Project Number 288094

eCOMPASS

eCO-friendly urban Multi-modal route PlAnning Services for mobile uSers

STREP

Funded by EC, INFSO-G4(ICT for Transport) under FP7

eCOMPASS – TR – 033

Algorithms for Transport Optimization Theory and Practice

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October 2013

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Public or private transport gives rise to several optimization problems, which are typically characterized by high complexity and sheer size, while some of them pose, in addition, real-time response constraints. Efficient algorithms can make a great difference towards an efficient and effective solution of such problems. In this talk, a few important algorithmic approaches are surveyed that are theoretically sound and practically efficient for the transport optimization problems they solve.

In the first part of the talk, robustness issues are investigated for the line planning problem in public transport under a specific uncertainty setting, motivated by recent market regulations in the railway sector. In this setting, a potentially large number of line operators, operating as commercial organizations, offer services to customers, while a central (typically state) authority manages the railway network infrastructure. The line operators act as competing agents for the exploitation of the shared infrastructure and are unwilling to disclose their true incentives (utility functions). The network manager wishes to set up a fair cost sharing scheme for the usage of the shared resources and to ensure the maximum possible level of satisfaction of the competing agents. The challenge is to provide a solution that is robust to the unknown incentives of the line operators, which are neither predictable or quantifiable nor statically describable. Towards this goal, a decentralized incentive-compatible mechanism is presented [1, 2] whose equilibrium point is (provably) the unknown social optimum. An accompanying experimental study of the aforementioned mechanism on both synthetic and real-world data shows fast convergence to the optimum. A wide range of scenarios is also explored, varying from an arbitrary initial state (to be solved) to small disruptions in a previously optimal solution (to be recovered). The experiments with the latter scenario show that the particular mechanism can be used as an online recovery scheme causing the system to re-converge to its optimum extremely fast.

In the second part of the talk, the route planning problem in large-scale road networks is investigated, focusing on two main issues: the efficient representation of such networks in a dynamic environment, and the computation (of not only a single optimal route but) of several source-to-destination alternative routes with specific quality characteristics.

To address the first issue, a new dynamic graph structure [3] is presented that is specifically suited for large-scale transportation networks providing simultaneously three unique features:

- *Compactness*: ability to efficiently access adjacent nodes or edges, a requirement set by all query algorithms in order to meet real-time response constraints.
- *Agility*: ability to change and reconfigure the graph's internal layout in order to improve the locality of the elements, according to a given algorithm.
- *Dynamicity*: ability to efficiently insert or delete nodes and edges.

The practicality and superiority of the new graph structure is demonstrated by an experimental study for shortest route planning in large-scale European and US road networks with a few dozen millions of nodes and edges. The particular structure is the first one that concerns the dynamic maintenance of a large-scale graph with ordered elements using a contiguous memory part, and which allows an arbitrary online reordering of its elements.

To address the second issue, improved methods are presented for computing a set of alternative source-to-destination routes in road networks in the form of an alternative graph [4]. The produced alternative graph is characterized by minimum path overlap, small stretch factor, as well as low size and complexity. Two existing approaches are surveyed and a new one is presented that improves upon those. An accompanying experimental study shows that the new approach can compute the entire alternative graph pretty fast even in continental size networks.

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