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Personalized Fully Multimodal Journey Planner

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Abstract.
We present an advanced journey planner designed to help travellers to take full advantage of the increasingly rich, and consequently more complex offering of mobility services available in modern cities. In contrast to existing systems, our journey planner is capable of planning with the full spectrum of mobility services; combining individual and collective, fixed-schedule as well as on-demand modes of transport, while taking into account individual user preferences and the availability of transport services. Furthermore, the planner is able to personalize journey planning for each individual user by employing a recommendation engine that builds a contextual model of the user from the observation of user's past travel choices. The planner has been deployed in four large European cities and positively evaluated by hundreds of users in field trials.

1 Introduction

The advent of new types of mobility services, such as bike, electric scooter or car sharing, real-time carpooling or next-generation taxi, has further expanded the already rich portfolio of means of travel available in modern cities. Providing intelligent tools that would help citizens make the best use of the mobility services on offer is thus needed more than ever.

Despite recent algorithmic advances [1], existing planners available in practise, such as Google Maps[5] or Here.com[6], address this need only partially. In particular, they only consider a limited subset of transport modes and their combinations, and they only provide limited ways for users to express their travel preferences.

Employing a generalized planning problem representation [4] and recommendation techniques [3], we have developed and deployed a journey planner that overcomes these limitations and provides a fully multimodal, contextually personalized journey planning capability.

2 System Description

The architecture of the planner follows standard system architecture patterns and comprises of the *data*, *business logic* and *presentation* layers (see Figure 1). The components of the data and business logic layers are deployed primarily on the backend server while the presentation layer components run primarily in a client's web browser. Below we describe the main components in a more detail.

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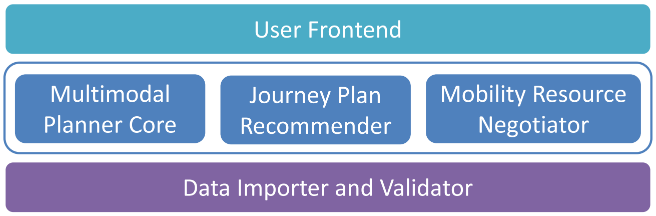

Figure 1. Conceptual architecture of the journey planning system.

2.1 Data Importer and Validator

Importing, validating and integrating various data sources required for fully multimodal journey planning is a complex and error-prone task. Even minor inconsistencies in underlying data, their mutual mapping or translation into internal data models can severely degrade the quality of resulting journey plans. Data import and validation tools are thus an essential component of our journey planning system. To facilitate deployment, the planner uses, where possible, open data formats for its input data. The most important types of input data are the following:

- *Road, cycleway and footpath networks* data are required for planning journeys involving car, bike and walk, respectively. For representing and importing such data, the system uses the *OpenStreetMaps*[7] format which is expressive enough to represent all transport network features considered by the journey planner.
- *Public transport stops, routes and timetables* are required for planning journeys involving scheduled public transport services. The widely adopted *General Transit Feed Specification (GTFS)*[8] format is used to represent public transport data.

The planner uses a range of additional data, including the information about vehicle and bicycle sharing stations, parking facilities, public transport fares and situational data, such as weather and pollution. Upon import, information from different data sources is translated, cross-referenced and integrated into a unified internal time-dependent graph representation (see below).

2.2 Multimodal Planner Core

At the centre of the system is the fully multimodal planner core capable of finding multi-leg intermodal journeys employing any transport mode and/or mode combination available in a city. Internally, the planner employs modified Dijkstra's and A* search algorithms

[7] http://openstreetmaps.org
[8] https://developers.google.com/transit/gtfs/

on top of generalised time-dependent graphs. The generalised time-dependent graph [4] is a recently proposed data structure that encodes the information about all transport modes in a single planning graph, thus enabling fully multimodal journey planning.

