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Towards System-Aware Routes*

Matthias Prandtstetter and Clovis Seragiotto

AIT Austrian Institute of Technology
Mobility Department – Dynamic Transportation Systems
`<firstName>.<lastName>@ait.ac.at`
`http://www.ait.ac.at/`

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1 Introduction

Within this paper, we focus on the development of algorithms capable of providing route suggestions to multiple simultaneously traveling users such that the (negative) impacts of the routes among each other are minimized. We refer to this kind of routes as *system-aware routes*. E.g., if multiple travelers are concurrently following the same route in a street network, it is most likely that traffic congestion occur. If the same set of travelers is, however, distributed over multiple roads/routes, the traffic flow is maintained and negative effects like increased CO_2 emissions are reduced.

Today's routing and navigation devices are, in most cases, not connected with each other, meaning that each user request is handled separately—even if the routing requests are all processed on a centrally operated infrastructure. However, dependent on the availability of traffic data, some devices adapt route suggestions based on observed (or typical) traffic conditions. This behavior leads to a so-called *user equilibrium* (UE) [5] where travelers cannot reduce their individual travel time by choosing another route.

In contrast to an UE, a *system optimum* (SO) [5] consists of a traffic state where the average travel time is minimized. Obviously, this statement is equivalent to the observation that in a SO the overall travel time, i.e. the sum of all travel times, is minimized or the (overall) traffic flow is maximized. Negative environmental impacts caused by traffic congestion are reduced as well. Reaching a SO requires cooperative travelers as well as supporting technologies sharing—among others—(traffic) information with each other.

First solutions to the basic underlying problem of finding a shortest route in a given network reach back to the late 50ies [2]. There were significant improvements in the last decade, especially with respect to speeding-up techniques via pre-processing, cf. [3] or [1] for a more comprehensive survey,. There is, however,

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only one other work focusing on the system-optimal traffic assignment [4] and—to the best of our knowledge—no other work focusing on the computation of a system optimum with respect to individual routes.

2 Computing System-Aware Routes

The basic problem of finding a route r_i for user $i \in U$, with U denoting the set of users, minimizing the (negative) impacts on all other users $j \in U$, $j \neq i$, can be modeled by:

$$\min \quad \alpha \cdot l(r_i) + \beta \cdot \sum_{j \in U \setminus \{i\}} e_i(r_j) \tag{1}$$

$$\text{s.t.} \quad r_i \text{ is a route from } o(i) \text{ to } d(i), \tag{2}$$

where function l denotes the length (e.g. travel time) of a route, $o(i)$ and $d(i)$ denote the origin and destination of traveler i and function e_i estimates the delay of one route due to another route, i.e. extra travel time due to congestion. Coefficients α and β can be used to (relatively) weight the actual route length to the effects on other routes. It is obvious that this formulation requires an iterative solution procedure if all mutual impacts shall be minimized. Therefore, we suggest a second, alternative formulation leading directly to a SO. The effects of route r_i on other route lengths, i.e. $e_i(r_j)$, are already incorporated in function l.

$$\min \quad \sum_{i \in U} l(r_i) \tag{3}$$

$$\text{s.t.} \quad r_i \text{ is a route from } o(i) \text{ to } d(i), \text{for all } i \in U \tag{4}$$

In the talk, we introduce two algorithmic approaches for solving the two stated problem formulations where for the first an iterated local search is applied and for the second a dynamic program is suggested. Experimental results—including a comparison of the practicability of the approaches—conclude the presentation.

References

1. Delling, D., Goldberg, A., Werneck, R., Pajor, T.: Route planning in transportation networks. Tech. Rep. MSR-TR-2014-4 (January 2014), https://www.microsoft.com/en-us/research/publication/route-planning-in-transportation-networks/
2. Dijkstra, E.W.: A note on two problems in connexion with graphs. Numerische Mathematik 1(1), 269–271 (1959)
3. Geisberger, R., Sanders, P., Schultes, D., Delling, D.: Contraction hierarchies: Faster and simpler hierarchical routing in road networks. In: McGeoch, C.C. (ed.) Experimental Algorithms, Lecture Notes in Computer Science, vol. 5038, pp. 319–333. Springer Berlin Heidelberg (2008)
4. Köhler, E., Möhring, R.H., Skutella, M.: Traffic networks and flows over time. In: Algorithmics of Large and Complex Networks, pp. 166–196. Springer (2009)
5. Wardrop, J.G.: Some theoretical aspects of road traffic research. Proceedings of the Institute of Civil Engineers, Part II 1, 325–378 (1952)