An Open Extensible Platform for Intermodal Mobility Assistance

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Abstract

Mobility can be considered as an important factor when it comes to assessing ones’ quality of life. Today, there are many different means of transportation available, each one with its particular advantages and drawbacks. Recently, a whole set of new transportation concepts made some noise in the world. As an example, consider electric vehicles or Car- and Ride Sharing providers. We do not wish to favour the one or the other concept, in fact, each mean of transportation has its own distinctive charm, depending on the situation. We see the future in an intelligent combination of many different means of transportation, where the selection is aligned with the traffic participants’ preferences and requirement, as well as with external factors. Nevertheless, any attempt implement an automated assistance is aggravated by the distributed nature of the data which is required for such calculation. In this paper we tackle this problem and propose an open, extensible platform on which (mobility) providers can offer their service in a standarised fashion. Based on this platform we present our mobility assistance system which supports users with urban trip-planning and outnumbers comparable approaches inasmuch as intermodal options are considered on yet another level.

Keywords: human mobility, mobility platform, intermodal routing, trip optimisation, mobility assistance

1. Introduction

Most people agree that mobility is one of the many factors which plays an essential role when it comes to assessing ones’ quality of life. Nevertheless, an ever increasing urbanisation aggravates the use of ‘classic’ modes of transportation. As an example, consider the vehicle. In Germany, the vehicle constitutes the number one mean of transportation. Following the Federal Ministry of Transport, Building and Urban Development, 59 out of 100 journeys are accomplished with a vehicle [1], which makes the vehicle the number one mean of transportation.

Nevertheless, the extensive use of vehicles aggravates the traffic situation of frequently insufficient infrastructures and thus implicitly puts a lot of stress on drivers – especially during rush-hour traffic. For
this exact reason, many traffic participants (although capable of driving a vehicle) use alternative means of transportation, such as the metro, busses, or bicycles.

Furthermore, the very established field of urban transportation seems to be in change. Several new ‘concepts of transportation’ have made some noise in the world – the most popular representative from this category is without a doubt the electric vehicle, or EV. As opposed to conventional vehicles, electric vehicles produce no direct CO₂ emissions¹ and thus contribute to a more sustainable future.

And there are even more transportation concepts that made the news most recently. To start with, Car Sharing services are currently implemented within major cities all over the world. The idea of car sharing is to provide a set of vehicles in an urban area and allow anyone to rent these vehicles at a given rate. A second ‘novel’ seedling among transportation concepts is Ride Sharing. On the one hand, the concept of ride sharing allows users to pick up ‘ride clients’ on journeys which they perform themselves. On the other hand, users are able to propose ride requests to other drivers and ask for a transport. While the ‘classic’ alternatives to regular driving (e.g. using the bus, or the metro) mainly aim to counter stressed infrastructures and to reduce emissions, new transportation concepts also aim to reduce the costs for users, since maintenance, taxes and ‘ownership’ in general is not required anymore.

The bottom line is, there are many transportation concepts available – and even more concepts coming up. We do not wish to favour the one or the other of these concepts, in fact, each mean of transportation has its own distinctive charm, depending on the situation. We see the future in an intelligent combination of many different means of transportation, where the selection is aligned with the traffic participants’ preferences and requirement, as well as with external factors, such as weather- or traffic conditions.

Nevertheless, for individual users it is difficult to optimise their transport selection, not least due to the many available options. An automated process, however, is able to retrieve required information and to calculate an intermodal route which may involve different modes of transportation and which is optimised with respect to the user’s preferences, such as costs, CO₂ efficiency or time, to name but a few. The only problem with intermodal routing, is the distributed nature of required data. Bus- and metro schedules, for instance, are listed in some proprietary format at the website of the local public transport. On the other hand, data on car- and ride sharing enterprises are hosted at the servers of the service provider, and let alone information on traffic congestion, which are offered somewhere else in the web in yet another format.

The distribution of required data aggravates the implementation of intermodal routing algorithms and this paper we propose a way to tackle this exact problem. We propose the development of an extensible platform where mobility service providers offer their services in a generic fashion and thus allow for autonomous processing in order to enable intermodal routing mechanisms and automated service selection processes. We start by presenting the state-of-the-art in intermodal routing algorithms (see Section 2.1), and intermodal mobility planning portals (see Section 2.2) and also present selected mobility service providers (see Section 2.3 and Section 2.4) in order to provide a feeling for mobility service descriptions. We conclude this analysis by presenting shortcomings of mentioned approaches (see Section 2.5) and thus motivate the development of an open and interoperable mobility platform, which we sketch subsequently (see Section 3). Finally we wrap up with a conclusion (see Section 4).

