Multi-Modal Route Planning *in Road and Transit Networks*

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Master's thesis
SS 18

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What's it about?

- Finding *optimal* route from A to B

- Road networks
  - Well understood, many algorithms
  - Dijkstra, A*, ALT, Arc-Flags, CH, SHARC, CHASE, HLC, TNR

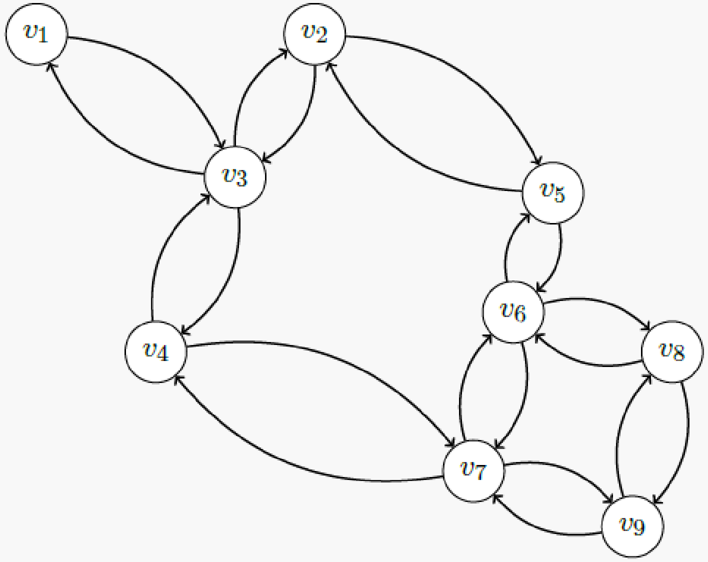
- Public Transit networks (train, bus, tram, …)
  - Differ a lot from road networks
  - Transfer Patterns, RAPTOR, CSA

What's it about?

- Multi-modal routing
  - Combining road and transit networks
- Hard to combine
  - Algorithms exploit network properties
  - Network structure is very different
- Access Node Routing
  - Compute route piecewise in isolated networks

