Advanced Route Planning and Related Topics

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http://algo2.iti.kit.edu/routeplanning.php
Agenda of this Talk

- Time-dependent Routing
- Energy-efficient Routing
- Alternative Paths
- Future Route-Planning
- I -

Time-dependent Routing
Edge weights are pairs \((f, C)\)
- Travel time function \(f : \text{point in time} \mapsto \Delta \text{travel time}\)
- Cost function \(C : \text{point in time} \mapsto \text{cost}\)

Kinds of user queries:
- optimal route for fixed departure time \(\tau_0\)
- cost profile for departure time interval \([a, b]\)

Special case FIFO earliest arrival routing
- \(f\) has FIFO-property and \(C := f\)
Time-dependent Routing
FIFO Earliest Arrival vs. Minimum Cost

FIFO earliest arrival Routing
- waiting does not help
- optimal route has optimal prefixes
- solved efficiently by
  [TCH09] [ATCH10] [SHARC08] [CALT08] [SHARC10]

Special case of Minimum Cost routing: \( C := f + c \)
- waiting does not help – nice
- suboptimal prefixes of optimal routes – not nice
- Solved unefficiently by bicriteria pareto search
⇒ Difficult enough!

Application: optimize travel time + \( p \cdot \text{distance} \)
Time-dependent Routing  
FIFO Earliest Arrival Routing with Contraction Hierarchies

German road network: $\approx 4.7 \text{ M nodes and } \approx 10.8 \text{ M edges}$

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Time-dependent Routing
FIFO Earliest Arrival Routing with Contraction Hierarchies

- Order nodes by importance
- Obtain the next higher level by contracting the next node
- Preserve shortest paths by using shortcuts

Difficult if optimal routes can have suboptimal prefixes
Time-dependent Routing
Suboptimal Prefix of Optimal Route – Example 1

When a *little loss in time* eats up a *great gain in distance.*
When an advantage in time cannot compensate a smaller distance.
1. Less shortcuts can be omitted — condition harder to fulfill: $\forall \tau : f_1(\tau) \leq f_2(\tau) \land c_1 \leq c_2$

2. Merging shortcuts removes less information — some suboptimal prefix information must be kept

3. Finding a witness pareto profile set is really expensive — pareto profile search takes much time

We hope to overcome by careful use of (conservative) heuristics
Time-dependent Routing

Shortcuts – Difficult with Suboptimal Prefixes

1. Less shortcuts can be **omitted**
   — condition **harder** to fulfill: \( \forall \tau : f_1(\tau) \leq f_2(\tau) \wedge c_1 \leq c_2 \)

2. **Merging** shortcuts removes less information
   — some subotimal prefix information must be kept

3. Finding a **witness pareto profile set** is **really** expensive
   — pareto profile search takes much time

We hope to overcome by careful use of (conservative) **heuristics**

\[
C_1 := f_1 + c_1 \\
C_2 := f_2 + c_2
\]
Energy Efficient Routing
Energy Efficient Routing

due to multiple input parameters complicated problem

- type of vehicle
- road characteristics
- driver behaviour
- physical laws
so why even care about energy efficient routing?
- to save money on gas?
- to save the world?

...very hard problem for something that is not going to happen

→ still interesting algorithmic problems to consider
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→ still interesting algorithmic problems to consider
Energy Efficient Routing

Resulting subproblems
- fast GPS matching
- classification of road characteristics, e.g.
  - elevation profiles
  - detection of traffic lights
  - …
- simplification of energy consumption models
- automatic driver classification
- adaptable route planning algorithms (e.g. FlexCH)
Energy Efficient Routing

- use categorization to tackle large parameter space
  - roads (surface, slope, . . .)
  - intersections (right of way, traffic lights, . . .)
  - drivers (aggressive, careful, . . .)
  - vehicle

- utilize detailed GPS-traces

- result: large scale energy consumption model
Acceptance of energy efficiency is crucial

- hourly wages model
- consider combination of energy savings and time spent
- offer as alternative
- usage in electric vehicle range prediction
- let user tune parameters for his best choice . . .
  . . . or even tune automatically
- III -

Alternative Paths
Alternative Paths

Introduction

Just the optimal route might not be enough
⇒ providing meaningful alternatives

- only slightly longer
- sufficiently disjoint
- locally optimal
Alternative Paths

Introduction

Just the optimal route might not be enough
⇒ providing meaningful alternatives

- only slightly longer
- sufficiently disjoint
- locally optimal
Several previous approaches exist:

- **Via Nodes Alternatives**  
  (Abraham et al. SEA2010)

- **Alternative Graphs**  
  (Bader et al. TAPAS 2011)
Alternative Paths
Via Nodes Alternatives

Improve results:
- CH with relaxed shortcuts yields more good candidates

Hasten queries:
- CHASE instead of CH (full Arcflags feasible due to PHAST)
- Store via candidates for all region pairs
  → small candidate set sufficient for each pair
  → fast lookup of alternative paths
Alternative Paths

Via Nodes Alternatives

Improve results:
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Alternative Paths

Procedure

Preprocessing:
- Partition graph
- Compute via nodes between all boundary nodes of each region pair

Query:
- Lookup via candidates
- Evaluate alternatives
- Report best one
Alternative Paths

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Alternative Paths

Efficiency

Preprocessing:
- Many-to-Many queries
- Minimize Via Nodes Set
- Online Computation

Query:
- CHASE w. compressed ArcFlags
- Precomputed Via Nodes Labels
Future Route-Planning
Car Routing

- Energy consumption
- Other modelling aspects (traffic lights, turn costs, ...)
- Take traffic situation into account
- Extrapolate into the future, e.g., secondary traffic jams
Multimodal Routing

- difficult
- language constrained paths may not be the answer
- consider useful special cases?
  - route alternatives at park-and-ride subway stations ignoring concrete departure times
  - public transportation around a single flight connection
  - ...
Pedestrian and Bicycle Routing

- Models again, danger, fun,…
- **Elevation** becomes important
- geometric routing on squares etc?
- “online”-routing, e.g., two blocks north five blocks west grasping opportunities for crossing streets
Routing-Intensive Applications

- Multiday trip planning, plan breaks, or multiple ferries (great advertising opportunities?), scenery and sights? Integrate social networking, photos, etc.
- Ride-sharing
- Call-busses
- Real-estate
  - sort offers regarding distances to work, schools, shopping, etc.
  - Show iso-driving-distance maps
Social Networking goes Geographic?

- Integrate with ride sharing
- Crowdsourcing works for OpenStreetMap
- Cooperate with them?
- Use GPS-Traces real-time
Thank you for Your Attention!

Time for Questions