Scalability of Route Planning Techniques
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Research Question  How do Route Planning Techniques scale on Road Networks?

Shortest Path Problem
Given graph $G(V, E)$
Query source $s \in V$, target $t \in V$
Goal distance of shortest path from $s$ to $t$

Route Planning Techniques on Western Europe
<table>
<thead>
<tr>
<th>Contraction Hierarchies</th>
<th>Transit Nodes</th>
<th>Hub Labels</th>
</tr>
</thead>
<tbody>
<tr>
<td>query 110 µs &gt; 2.09 µs &gt; 0.56 µs</td>
<td></td>
<td></td>
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<tr>
<td>space 0.4 GB &lt; 2.5 GB &lt; 18.8 GB</td>
<td></td>
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</tbody>
</table>

Road Network Generator

Step I: Cut Tiles from Real-World Network

Step II: Combine Tiles

Validation

Relative network length of road types

<table>
<thead>
<tr>
<th>degree</th>
<th>1 2 3 4 &gt; 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>network</td>
<td>6.5% 75.5% 15.6% 2.2% 0.3%</td>
</tr>
<tr>
<td>Germany</td>
<td>6.2% 76.1% 15.3% 2.2% 0.3%</td>
</tr>
</tbody>
</table>

Scalability Study

Setup
Networks with 2 000 to 800 million nodes
Route Planning Techniques
Contraction Hierarchies (Edge Difference)
Hub Labels (CH-based)
Hub Labels (Skeleton-based)
Transit Nodes (CH-based)

Model functions
polylogarithmic growth $f(x) = a \cdot \log_2(x)^b$
polynomial growth $g(x) = a \cdot x^b$

Fitting
Marquardt-Levenberg algorithm modifies parameters iteratively
Sum of squares of residuals (SSR) gaps between data and fitted function
Asymptotic standard error (ASE) approximation for the standard deviation

Results
Hub Labels (CH-based) $O(n^{0.25})$, $O(n^{1.25})$
Hub Labels (Skeleton-based) $O(n \log^{0.36} n)$, $O(n \log^{0.36} n)$
Contraction Hierarchies $O(\sqrt{n})$, $O(n)$
Transit Nodes $O(n)$, $O(n \sqrt{n})$