Models

- Road graph
  - Nodes: Road junctions
  - Edges: Roads connecting the junctions

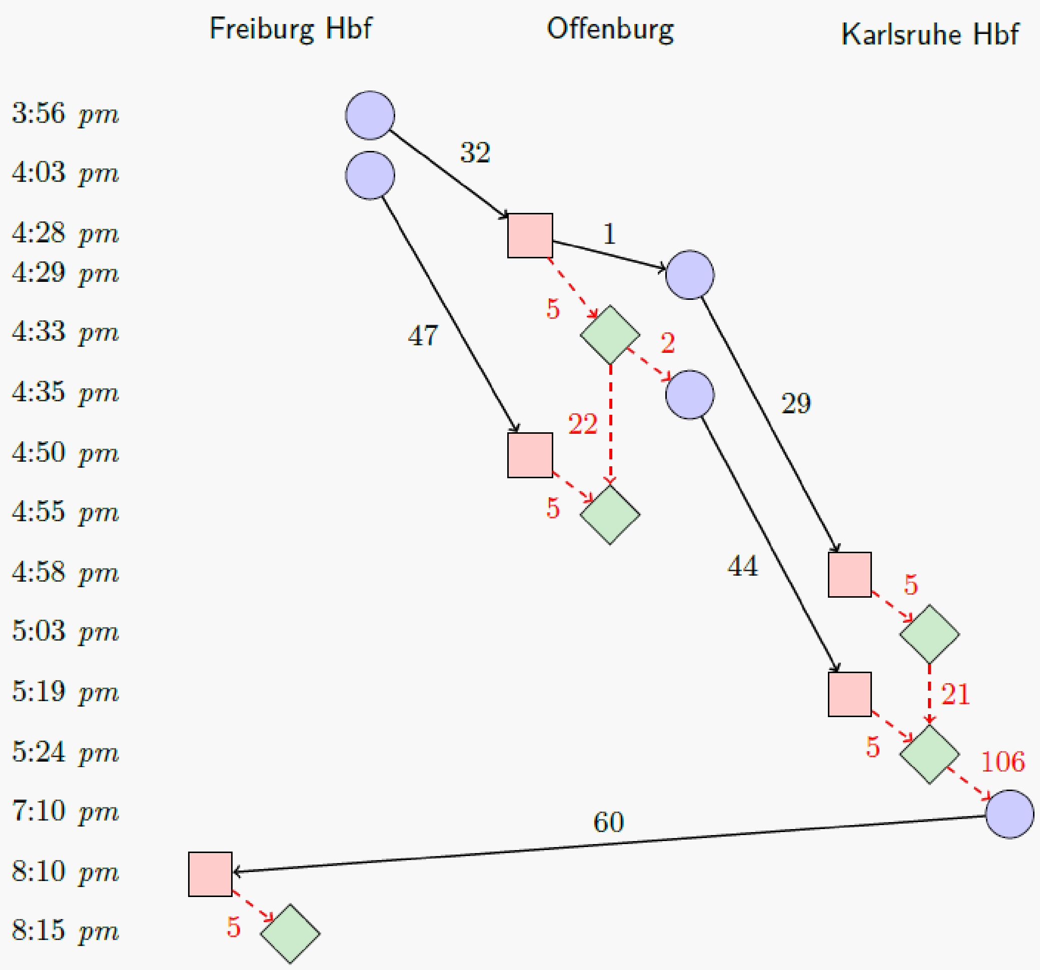


Models

- Transit graph (realistic time expanded)
  - One node per event
    - arrival
    - departure
    - transfer
  - Edges indicating
    - traveling
    - transfer

Models

⟶	Freiburg Hbf	Offenburg		Karlsruhe Hbf
	departure	arrival	departure	arrival
ICE 104	3:56 *pm*	4:28 *pm*	4:29 *pm*	4:58 *pm*
RE 17024	4:03 *pm*	4:50 *pm*		
RE 17322			4:35 *pm*	5:19 *pm*
⟵	arrival	departure	arrival	departure
ICE 79	8:10 *pm*			7:10 *pm*



Models

- Link graph
  - Find road node for every transit stop
    - For example: nearest
  - Link edges
    - From road node to
    - all arrival nodes of transit stop

- Graph based combined network

⟶	Freiburg Hbf	Offenburg		Karlsruhe Hbf
	departure	arrival	departure	arrival
ICE 104	3:56 *pm*	4:28 *pm*	4:29 *pm*	4:58 *pm*
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⟵	arrival	departure	arrival	departure
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Models

- Timetable
  - non-graph based transit network
  - tuple (S, T, C, F)

- Stops $S = \{ f, o, k \}$

- Trips $T = \{ t_{104}, t_{17024}, t_{17322}, t_{79} \}$

Models

$\longrightarrow$	Freiburg Hbf	Offenburg		Karlsruhe Hbf
	departure	arrival	departure	arrival
ICE 104	3:56 *pm*	4:28 *pm*	4:29 *pm*	4:58 *pm*
RE 17024	4:03 *pm*	4:50 *pm*		
RE 17322			4:35 *pm*	5:19 *pm*
$\longleftarrow$	arrival	departure	arrival	departure
ICE 79	8:10 *pm*			7:10 *pm*

- Connections C
  - (f, o, 3:56 pm, 4:28 pm, t104)
  - (o, k, 4:29 pm, 4:58 pm, t104)
  - (f, o, 4:03 pm, 4:50 pm, t17024)
  - (o, k, 4:35 pm, 5:19 pm, t17322)
  - (k, f, 7:10 pm, 8:10 pm, t79)

- Footpaths F
  - (f, 300, f)
  - (o, 300, o)
  - (k, 300, k)

Routing

- Multi-modal route planning
  - Combining road and transit networks
  - Queries have transportation mode restrictions
- Modified Dijkstra
  - Simple baseline
  - Runs on Link graph
  - Combinable with optimizations (A^*, ALT, …)

Routing

- Access Node Routing
  - Generic approach
  - Piecewise computation on isolated networks
  - Any road algorithm for road network (ALT)
  - Any transit algorithm for transit network (CSA)

