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
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
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

- **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 | 2260      | 86         | 743003         | 1494883        |
| Stuttgart| 2420      | 118        | 973142         | 1950978        |
| Switzerland | 5530   | 279        | 2627645        | 5226060        |

|          | data (KB) | Transit graph |                |                |
|----------|-----------|---------------|----------------|----------------|
|          | raw       | nodes         | edges          |                |
| Freiburg | 1713      | 613329        | 1006862        |                |
| Stuttgart| 32213     | 4517511       | 7415894        |                |
| Switzerland | 75477  | 32688498      | 53370236       |                |

|          | Transit timetable |                |                |
|----------|--------------------|----------------|----------------|
|          | stops              | trips          | connections    | footpaths      |
| Freiburg | 713                | 13249          | 191194         | 255495         |
| Stuttgart| 7877               | 90475          | 1415362        | 1926611        |
| Switzerland | 30227   | 1014699       | 9881467        | 3793581        |
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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