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Summary of Recent Research

Fast and Accurate Route Planning in Road Networks

http://algo2.iti.uka.de/schultes/hwy/

Highway Hierarchies. The computation of shortest paths in a graph is a well-known problem in graph theory. One of the most obvious practical applications is route planning in a road network, i.e., finding an optimal route from a start location to a target location. It is often assumed that a given road network does not change very often and that there are many source-target queries on the same network so that it pays to invest some time for a preprocessing step that accelerates all further queries.

We developed a new speedup technique for route planning—*highway hierarchies* [1, 2, 3]—that exploits the hierarchy inherent in real-world road networks. In a preprocessing step, we investigate the given road network in order to extract and prepare a hierarchical representation. Our route planning algorithm then takes advantage of this data. It is an adaptation of the bidirectional version of Dijkstra's algorithm, massively restricting its search space.

In several experiments, we concentrate on the computation of fastest routes in Western Europe and the USA. Both networks consist of about 20 million nodes each. Our algorithm preprocesses these networks in 20 minutes using linear space. Queries then take less than one millisecond to produce optimal routes. This is more than 7 000 times faster than using Dijkstra's algorithm.

Combination with Goal-Directed Search. A combination [4] with a goal-directed approach, namely landmark-based A*-search, yields a slight reduction of the query times. In particular, such a combination is useful when we deal with approximate queries or with a distance metric (instead of the usual travel time metric).

Many-to-Many Shortest Paths. A many-to-many variant [5] of the highway hierarchies is capable of computing distance tables that contain for given source and target node sets the shortest path distances between all source-target pairs. For example, a $10\,000 \times 10\,000$ table can be filled in about one minute.

Transit Node Routing [6, 7, 8] is based on the following observation: "When you drive to somewhere 'far away', you will leave your current location via one of only a few 'important' traffic junctions [*transit nodes*]". Distances from each node to all neighbouring transit nodes and between all transit nodes are precomputed so that a non-local shortest-path query can be reduced to a small number of table lookups. That way, average query times can be reduced to around five microseconds, which is about one million times faster than using Dijkstra's algorithm.

Highway-Node Routing [9] is a *dynamic* technique for fast route planning in large road networks. For the first time, it is possible to handle the practically relevant scenarios that arise in present-day navigation systems: When an edge weight changes (e.g., due to a traffic jam), we can update the preprocessed information in 2–40 ms allowing subsequent fast queries in about one millisecond on average. When we want to perform only a single query, we can skip the comparatively expensive update step and directly perform a prudent query that automatically takes the changed situation into account. If the overall cost function changes (e.g., due to a different vehicle type), recomputing the preprocessed information takes typically less than two minutes.

The foundation of our dynamic method is a new static approach that generalises and combines several previous speedup techniques. It has outstandingly low memory requirements of only a few bytes per node.

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