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Multimodal transport planning for Brno and the South Moravian Region

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Abstract
This paper presents the design and implementation of a multimodal transport planner as a web application. The solution realizes journey planning for several transportation modes, with walking, car transport and public transport being among those included. The planner is specialized for the city of Brno and the region surrounding it. Its design and main source of data, however, allow deployment for many transport systems around the world. The primary data source for the application is a *GTFS* dataset. An external service, such as *OpenTripPlanner 2*, supported by this GTFS data is used to facilitate routing. However, a clever use of the *adapter* design pattern enables the use of an arbitrary routing service. The planner targets a wide range of users, including daily commuters and tourists.

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1. Introduction

The market of journey planners includes many popular applications. Travellers in and around the city of Brno primarily make use of solutions such as Mapy.com[1], Waze[2] and IDOS[3]. The mentioned applications, and many other alternatives, are well established and approach the problem they aim to solve very well. However, they can often fall short in several important aspects.

These solutions often lack support for combining multiple transport modes within a single journey. This can be problematic in scenarios such as combining car and public transport or planning trips involving walking and commuting, often forcing users to plan multiple routes separately or worse, use several applications.

A couple of promising approaches to multimodal transport routing have been developed at Brno University of Technology. *CarPub* [1] tackles the combination of car and public transport, using clever algorithms to find *Park and Ride* transfer points between these two modes. Also incorporating a scoring system to suggest only the best options to the user. *Walk And Ride* [2] integrates the use of walking alongside public transport, even allowing the user to define midpoints along the route. This work builds upon these approaches and combines all three mentioned modes into a single application.

[1]https://mapy.com/
[2]https://www.waze.com/
[3]https://idos.cz/

2. Architecture

The planner architecture (along with utilised technologies) is shown in Figure 1. The system is divided into three layers: client, application and database.

The client layer provides the user interface for trip requests, route visualization, preference configuration and route export.

The application layer processes trip requests, retrieves route options using the routing service adapter (described in section 2.1), and filters and rates them, returning up to five options. Necessary route visualization data is fetched from the database layer.

The database layer holds the current and historical state of the transport system, created from daily GTFS data. However, the implemented database is not specific to the planner, as it is a part of an existing application the planner is integrated into. The integration is discussed in section 2.2.

The planner also uses external APIs: *Nominatim* for reverse geocoding and *Overpass* for retrieving parking locations.

2.1 Routing Service Adapter

OpenTripPlanner 2 is a well-established routing service. However, it can be beneficial to have the ability to use different services based on configuration.

This is made possible by utilizing the *adapter* design pattern, shown on Figure 2. This design allows for static or dynamic switching between these services.

2.2 Lissy Integration

As was mentioned before, the planner is integrated as a new module into an existing application. This application is called Lissy[4], which is a tool providing analysis and visualization of public transport data in Brno. It is under maintenance of Ing. Juraj Lazúr at Brno University of Technology [3].

The previously mentioned applications CarPub and Walk and Ride already use Lissy as an external service, which would be no different for the new solution. For this reason, the integration of the new planner directly into Lissy presents itself as advantageous. It would enable centralization of related tools and local communication and UI consistency between modules.

3. Implementation and Key Functionality

The implementation follows the existing Lissy technology stack. The client is built using `Angular`, while the server uses `Node.js`. The application layer is implemented in `TypeScript`.

The user interface supports both desktop and mobile devices, as shown in Figures 5–8.

3.1 Smart Combining of Modes

The planner supports a set of different transport modes. It is essential to suggest the right options in scenarios, where a combination of at least two modes is used.

- Car and walking: selection based on distance and user-defined walking limits.
- Car and public transport: combines both modes using an improved Park and Ride approach (Section 3.2).
- Walking and public transport: combines public transport options with walking-only alternatives.
- All modes: combines the above strategies.

3.2 Park and Ride trips

For trips combining car and public transport, a scoring mechanism based on an adjusted version of the *Public Transport Access Level* (PTAL) [4] measure is used. This mechanism evaluates stop quality based on service frequency and mode diversity.

Scores of stops near the origin and destination are evaluated to avoid multimodal routing in situations, where it might not be beneficial (such as origin and destination being high-frequency hubs in the same city).

If the multimodal trip is suitable, these scores are used to select transfer hubs based on a score threshold and parking availability. Candidate hubs for the trip will only be found in a certain radius between the trip origin and destination points. A geometric explanation of the candidate catchment area is shown in Figure 4.

If the number of these candidates reaches a certain threshold, *KMeans* clustering is performed, in order to limit the number of possibilities. The best-scored hub is picked from each cluster.

3.3 Route Selection System

Routing services, such as OTP, may return a larger number of possible route options than suitable for showing in the client. For this reason, a route selection system is implemented in the application layer. Figure 3 contains a diagram describing this system.

A list of initial route options is fetched from the service adapter (section 2.1). Some of the options are filtered out, because they don't comply with user-specified preferences. A deduplication step is also performed to remove options that have the exact same shape as other options, but leave at a different time.

The filtered list is limited to only pareto-optimal options within a set of four criteria [5]. The values of these criteria are utilized to calculate a normalized 0–100 score for each option using Equation 1.

The last step is a selection of up to 5 options. This selection always includes the best scored, fastest and cheapest options. The remaining spots are filled with the next best options, according to the calculated scores.

3.4 Other features

A few more of the planner functionalities worth mentioning include:

- Transit leg re-routing (next/previous connection)
- Return trips respecting parked vehicles
- Use of current device location
- Route import and export

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[4] https://dexter.fit.vutbr.cz/lissy/

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