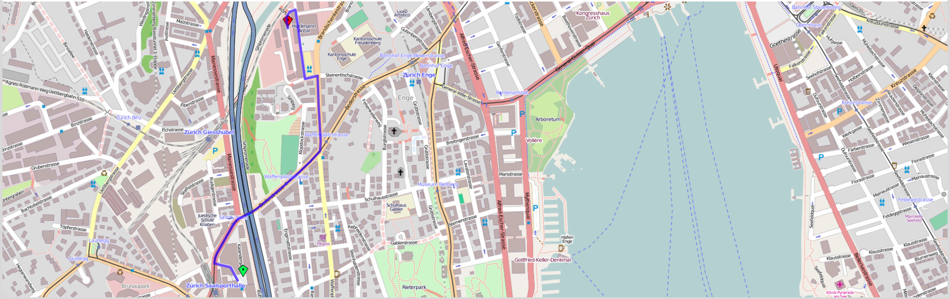
Karlsruhe Institute of Technology

Advanced Route Planning and Related Topics

G.V. Batz, M. Kobitzsch, D. Luxen, *P. Sanders*, D. Schieferdecker

`http://algo2.iti.kit.edu/routeplanning.php`

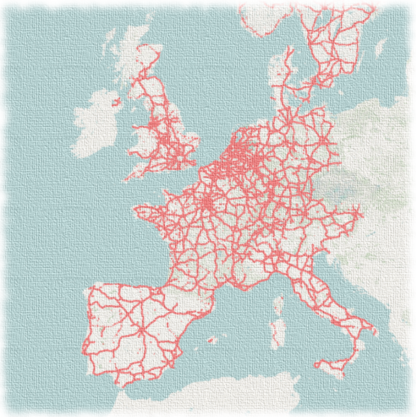
Department of Informatics, Institute for Theoretical Informatics, Algorithms II



KIT – University of the State of Baden-Württemberg and
National Large-scale Research Center of the Helmholtz Association

Agenda of this Talk

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



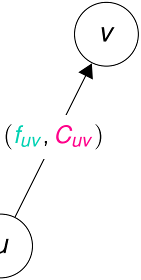
- I -
Time-dependent Routing

Time-dependent Routing

Time-dependent Minimum Cost Routing

Edge weights are pairs (f, C)

- Travel time function f : point in time $\mapsto$ Δ travel time
- Cost function C : point in time $\mapsto$ cost



Kinds of user queries:

- optimal route for fixed departure time τ_0
- cost profile for departure time interval $[a, b]$

Special case FIFO earliest arrival routing

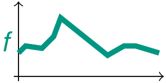
- f has FIFO-property and $C := f$

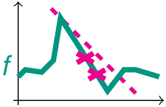
Time-dependent Routing

FIFO Earliest Arrival vs. Mininimum Cost

FIFO earliest arrival Routing

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

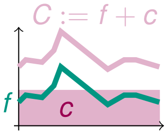


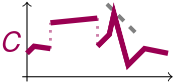


Special case of Minimum Cost routing: $C := f + c$

- waiting does not help – nice
- suboptimal prefixes of optimal routes – not nice
- Solved unefficiently by bicriteria pareto search

$\Rightarrow$ Difficult enough!





Application: optimize travel time $+\ p \cdot$ distance

Time-dependent Routing

FIFO Earliest Arrival Routing with Contraction Hierarchies

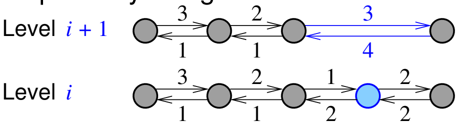
German road network: $\approx$ 4.7 M nodes and $\approx$ 10.8 M edges

	ε	space	EA query		profile query		error [%]	
method	[%]	ovh. [B/n]	[ms]	SPD	[ms]	“SPD”	MAX	AVG
TCH	–	898	0.85	1 252	1114.96	11.75	0.00	0.00
ATCH	1.0	144	1.15	922	33.27	31.88	0.00	0.00
ATCH	2.5	112	1.24	854	36.56	27.65	0.00	0.00
ATCH	∞	22	1.47	720	77.66	13.66	0.00	0.00
CALT	–	50		280	–	–	0.00	0.00
SHARC	–	150		60		0.02	0.00	0.00
SHARC+ALT	–	219		238	–	–	0.00	0.00
inexact TCH	1.0	118	0.72	1 467	2.96	358.13	1.03	0.27
inexact TCH	2.5	76	0.74	1 429	2.09	506.39	2.44	0.79
approximate CALT	–	50		804		–	13.84	
heuristic sharc	–	137		2 164		1.04	0.61	
space-eff. SHARC	–	68		1 177		–	0.61	
space-eff. SHARC	–	14		491		–	0.61	