2. State of the art

Due to the increasing traffic density in urban areas, the intermodal travel assistance will play an important role in future mobility scenarios. The combination of different means of transport as well as mobility concepts allows for the computation of an optimal solution to the transportation problem according to actual traffic situations and preferences of each user. In the following we give an overview over both, the scientific and algorithmic approaches and the systems, which are publicly available, today. Further, we provide an

¹Electric vehicles still produce CO₂, yet, as opposed to conventional vehicles the emissions are not a result from the vehicles combustion process, but a result from the production process that is required to produce the energy which is required to recharge the battery of the electric vehicle
overview over interoperable systems in the eMobility domain and discuss what can be learned for the mobility domain as a whole. Finally, we put a focus on one promising mobility concept, namely ridesharing, and identify its drawbacks without any connection to a wider mobility system.

2.1. Intermodal mobility planning - algorithms

Current approaches for solving intermodal transportation problems mainly apply concepts which are confined to the realm of graph theory [2, 3, 4], yet, to formulate such problems as constraint-satisfaction-problems (CSPs) [5] is also a common strategy. The computation of the optimal combination of routes is mostly processed according to the factors time, costs or comfort. The ecological aspect is more or less neglected. The graph theory approaches transfer these parameters into a cost function, which enables to define the optimisation problem as a shortest path problem (SPP). For the solution different algorithms are being used, such as the Dijkstra algorithm [2], breadth-first search [6] or heuristics [7]. For the selection of an intermodal solution the scheduling factor has to be considered as well [8], which leads to a discrete, time-dependent network.

A huge challenge in the development of intermodal transport algorithms lies within the high degree of distribution and the heterogeneous presentation of required data, which can limit the interoperability between services. In many cases the services are represented in WSDL. However, this does not allow for an automated composition and also requires much manual intervention. The usage of semantic service descriptions is still rare in current approaches.

2.2. Intermodal mobility planning - portals

There are many companies engaged in the topic of intermodal route planning\(^2\). The Hafas system\(^3\), which is developed by Hacon, is being used by different transportation companies as a travel assistance system (for example Deutsche Bahn, ÖBB, BVG). In certain installations the system is able to compute and propose intermodal routes\(^4\), considering bicycles, private vehicles and public transport. As a result the system proposes a selection of travel opportunities in combination with detailed information such as costs, \(CO_2\) footprints and the means of transportation, which have to be used. The usage of electric vehicles with its specific challenges and mobility concepts such as carsharing and ridesharing are not considered in this approach.

The routing software of the Mentz GmbH provides similar solutions, only that bicycles, private vehicles, public transport and a regular walk are considered as well. It applied in different urban areas, such as Munich and London\(^5\). As an intermodal service the park&ride approach is being offered. A publicly accessible intermodal system, which considers further concepts beside private vehicles and public transport does not exist.

The University of Berkeley developed the Networked Travel System [4], which proposes intermodal routes regarding public transport and bicycle information. However, the majority of intermodal travel assistance portals only consider the combination of different types of public transportation types. An interconnection with mobility concepts like car- and ridesharing is (to the best of our knowledge) not implemented in current approaches.

Each of the above mentioned portals is designed as centralised application, where travel information are collected in one central unit, which calculates an optimal solution. On the one hand, this is highly efficient, on the other hand this makes the realisation of an open platform, where new service provider can integrate their functionalities easily, nearly impractical. Furthermore the autonomy of services is not given, since only one instance (the planning unit) decides which information to choose. In a distributed environment the service provider could be able to dynamically add or remove its services from the platform. Within the domain of eMobility the topic of interoperability between service provider is highly discussed. In the following we present the current approaches in this area and relate them to the more generic topic of intermodal mobility planning.


\(^3\)http://www.hacon.de/hafas

\(^4\)http://reseplanerare.trafiken.nu

\(^5\)http://journeyplanner.tfl.gov.uk/, http://www.mvv-muenchen.de/
2.3. Interoperable eMobility systems

The eMobility domain, which is still in its dawn, turns out to consist of stakeholders of different business areas. In order to make the use case of riding an EV in daily life work, involved parties like car manufacturers, charging infrastructure providers, charging management sellers, energy provider and parking facility provider might be involved. All of these actors have to cooperate, yet, due to the different industrial starting points, there is currently no consensus on how such cooperation can be realised. The one thing which is required is a common system / platform / marketplace that enhances the interoperability between them.

Within the European Union, there are several projects concerned with this issue. The Green eMotion project for example ‘is elaborating the IT architecture for a European marketplace, including interfaces that will allow competition in the implementation of e-mobility solutions.’ Projects like Mobi.Europe\(^7\), ELVIRE\(^8\) and ECOGEM [9] are facing quite similar goals, just differing in the degree of extensibility and interoperability and having the main focus on different aspects of driver assistance.