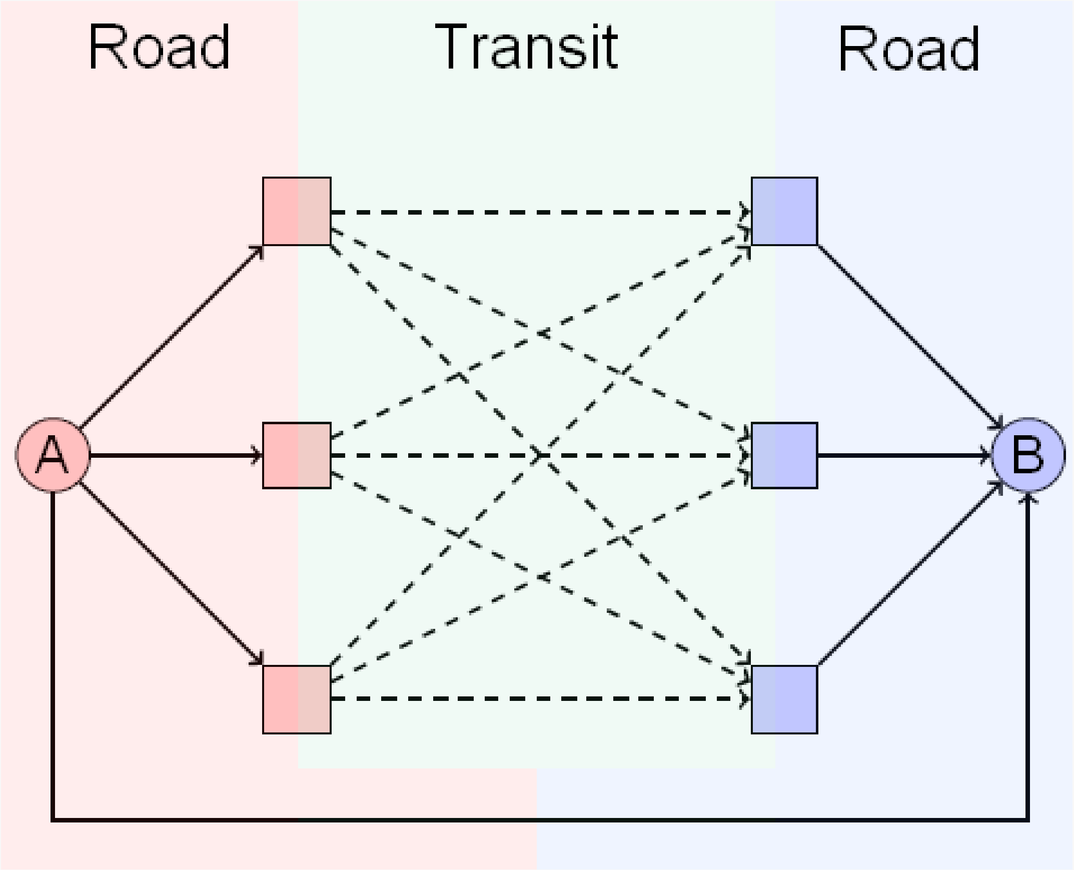
- Access nodes for A and B
  - A and B in road network
  - Access nodes in transit network

Routing

- *Good* access nodes
  - Difficult to find, focus of research
  - Simple solution: k-nearest nodes ($k = 3$)

- Route consists of
  - A to access nodes (road network)
  - Access nodes of A to access nodes of B (transit network)
  - Access nodes to B (road network)

Routing



Experiments

- Generic route planning framework Cobweb
  - Data formatted as OSM or GTFS
  - Database for metadata
  - Represented in models (with serialization)
  - Extensive configuration and documentation

- Several algorithms
  - Dijkstra, A*, ALT,
  - CSA,
  - Modified Dijkstra, ANR,
  - Cover Trees,
  - Fuzzy prefix search

Experiments

- Model sizes

	data (MB)		Road graph	
	raw	filtered	nodes	edges
Freiburg	2 260	86	743 003	1 494 883
Stuttgart	2 420	118	973 142	1 950 978
Switzerland	5 530	279	2 627 645	5 226 060

	data (KB)	Transit graph	
		nodes	edges
Freiburg	1 713	613 329	1 006 862
Stuttgart	32 213	4 517 511	7 415 894
Switzerland	75 477	32 688 498	53 370 236