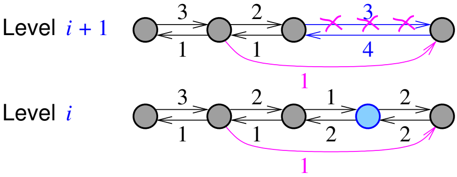
Time-dependent Routing

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



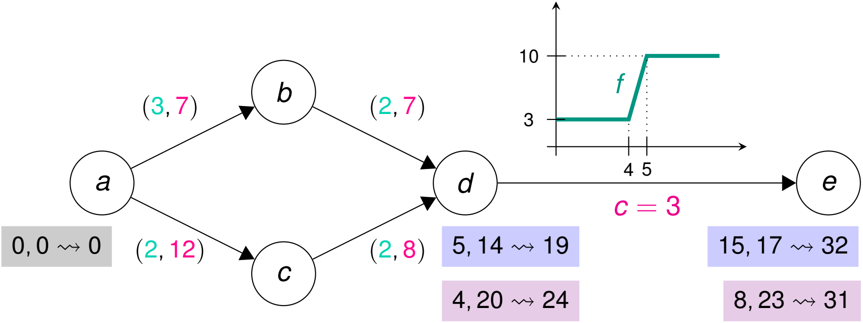
- **But** shortcuts are not always needed:



Difficult if optimal routes can have suboptimal prefixes

Time-dependent Routing

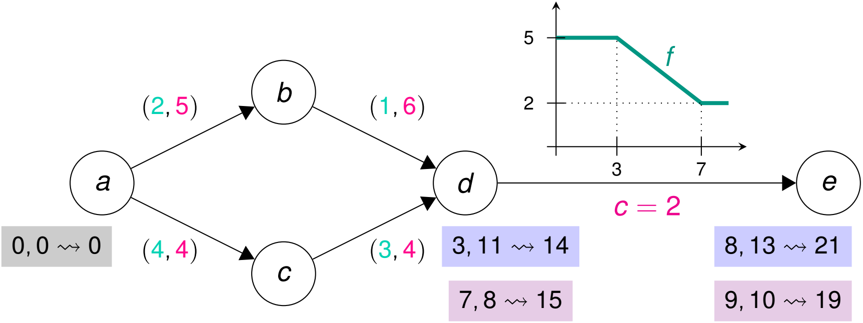
Suboptimal Prefix of Optimal Route – Example 1


10
3
f
4
5
a
b
c
d
e
(3, 7)
(2, 7)
(2, 12)
(2, 8)
$c = 3$
$0, 0 \rightsquigarrow 0$
$5, 14 \rightsquigarrow 19$
$4, 20 \rightsquigarrow 24$
$15, 17 \rightsquigarrow 32$
$8, 23 \rightsquigarrow 31$

When a little loss in time eats up a great gain in distance.

Time-dependent Routing

Suboptimal Prefix of Optimal Route – Example 2



When an an advatage in time can not compensate a smaller distance.

Time-dependent Routing

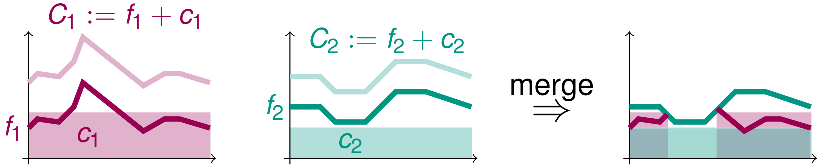
Shortcuts – Difficult with Suboptimal Prefixes

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



Time-dependent Routing

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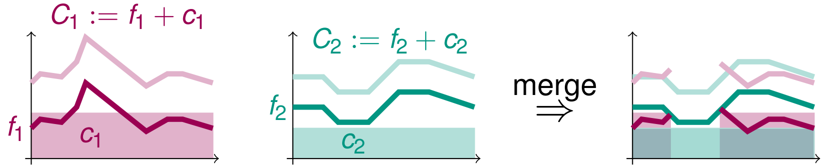