To promote modularity and extensibility, the planner employs a novel multi-critics architecture that relies on the notion of *critics*, specialized modules for evaluating candidate journey plans from a certain perspective, e.g., price, emissions or user convenience. The multi-critics architecture allows introducing new concerns and/or objectives to journey planning without modifying the core planning logic. At the moment, the planner considers distance, duration, CO_2 emissions, physical effort and user satisfaction in journey planning.

2.3 Recommender Engine

The personalization of journey plans is implemented through the recommender module. By observing past users' travel choices and their situational context, the recommender learns a model of the user and leverages this model to provide tailored journey plans reflecting the unique preferences of each user. The recommender employs latest developments in context-aware recommendation [3] as well as collaborative filtering algorithms to enhance journey plans with points of interest that might be relevant to the user. Technically, recommendation is integrated with journey planning through a critic that provides user satisfaction scores for different candidate journey plans.

A number of journey features are used for building the user model, including journey elevation, duration, distance, transport mode, cost and physical effort exerted. Furthermore, situational context attributes concerning the city (i.e., weather, illumination, pollution and time of the day) as well as the user perspective (i.e., purpose of journey and companionship) are reflected in journey recommendations.

2.4 Mobility Resource Negotiator

The planner supports the full range of transport modes, including services with limited capacity, such as parking, or those that need to be arranged on request, such as taxis or car sharing. To facilitate the use of such services the planner employs a *mobility resource negotiator* component. The mobility negotiator interacts with the transport service providers on behalf of the user and allows selecting and reserving services that best match the requirements of the journey plan under consideration. Similarly to the recommender, the resource negotiator is integrated with journey planning through a resource critic, which provides the planner with the feedback on the expected availability and price of requested mobility resources and which can automatically reserve the resources if authorized to do so by the user.

2.5 Web-based Frontend

The demonstration version of the planning system includes a simplified web-based frontend which allows users to submit journey planning requests and interactively explore recommended journey plans (see Figure 2). More feature-rich frontends, both web- and smartphone-based, are available as part of the full SUPERHUB software platform [2]. The frontend is integrated with the planner backend through a web services API. This allows additional, third party applications and services to be developed on top of the planner.

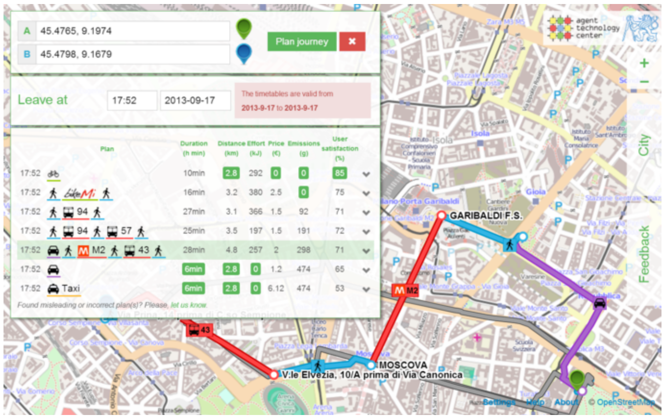

Figure 2. Web-based frontend for the planner. A set of fully multimodal journey plans returned by the planner for the city of Milan is shown together with the values of six supported journey criteria for each plan.

3 Real-World Deployment and Evaluation

We deployed the presented planner, along with additional components, as part of the SUPERHUB project's[9] field trials in three large European cities (Barcelona, Helsinki, and Milan). Several hundred trial participants used the planner for a period of three weeks. The feedback was largely positive – the users commended the quality of plans and the responsiveness of the system, which was able to return plans within one second in most circumstances.

As part of the evaluation process, we compared our planner with the Google Maps multimodal journey planner provided through Google Directions API[10]. Despite having a broader set of features, our planner provided comparable or better journey plans when compared in terms of journey duration and the number of transfers.

We currently work on a significantly extended version of the planner supporting planning with real-time traffic and transport data, automated on-trip replanning and improved booking and reservation. The lastest version of the planner is accessible on-line from http://agents4its.net.

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[9] http://superhub-project.eu

[10] https://developers.google.com/maps/documentation/directions/