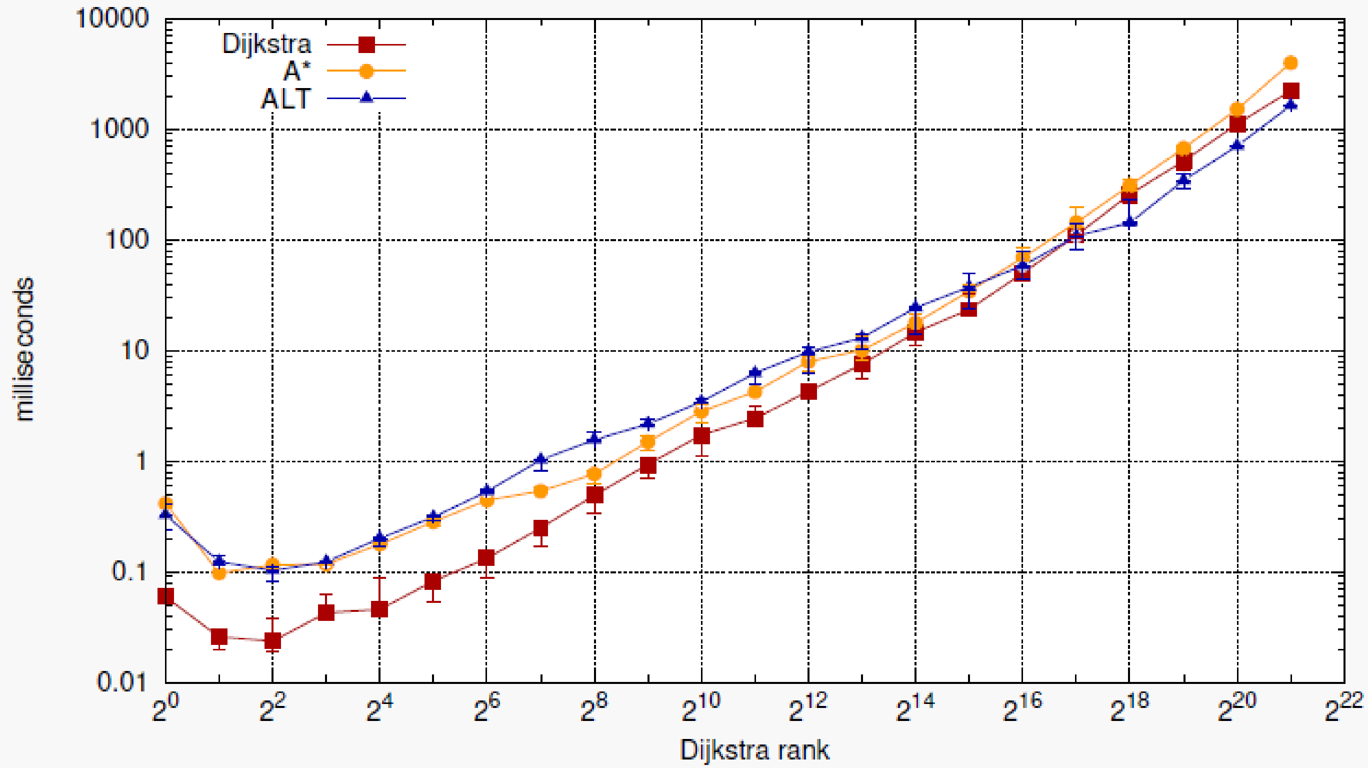
	Timetable			
	stops	trips	connections	footpaths
Freiburg	713	13 249	191 194	255 495
Stuttgart	7 877	90 475	1 415 362	1 926 611
Switzerland	30 227	1 014 699	9 881 467	3 793 581

Experiments

- Dijkstra rank
  - Measure for distance
  - The higher the rank, the greater the distance