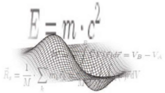
- II -

Energy Efficient Routing

Energy Efficient Routing

due to multiple input parameters complicated problem

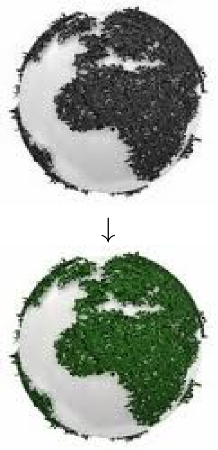
- type of vehicle
- road characteristics
- driver behaviour
- physical laws



Energy Efficient Routing

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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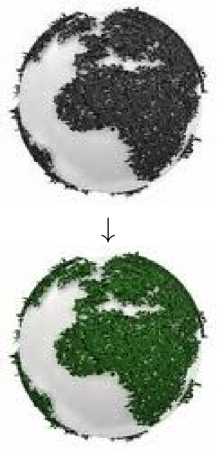


Energy Efficient Routing

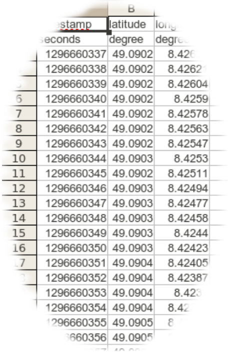
Resulting subproblems

- 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)

Heidelberg

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



		B	
	stamp	latitude	long
	seconds	degree	degre
	1296660337	49.0902	8.426
	1296660338	49.0902	8.4262
5	1296660339	49.0902	8.42604
6	1296660340	49.0902	8.4259
7	1296660341	49.0902	8.42578
8	1296660342	49.0902	8.42563
9	1296660343	49.0902	8.42547
10	1296660344	49.0903	8.4253
11	1296660345	49.0902	8.42511
12	1296660346	49.0903	8.42494
13	1296660347	49.0903	8.42477
14	1296660348	49.0903	8.42458
15	1296660349	49.0903	8.4244
16	1296660350	49.0903	8.42423
17	1296660351	49.0904	8.42405
18	1296660352	49.0904	8.42387
	1296660353	49.0904	8.423
	1296660354	49.0904	8.42
	1296660355	49.0905	8.
	660356	49.0905	

Energy Efficient Routing

Acceptance of energy efficiency is crucial

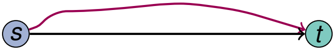
- hourly wages model
- consider combination of energy savings and time spent
- offer as alternative
- usage in electric vehicle range prediction
- let user tune parameters for his best choice . . .
  . . . or even tune automatically

- III -
Alternative Paths

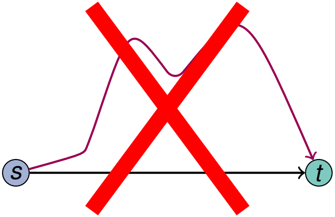
Alternative Paths

Introduction

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



- only slightly longer
- sufficiently disjoint
- locally optimal



Alternative Paths

Introduction

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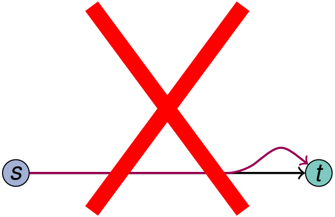
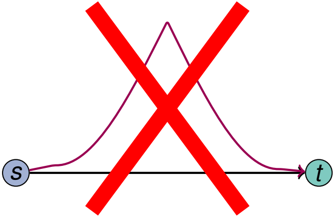


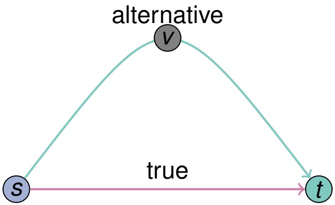


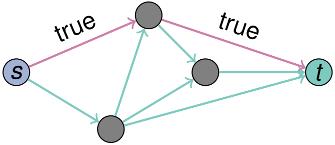
Alternative Paths

Previous Work

Several previous approaches exist:

- Via Nodes Alternatives
  (Abraham et al. SEA2010)
- Alternative Graphs
  (Bader et al. TAPAS 2011)





