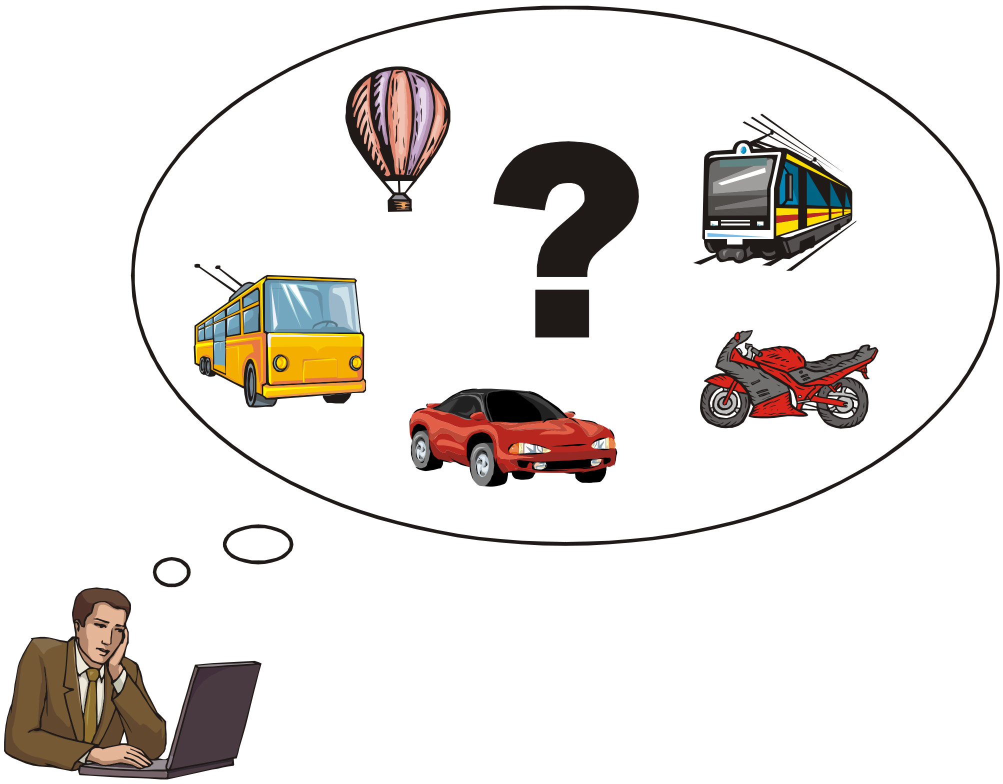

The importance of computing intermodal roundtrips in multimodal guidance systems

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Conference paper STRC 2004

STRC | 4th Swiss Transport Research Conference
Monte Verità / Ascona, March 25-26, 2004

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Abstract

Most of the current intermodal traveller information applications still consider one-way journeys only. For the calculation of a roundtrip two simple one-way trips are taken into account. However, most of the journeys do not consist of simple one-way trips, as a traveller usually returns to the starting point (home, office for business trips, etc.). Also, arc cost – travel time in general – tend to be time dependent, which means that the cost of the optimum roundtrip is not necessarily the double of the cost of the optimum one-way trip. The diverse arc cost values can be based on dynamic and/or historic data. A lot of effort is spent in order to obtain and store this type of data, which is necessary for describing real-time traffic states and to make forecasts. So the next step is to make better use of this data by integrating them into the calculation of trips that take place in the future.

A multimodal information service usually works as follows: The traveller indicates his starting point, his destination and the desired time of departure or arrival. The system then computes the optimum trips for private modes (car, bicycle, etc.) and public transport (all modes). It is up to the user to compare the different possibilities and to decide which one to take. Dynamic data are integrated where available. The possibility of switching between different transportation modes during the trip is rarely offered. The main reasons are the difference in the models (different graphic levels are used for different modes) and the different parameters for describing the arc cost for the different modes.

Roundtrips can usually be computed for certain modes, especially for public transport, which relies on static timetable data. In this case, the intermodality is limited to some or several public transport modes of a certain region. More and more service providers offer the possibility to optimise a door-to-door trip, taking into account the time necessary to reach the first transport mode used, as well as the time to reach the destination from the last stop.

This paper describes the importance of computing entire intermodal roundtrips rather than two one-way trips, as arc cost tend to vary depending on different parameters (time of the day, special events, etc.). Having more and more dynamic and historic data at hand, it should be used to the maximum possible, in order to optimise mobility habits. Computing intermodal roundtrips also means taking into account several constraints that may arise on the way, like the dependence on a certain mode or leaving behind a private vehicle at certain nodes of the network. The main constraints are pointed out, along with their importance for the calculation.