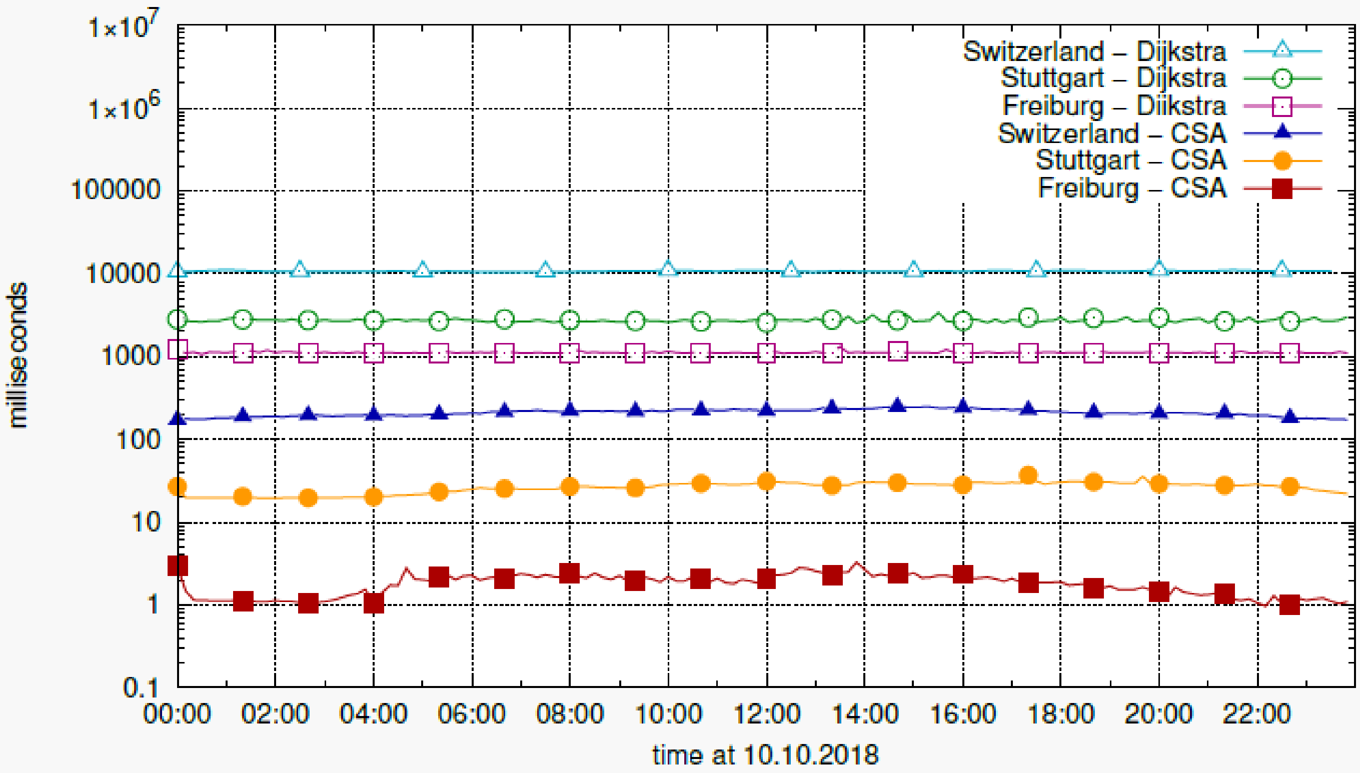
- Experiments
  - Time independent (Dijkstra, A*, ALT)
  - Time dependent (Dijkstra, CSA)
  - Multi-modal (Modified Dijkstra, ANR)