Alternative Paths

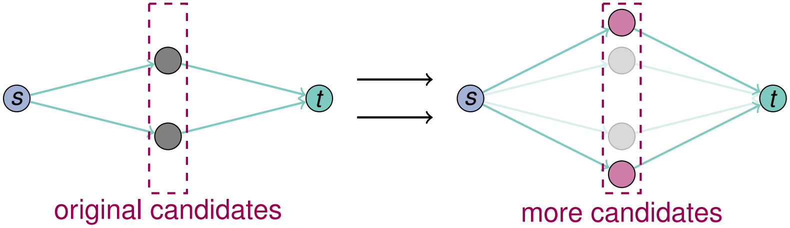
Via Nodes Alternatives

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

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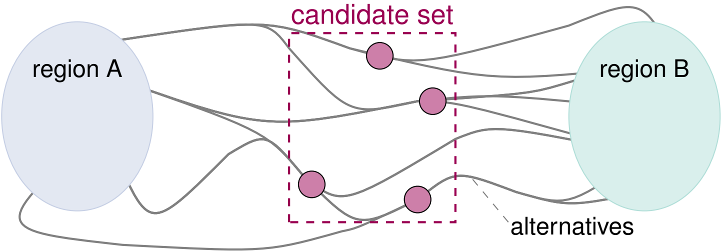


Alternative Paths

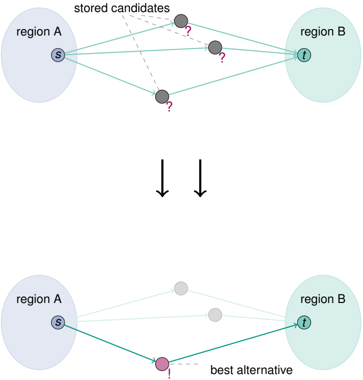
Procedure

Preprocessing:

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

Query:

- Lookup via candidates
- Evaluate alternatives
- Report best one



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Wolfsburg
Potsdam
Berlin
sheim
Magdeburg
Cottbus
ingen
Halle (Saale)
Leipzig
Erfurt
Jena
Gera
Dresden
Chemnitz
Ústí nad Labem
Praha
Bamberg
zburg
Erlangen
Fürth
Plzeň
Regensburg
České Budějov
Ingolstadt
Ulm
Augsburg
München
Linz
Wels
Salzburg

Alternative Paths

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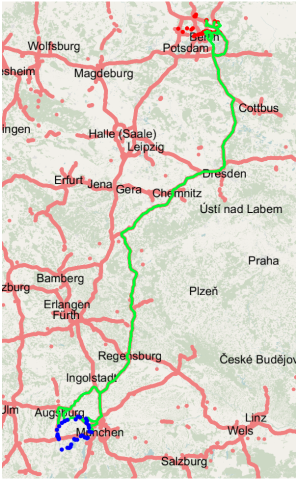


Alternative Paths

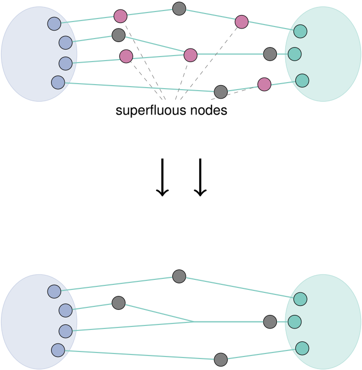
Efficiency

Preprocessing:

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

Query:

- CHASE w. compressed ArcFlags
- Precomputed Via Nodes Labels



- IV -
Future Route-Planning

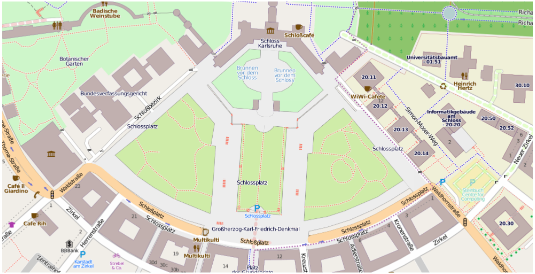
Car Routing

- 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

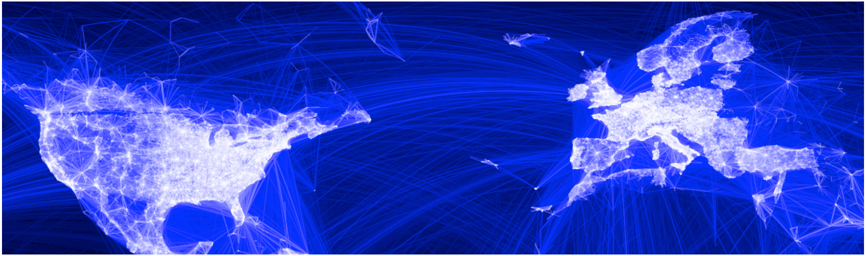


- Models again, danger, fun,. . .
- Elevation becomes important
- geometric routing on squares etc?
- “online”-routing, e.g., two blocks north five blocks west grasping opportunities for crossing streets

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