Keywords

Intermodal travel planner – Roundtrip – Shortest path – Cost function – 4th Swiss Transport Research Conference – STRC 2004 – Monte Verità

1. INTRODUCTION

Resolving shortest path problems has always interested engineers and mathematicians alike. Many solutions have been found for different applications. The introduction of intermodal transport chains has added to the complexity of the algorithms. At present, most efforts are being applied to the acquisition of dynamic data, in order to integrate them into the calculation. In addition, most of the current applications still consider one-way journeys only. For the calculation of an intermodal roundtrip two simple one-way trips are taken into account. However, most of the journeys do not consist of simple one-way trips, as a traveller usually returns to the starting point (home, office for business trips, etc.). Also, arc cost – mostly based on travel time – tend to be time dependent, which means that the cost of a trip can vary during the day and from one day to another. The diverse arc cost values can be based on dynamic and/or historic data. A lot of effort is spent in order to obtain and store this type of data, which is necessary for describing real-time traffic states and to make forecasts. So the next step is to make better use of this data by integrating them into the calculation of trips that take place in the future. This paper points out the major problems that have to be resolved for a true roundtrip calculation and proposes an approach for computing intermodal roundtrips.

Numerous research projects focused on different services that have to be provided in order to obtain an advanced traveller information system (ATIS) have been completed or are currently ongoing. Usually, an application of the services is established in one or more test regions, in order to assess the proposed services and systems. A multimodal information service usually works as follows: The traveller indicates his starting point, his destination and the desired time of departure or arrival. The system then computes the optimum trips for private modes (car, bicycle, etc.) and public transport (all modes). It is up to the user to compare the different possibilities and to decide which one to take. Dynamic data are integrated where available.

The possibility of switching between different transportation modes during the trip is rarely offered. The main reasons are the difference in the models (different graphic levels are used for different modes), the inadequate representation of the mode switching interfaces and the different parameters for describing the arc cost for the different modes. Roundtrips can usually be computed for certain modes, especially for public transport, which relies on static timetable data. In this case, the intermodality is limited to some or several public transport modes of a certain region. More and more service providers offer the possibility to optimise a door-to-door trip, taking into account the time necessary to reach the first transport mode used, as well as the time to reach the destination from the last stop.

1.1 Research

The development of algorithms to solve shortest path problems is usually done by mathematicians, as they have the best knowledge of the operations research involved. Their findings are published in mathematical reviews and thus pass often unnoticed by a lot of potential users. Pallottino and Scutella [1] have published an interesting overview of the existing techniques for shortest path algorithms in transportation models. In their paper they describe different approaches used in the past and in the present.

In recent years, two major approaches for dynamic shortest path algorithms have been developed. The first one is based on a space-time network proposed by Chabini [2], which is a very efficient algorithm for cost functions taking into account one single parameter. In general, this parameter is the path travel time. The main advantage of this kind of algorithm is its computation speed. Nevertheless, multimodal transport models often take into account several parameters and the algorithm shows its limits.

The second algorithm, developed mainly by Ziliaskopoulos and Mahmassani, is using labelled arc cost [3], which allows the use of several parameters within the cost function. Ziliaskopoulos and Wardell [4] propose an algorithm taking into account multimodal networks, dynamic arc travel times and switching delays. They point out several problems encountered when computing intermodal optimum paths and test the computational performance of their algorithm. Whether their algorithm allows calculating return journeys has yet to be examined.

1.2 Applications

It is more interesting to see how the algorithms are used within different applications. As the main focus is being laid on the services, the tools used come from different sources. Unfortunately, the shortest path calculation is in general based on algorithms developed by private companies. They are seen as black boxes, for which the internal functions are not accessible. In the following some of the greater applications that have taken place in Europe and the United States are presented. The list is, of course, far from being exhaustive, but project results are easily available and the services are still in operation.

- EU-SPIRIT (Source: www.eu-spirit.com) is not a traveller information service by itself, but an initiative to compile information of different existing regional travel planners.
- VMZ Berlin [5] offers good real-time information about the actual state of traffic. One can also compute the best door-to-door connection for different modes, but no direct comparison of the different modes is available. It is possible to calculate a roundtrip by entering the same address for origin and destination and by specifying a waypoint, but no time delay can be given for the stopover.