In autumn 2012 a group of key players in the eMobility business founded the eMobility ICT Interopility Interest Group (EMI\(^3\))\(^9\), which aims to standardise ICT interfaces, application level protocols and to define a common eMobility domain model.

The focus on all these efforts lies in the realisation of interoperable eMobility systems. However, the vision of setting up a platform that is not only related to eMobility, but to all types of passenger transportation and mobility concepts is still missing. Further, questions like self-explanation and automated integration of services into a platform are not discussed.

One interesting mobility concept is ridesharing in urban areas. In the following we will identify current solutions and relate the advantages of integrating them to our vision of an open intermodal platform.

2.4. Dynamic ridesharing - portals

Following a survey on ridesharing\(^10\), the current ridesharing portals can be classified as follows: there are portals which are especially developed for commuters and compute outward and return journeys on a long range. Further, some carsharing agencies concentrate on the matching of long-distance journeys, where the factor of short-term matches plays an subsidiary role. Another approach are pure information portals\(^11\), which do not provide real matching algorithms, but only a list of offers and requests on which the user can search for its best match. In contrast to that, flexible carpooling portals do not provide any mechanism to select a specific journey partner, but do offer certain points of departure where they can meet other travelers and negotiate about journeys spontaneously. The most flexible alternative is the dynamic ridesharing, where a high degree of automation is possible and the user can find journeys rapidly. However, in this approach aspects like routing, scheduling, trust but also payment have to be considered. Portals, which try to cover all of these aspects are still rare. In the United States there are a few providers, which consider payment besides dynamic routing\(^12\). In Germany the first publicly available DRS system started in 2010 named flinc\(^13\). This portal supports matching on a short-term basis, while it does not have a real solution to the payment problem. It only provides suggestions to the travelers according to prospected fuel costs. One outstanding characteristic of flinc is the interconnection to navigation software, which enables drivers to receive suggestions on the way. However, the matching algorithm cannot match multiple passengers to one vehicle driver, which neglects a high potential of optimisation. Especially short-term ridesharing requires a critical set of participants in order to work. On the other hand, the potential user will just utilise such an application if the results are satisfactory. This dilemma can be solved by integrating such applications into a wider platform, where the integration of these services into the user requests happens seamlessly and where the user is provided with alternative solutions if a ridesharing offer is not available.

\(^6\)http://www.greenemotion-project.eu/
\(^7\)http://www.mobieurope.eu/
\(^8\)http://www.elvire.eu/
\(^9\)http://www.greenemotion-project.eu/upload/pdf/472_120472_pressemittlung_0812_220Green_eMotion.pdf
\(^10\)http://www-bcf.usc.edu/aged/publications/RS_Survey.pdf
\(^13\)www.flinc.de
2.5. Conclusion

There are numerous scientific and commercial approaches interconnecting public transport and private vehicles for an intermodal routing. However, none of the approaches considers integrating mobility concepts like car sharing and ridesharing and discuss the topic of an open and interoperable platform. Furthermore, the application of EVs and their respective challenges is on the one hand discussing exactly the topic of interoperability, but has to be seen as an isolated topic and not integrated in the domain of intermodal travel assistance systems. As a consequence there are no evaluations so far on how much impact a combination of all these approaches can have on urban areas.

3. Intermodal Mobility Assistant (IMA)

The aim of the project IMA (Intermodal Mobility Assistance for Megacities) is a more efficient and sustainable mobility behaviour of citizens and tourists to increase the quality of life in megacities. To reach this goal an open mobility platform with intermodal trip planning and monitoring functionality will be developed, where different mobility and infrastructure provider can be easily integrated.

3.1. System Architecture

Figure 1 shows the overall architecture consisting of the IMA platform, the users and the different providers. Each user will be dynamically informed about individual recommendations for intermodal routes of his trips based on his profile and the analysis and combination of the semantically described information from the providers. Adaptive user interfaces allow the usage of different kinds of mobile devices for the
interaction with the system. In case of limited availability of cellular networks, ad-hoc networks will be used especially for the transmission of huge amount of non time-critical data.

In addition to the intermodal trip planning and dynamic route adaptation, the IMA platform also analyses the traffic flow based on GPS data from the users and data from selected stationary cameras to extend and improve the data from external traffic information providers. The planned and monitored routes are therefore used to identify the current transportation mode of the users and to select the most relevant cameras. From the provider perspective, historical and anonymised mobility profile data of the users enables the platform to simulate the influence of changed offers of the mobility and infrastructure providers.

Security and privacy is one important aspect of IMA, which accounts for identity management, encrypted communication, access control for data and services as well as for management, enforcement and conflict resolution of security policies.