Experiments



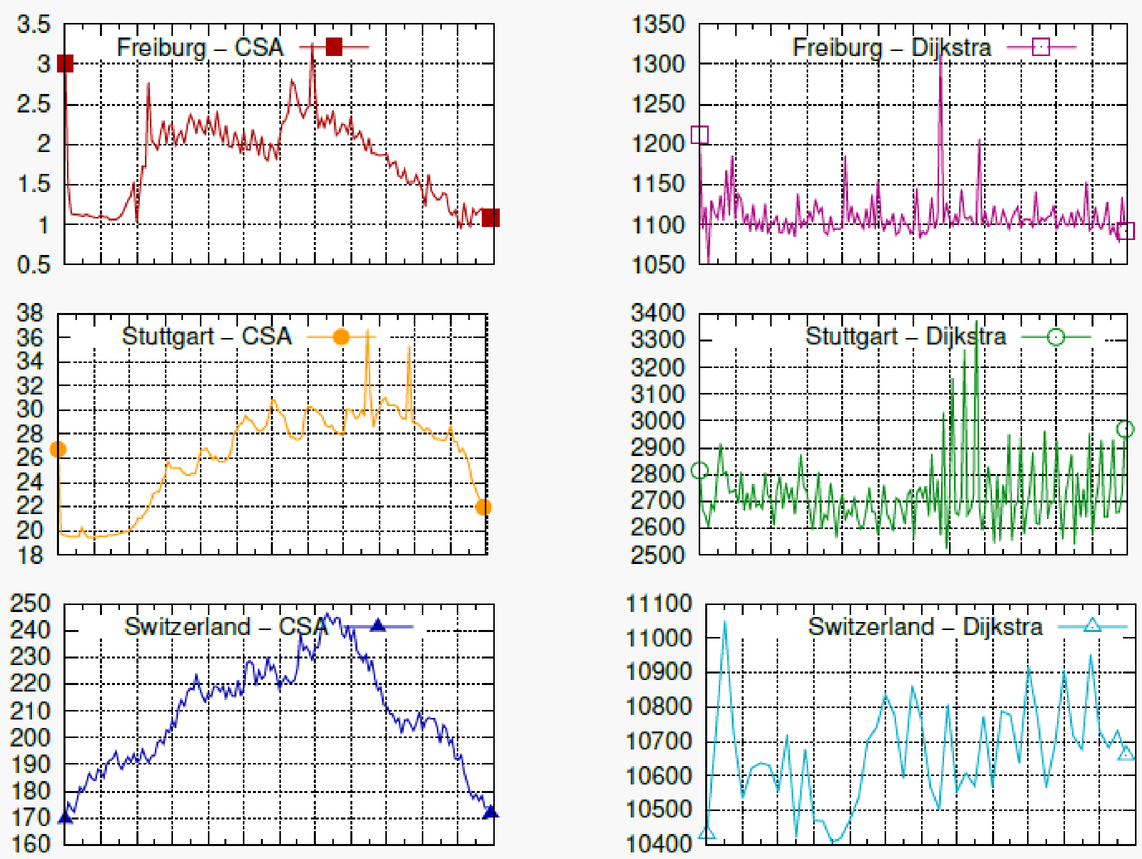
- Bad scaling for increasing range
- A^* is bad, ALT can perform better