- Covering the surroundings of Basel (three countries: Switzerland, France, Germany), the service Trans 3 [6] provides information about traffic and public transport. The engine proposes different transport chains for a given origin and destination. No waypoints can currently be integrated into the trip calculation, but dynamic data is taken account of if available.
- Information about the real-time traffic state, public transport and car-pooling in the San Francisco Bay area can be obtained from TravInfo® [7]. The traveller can call a service number in order to receive the information. No traffic information is given by internet.

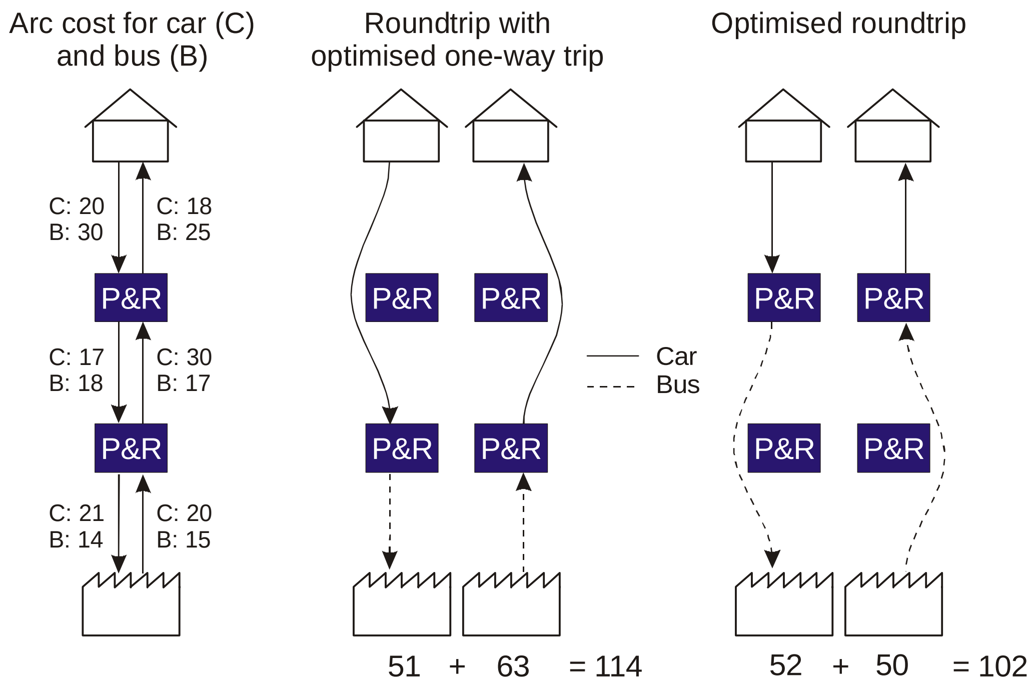
The list of available regional traveller information project could go on for pages (see also [8], [9], [10], [11], [12], [13], [14], [15], [16]), but most of them are similar to those stated above.

2. PROBLEMS CALCULATING INTERMODAL ROUNDTRIPS

When doing a roundtrip, the choice of the transport mode for the second (the return) trip is closely bound to the choice made leaving the starting point. For example, if the traveller takes his car to work in the morning, he will very likely return by car in the evening. If he leaves his car at a park and ride in order to switch to public transport (as proposed by his classic information system), he will have to pass the same park and ride to reclaim his vehicle. As for the return trip the chosen transport chain is not necessarily the fastest one, it is possible to lose time compared to the use of another transport mode for the entire journey. Thus, the optimisation of a roundtrip has to take into account the dynamic and historic data for calculating both trips. It must also be possible to switch between different transport modes during the journey at specially designed interfaces. This needs a detailed definition of the interfaces including the time needed for changing modes. It may also add constraints regarding personal vehicles, as they are left behind during one of the trips. New and alternative transport modes, like car sharing, vehicle hiring, etc. should also be proposed to the user by the information system.

The following simple example (Figure 1) illustrates this problem. Let’s assume that a person can go to work either by bus (B) or by car (C). Both modes use the same route, but with different arc cost (e.g. travel time). Also, the arc cost is different in the morning than in the evening (for the return trip). Two park and ride (P&R) installations allow switching between modes during the trip (The switching delay is ignored for the simplicity of the example). The optimisation of the morning trip to work indicates to use the second P&R and to take the bus for the rest; which takes 51 minutes in total. Having left the car at the second P&R the person has to pass by that interface in order to pick up his car. The return trip takes 63 minutes in that configuration. The quickest way to return home (50 minutes) is to take the bus to the first P&R, which is not possible, as the car has not been left there. Optimising the entire roundtrip shows that it is actually better to leave the car at the first P&R, as the total journey takes 102 minutes, compared to 114 when leaving the car at the second P&R.