3.2. Use Cases

Figure 2 shows the actors and the use cases of the system. The use cases are grouped into the four main categories, namely User Management, Service Management, Intermodal Routing and External Information, which are described in the following sections in more detail.
3.2.1. User Management

The User Management contains the registration of a new user on the IMA platform, the definition of the user profile, the customization of services according to usability and last but not least the login into the platform. Examples of user profile entries are the weights of route optimization criteria (time, sustainability, costs), the selection of mobility providers and the own transportation means. These information will be used for creating the recommendations of the intermodal trip planning. Anonymous users will also be able to use the system but without stored preferences.

3.2.2. Service Management

A service provider can either develop a new IMA-compliant service or implement an appropriate adapter for an already existing service to attract more customers for his offers. An IMA-compliant service has to be semantically described based upon a consistent vocabulary and must implement predefined operations and protocols.

In order to be integrated into the IMA system the service provider has to register his services on the IMA platform. For this purpose he need a unique identity which must be verified before.

3.2.3. Intermodal Routing

Use cases which are related to routing are responsible for all aspects of assisting the user in finding an optimal mobility solution according to his specific needs. In these scenarios, there are at least four actors involved, namely the User Agent, the Vehicle Agent, the Traffic Operator Agent and the Mobility Provider Agent. The most essential scenario is obviously the trip planning itself, which can be divided into two chronologically different scenarios. One is the task of forward planning, which happens before a trip is initiated, and the other one is the planning at ‘runtime’, which means that the user already started his trip and the forward planning is either being refined or replaced by a new solution.

In order to receive a solution the user has to define his routing goals, which have to be transformed into a formal goal definition based upon a consistent vocabulary. In the following the IMA system evaluates which of the registered mobility- and routing-services are available and adds them to the knowledge base of the planning component. In a next step all services, which do not fit into the user’s preferences or attributes are being filtered, e.g. mobility services such as car sharing which presume the ownership of a drivers licence.

After these preparative tasks, the actual trip computation is being initiated. By means of specific map information of the region the route belongs to, the system evaluates important and therefore potential changing points for the user. Then a goal-oriented service composition process is started upon this information. Specifically, this means the concatenation of single routes plus the fulfilment of requirements, such as the availability of transportation at specific times. Each of the single steps are evaluated by a user-dependent weighting function and finally aggregated. The best scoring results are proposed to the user. If the option the user selects involves external resources, such as car sharing or bike sharing, the system takes over the task of booking these means of transportation. During the time the user is on his way his GPS data is being monitored and leads to a re-planning process if the data deviates from the forward planning. Furthermore the monitoring process accesses context information, such as traffic data or weather data, in order to recognise and react on delays, traffic jams, or other unforeseeable events.

The current approach of the intermodal routing process is still in its early stage. Issues like the definition of a user-dependent weighting function or the identification of appropriate changing points will be elaborated within the next working steps.

3.2.4. External Information

For usability purposes, the user is able to move information from websites or other services to the routing service via a so-called Inventory Service. For example, the manual input of addresses will be unnecessary in most cases.
4. Conclusion

In this paper we presented our approach in developing an open, extensible platform where mobility providers can offer their service in a standardised fashion. We began the paper with a comprehensive review of state-of-the-art approaches of intermodal mobility planning algorithms and service portals and also put a focus on eMobility systems and dynamic ridesharing as examples for ‘novel transportation concepts’. We used the dynamic ridesharing scenario to emphasise the effects of a lacking connection between different transportation concepts and motivated the development of an open, extensible platform, namely the IMA platform, which we sketched subsequently. First we presented the platform’s architecture and general operation principle. We continued our description by presenting use cases, the platform is supposed to handle. To start with, the IMA platform has to deal with profile management and allow different users to register at the platform. Secondly, we described the service development functionality of IMA. This feature allows mobility providers to develop their own mobility services at the IMA platform. Thirdly, we emphasised the routing functionality of the IMA platform, which accesses data from available mobility services and computes a route which is optimal with respect to the user’s preferences. Finally we outlined the platform’s feature to access so called external information, that is, data which is able to affect route decisions without being necessarily related to traffic itself. The aim of this paper was to motivate our idea and to outline the system’s architecture and functionality, rather than presenting a complete an evaluated approach. Most parts of the IMA platform are currently designed and about to be implemented. We are convinced that a unique representation of mobility services as well as an open accessible platform is able to increase the quality of mobility assistance systems in at least four aspects. First of which, different means of transportation can be considered far more precisely, since detailed information (e.g. availability, schedules, position, etc.) on each supported transport is centrally available. Secondly, mobility providers are able to easily offer their services. This openness mainly comforts small and medium-sized companies, which are able to challenge larger providers in a free competition. Thirdly, cascading aspects can be considered, since the platform is aware of the utilisation of each mean of transportation and also able to forward such information to routing procedures. Finally, the system ensures reliability due to many concurrent service offers.

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References