Experiments



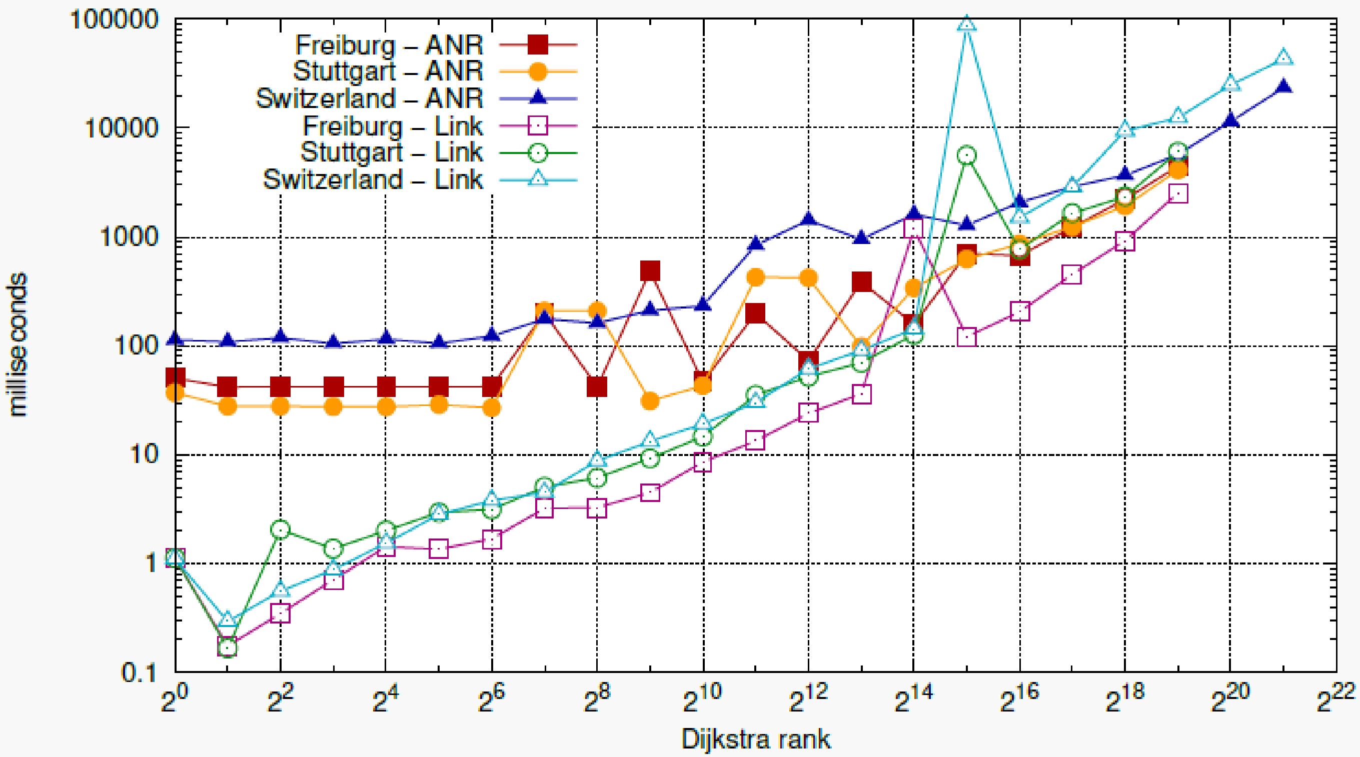
- CSA is way faster than Dijkstra
- CSA is viable

Experiments



- CSA is subject to traffic congestion

Experiments



- ANR has much overhead
- If used with good algorithms, faster and feasible

Conclusion

- Multi-modal routing
  - Difficult, networks are very different
- Instead, hybrid approach
  - Isolate networks
  - Specialized algorithms for individual networks
- ANR is a promising technique

Conclusion

- However, still a lot to do
  - Turn penalties
  - Multi-criteria routing
  - Complex transportation mode restriction models
  - Integrating real-time data

- Many subproblems
  - Leading to many specialized techniques
  - So far, no viable approach that addresses all problems

Related links

- Cobweb, a multi-modal journey planner
  - Daniel Tischner. Cobweb. https://github.com/ZabuzaW/Cobweb, 2018.
  - https://github.com/ZabuzaW/Cobweb

- Route Planning in Transportation Networks
  - Hannah Bast, Daniel Delling, Andrew Goldberg, Matthias Müller-Hannemann, Thomas Pajor, Peter Sanders, Dorothea Wagner, and Renato F. Werneck. *Route Planning in Transportation Networks*, pages 19-80. Springer International Publishing, Cham, 2016.
  - https://arxiv.org/abs/1504.05140

Related links

- Connection Scan Algorithm
  - Julian Dibbelt, Thomas Pajor, Ben Strasser, and Dorothea Wagner. *Connection scan algorithm*. CoRR, abs/1703.05997, 2017.
  - https://arxiv.org/abs/1703.05997

- Accelerating Multi-modal Route Planning by Access-Nodes
  - Daniel Delling, Thomas Pajor, and Dorothea Wagner. *Accelerating multi-modal route planning by access-nodes*. In Amos Fiat and Peter Sanders, editors, Algorithms - ESA 2009, pages 587-598, Berlin, Heidelberg, 2009. Springer Berlin Heidelberg.
  - https://link.springer.com/chapter/10.1007/978-3-642-04128-0_53

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