Figure 1 Example for differences in roundtrip cost having time dependent data



3. PROPOSAL FOR AN APPROACH OF AN OPTIMUM INTERMODAL ROUNDTRIP

The constraint problem described above is easily understood and probably known by most professionals. Its integration into the shortest path optimisation, however, is not as quickly explained. This chapter tries to set the conditions for the development of an algorithm responding to the problems stated above.

First, certain assumptions have to be made. Not all of the assumptions are presently established or available, but at the same time they indicate present or future research domains. Afterwards, the proposed method for computing intermodal roundtrips is explained. No new algorithm will be given, but an approach towards it as seen from the transportation engineering point of view. Next, the specific problem of the constraints that arise when computing intermodal roundtrips is described, like, for example, changing modes during the one-way trip may influence the return trip. Finally, a list of necessary input parameters for the desired algorithm is given.

3.1 Assumptions

Time dependent (historic and/or dynamic) data is required and available. With static data, the return trip has the same cost as the first one-way trip, and therefore optimising one of the trips results in the optimisation of the entire intermodal roundtrip. Hence, this first assumption is the essential condition for the proposed approach to make sense. Also, the database allows the creation of a historic profile, which gives information for all the different parameters needed for the cost function.

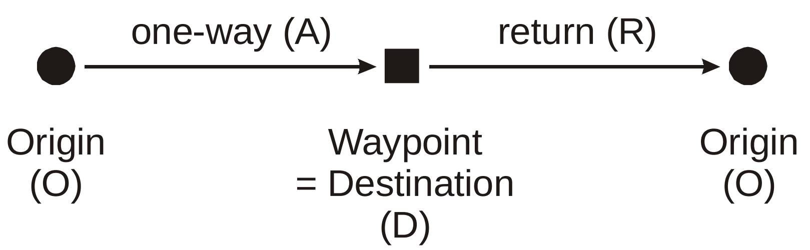
The parameters for comparing general arc cost must be the same for all modes (same cost function). Research is necessary in this field, but for this article, it is assumed that such a function is available. The main reasons for the unlike parameters are the different graphs representing public and private transport, as well as the diverse characteristics of the different modes. For private transport, for example, nodes and arcs represent crossroads and the streets in-between, whereas the public transport model is based on stations/stops (nodes) and the route in-between. Thus, any interdependence between the models, like buses using the public roads, is ignored. Another difference is the price to pay for one arc, which can be measured per linear distance (private transport) or per zone (urban public transport). In the latter case, fare cards (monthly, annual, etc.) add to the complexity of the calculation. Efforts to include all the transport modes into the same graph are presently being made [17], which will allow a direct comparison.

The algorithm should be of a non-FIFO (First In First Out) type. As all movements will be modelled on the same graph, some transport modes may be faster than others (a car overtaking a bicycle, a bus using a bus lane, etc.). Overtaking of vehicles of the same mode is also an option that could be considered, but strict conditions must be imposed.

3.2 General method

The entire journey is modelled as one single trip with intermediate waypoints (Figure 2). The waypoints allow stops that can be short (for changing modes) or long (time spent at the office, shopping, etc.). The destination (D) of the traveller is therefore modelled as a waypoint, reached after the first one-way trip (A). The intermodal roundtrip continues with the return trip (R), in order to come back to the origin point.

Figure 2 Schematic illustration of an intermodal roundtrip



To define the duration of the stopover at the waypoint, different possibilities must be offered, independently of the parameters given for trip A:

- The first and probably the simplest one consists of giving the time during which the traveller tends to stay at his destination. Thus, the departure for the return trip depends on the time of arrival of the one-way trip.
- The traveller indicates his intended time of departure for the return trip, independently from his time of arrival at the destination.
- The traveller gives the desired time of arrival at the origin. Again, no dependence on the arrival time at the destination exists.

The second and the third possibilities must also be available for the computation of trip A (Time of departure at O or time of arrival at D), of course. The algorithms currently available already offer the possibility of including waypoints in the trip (and thus roundtrips), but no time delay can be forced at the intermediate waypoints and the trip continues straight away.

The first of the three possibilities might be integrated in such an algorithm, by defining an arc from point D to point D, which has the defined time as travel time.

3.3 Constraints of changing modes

As soon as the traveller is supposed to change modes during trip A, some additional constraints may be introduced to the calculation of the second trip (R). Leaving a private vehicle behind means that it has to be picked up later on at that same interface. Changing between public transport modes does not introduce such a spatial constraint, but it may have an impact on the ticket that has to be used.

