Intermodal route planning

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Intermodal route planning allows the use of different modes of transportation along a route from a starting point to a destination. The challenge is to compute reasonable sequences of transportation modes along a route. For example, it is generally not possible to start a route on foot or by bus and then get into a car, as these are not available at every location. Furthermore, time-dependent public transportation timetables pose additional challenges when modeling departure and transfer times.

Intermodal route planning is becoming increasingly important due to the mobility transition and the associated goal of avoiding pollution. Routes from home to the nearest supermarket, pharmacy, recreational facilities, or doctor should not be significantly longer or more inconvenient than the direct route by car when using public transportation. Intermodal accessibility also plays an important role in the evaluation of different districts, neighborhoods, or individual locations. The theory provides a basis for assessing the accessibility of locations by public transportation. Good public transport connections can significantly increase the attractiveness of residential areas for broad parts of the population.

In this talk, we present the mathematical theory for algorithmically computing intermodal shortest paths and show computations of intermodal routes on real road networks.

The mathematical modeling of intermodal shortest path problems was first introduced by Barrett et. al in 2000 and extended by Kirchler in 2013. Real road networks can be abstracted and modeled as a mathematical graph. This abstraction preserves important properties such as intersections, turn restrictions, and one-way streets. If a certain mode of transport is allowed or available on a road, a corresponding edge can be created in the network for each mode of transport with the corresponding, possibly time dependent, travel time. With the help of so-called automata theory, individual combinations of different means of transport can be specifically prohibited. The theory also allows other important criteria to be taken into account on intermodal routes. For example, the length of individual walking or cycling segments can be limited. The number of changes in local public transport or the number of different modes of transport on a route can also be regulated with the help of automatons.

The computation of intermodal shortest paths provides the basis for more complex intermodal accessibility analyses of a smart city. In addition to the mathematical foundations, we demonstrate several such analyses. In a standard variant, a set of points of interest is given and for each point of the road network the shortest intermodal path to the nearest point of interest is calculated. This variant can easily be extended to include the distance to the second or third closest point of interest. Development plans can also be taken into account to reduce the weight of uninhabited areas or can even exclude them from the analysis. Furthermore, catchment areas of selected points of interest, such as doctors' surgeries or recreational facilities, can be calculated if a fixed time frame is specified for the duration of the trip. Different points of interest often have different user groups. Automata theory can be used to simulate the analyses for different user profiles.

We also show how these analyses can be performed on a time-dependent basis, into account taking public transportation timetables. For a meaningful accessibility analysis, the calculations can be performed at different times of the day and the results can then be averaged. To visualize our results, we use heat maps that color areas of a city according to their intermodal accessibility to the selected points of interest.

Literature:

Barrett, C. et al.: Formal-Language Constrained Path Problems, SIAM J. Comput. 2000

Kirchler, D.: Efficient routing on multi-modal transportation networks, Ecole Polytechnique X, 2013.