The following figure shows the spatial constraints introduced to the return trip by changing from one mode to another during the one-way trip A. Private vehicles and public transport form one category each, as all possible modes for these categories can be treated the same way. A closer investigation is needed where private vehicles that may be transported on vehicles of another mode (bicycle on the bus, car on the train, etc.).

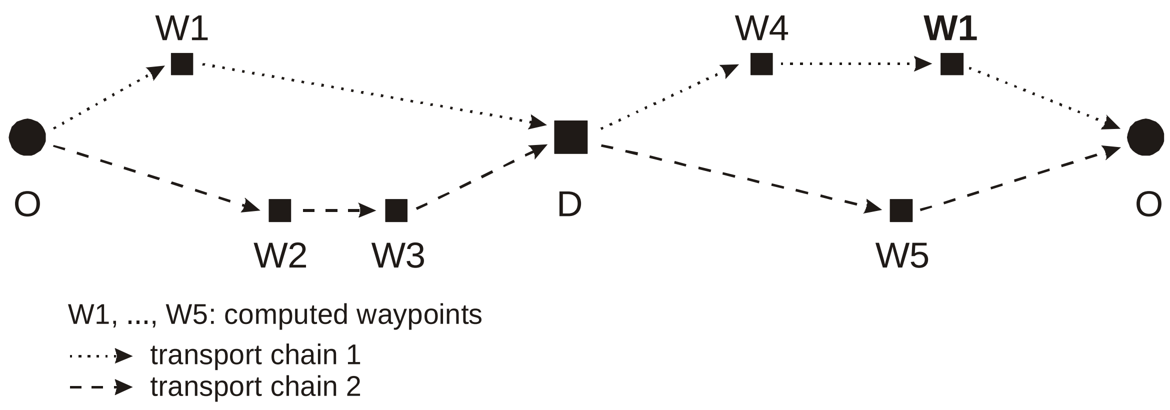
Figure 3 Spatial constraints introduced by changing modes during the one-way trip

from \ to	walking	private vehicle	public transport	taxi	car sharing	car pooling	vehicle hiring
walking		n	n	n	n	n	n
private vehicle	y	y	y	y	y	y	y
public transport	n	n	n	n	n	n	n
taxi	n	n	n		n	n	n
car sharing	y	y	y	y		y	y
car pooling	n	n	n	n	n		n
vehicle hiring	y	y	y	y	y	y	

y: constraint
n: no constraint

Figure 4 serves as simplified example of the constraint problem. Let's assume that for the roundtrip two possible transport chains are found. The first one passes by waypoint 1, where changing modes with constraint takes place. Therefore, the return trip has to pass by the same waypoint (W1). The second transport chain has two waypoints, but without constraints. Thus, the return trip can be completed without constraints and may even pass by another waypoint.

Figure 4 Two possible multimodal transport chains for an intermodal roundtrip



Of course, it is not possible to switch modes at any node of the network. An exact definition of the interfaces between the different mode networks is compulsory.

3.4 Necessary input

Different parameters have to be introduced by the traveller. The ones currently used are the addresses of the origin, the destination and eventual waypoints, the travel date, as well as the desired departure or arrival time. In addition to them, the delay time at the waypoint has to be fixed, using one of the three methods described above.

The system also has to know at what point of the network, private vehicles are available, as it is not always possible to have them at home, especially in urban areas. Also, the trip does not necessarily start at home and no private vehicle may be available nearby. This information has to be given by each user and can be stored in a user profile, but has to stay variable for modification.

Any kind of personal preferences should be integrated in the calculation (no public transport if more than two changes necessary, for example). Also, the availability of special fare cards or service subscription may lead to a different result of the roundtrip calculation.

The historic database has to be up to date, in order to be the most helpful possible. This can be done by gathering data measured in the field or by using user feedback (post-trip). The historic date is used for creating historic profiles which describe standard situations. An adaptation of these historic profiles to the actual situation can be made by analysing the real-time data.

4. CONCLUSIONS

This paper described the importance of computing entire intermodal roundtrips rather than two one-way trips, as arc cost tend to vary depending on different parameters (time of the day, special events, etc.). Having more and more dynamic and historic data at hand, these should be used to the maximum possible, in order to optimise mobility habits.

Computing intermodal roundtrips also means taking into account several constraints that may arise on the way, like the dependence on a certain mode or leaving behind a private vehicle at certain nodes of the network. The main constraints have been pointed out, along with their importance for the calculation.

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