Karlsruher Institut für Technologie

Algorithmen für Routenplanung

18. Sitzung, Sommersemester 2013

Thomas Pajor | 10. Juli 2013

INSTITUT FÜR THEORETISCHE INFORMATIK · ALGORITHMIK · PROF. DR. DOROTHEA WAGNER

Undesired Modal Transfers

Problem: Unrestricted paths have arbitrary modal transfers.

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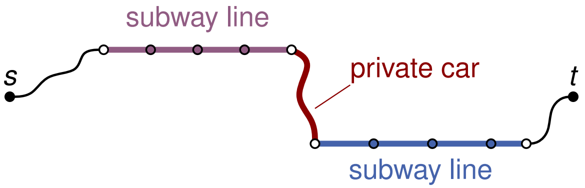

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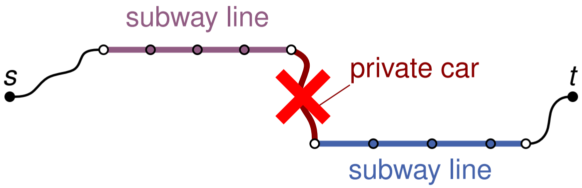

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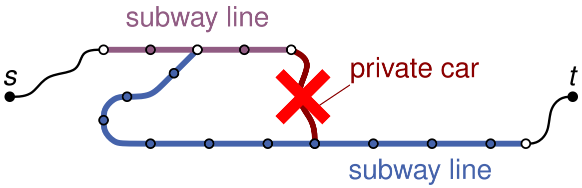

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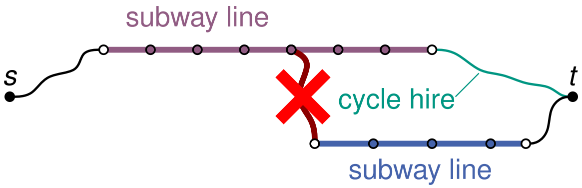

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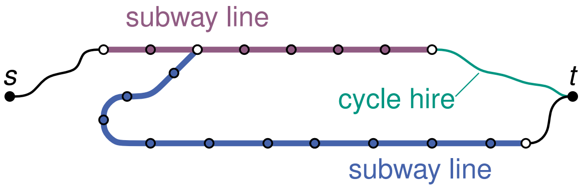

- Not all modal sequences feasible, and
- available/desired modes of transport depend on user.

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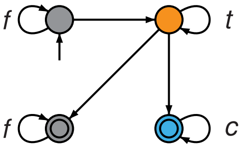
Existing Solutions

Label Constrained Shortest Path Problem (LCSPP)

- Define alphabet of transport modes.
- Consider edge-labeled graph.
- Any feasible path must obey regular language constraints (input).



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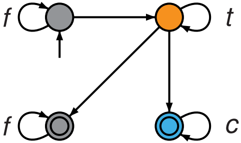

Algorithms for LCSPP

- Dijkstra on product graph with automaton works.
- Speedup techniques: Access-Node Routing, SDALT.
- Constraints as query input: UCCH.

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Problem solved?

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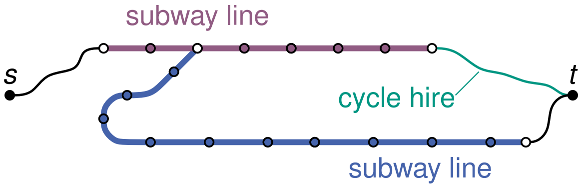
Existing Solutions

Shortcomings of LCSPP



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- Constraints must be specified in advance,
- but user may not know them.
- Only single journey computed (no alternatives).

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Existing Solutions

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Goal: Compute *reasonable set* of multimodal journeys.

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Approach

Idea: Compute *multicriteria* multimodal Pareto sets.

- Optimize arrival time plus
- mode-dependent *convenience* criteria.
  Such as # transfers (public transit), walking duration, taxi cost, etc.

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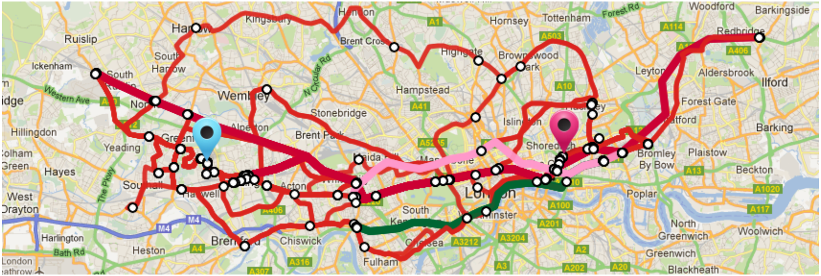

Criteria: Arrival time, # transfers, walking duration. Sixty-nine solutions.

Known problem: Pareto set significantly grows with # criteria.

Pareto Sets

Definition (Domination, Pareto Set)

A journey J_1 *dominates* a journey J_2 iff. J_2 is worse (or equal) in all criteria.
A *Pareto set* is a (maximal) set of nondominating journeys.

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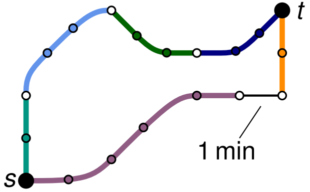
Insignificant Solutions

Nondominated journey may have

- tiny improvement for criterion A,
- even if much worse in criterion B.

Many criteria $\Rightarrow$ Combinatorial explosion.



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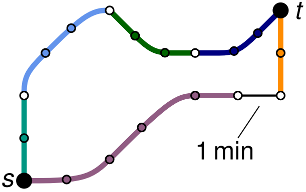

How do we identify the *significant* solutions of a Pareto set?

Fuzzy Dominance

Observation: User has *fuzzy perception* for some criteria.

- Walking ± 1 minute is “almost the same”,
- but ± 30 minutes matters.

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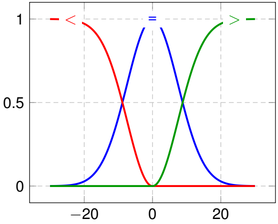
- Fuzzy operators $<$, $>$ and $=$.
- Different parameters per criterion.

$\Rightarrow$ *Degree* of domination $d(J_1, J_2) \in [0, 1]$.
"How much does J_1 dominate J_2."



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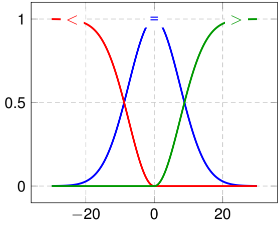

Journey J_1 may, e. g., 90 %-dominate J_2, even if J_2 has 1 min less walking.

Identifying Significant Journeys

Approach:

- Compute full (exact) Pareto set by multicriteria algorithm.
- Score each journey J by $1 - \max(d(J_1, J), \ldots, d(J_n, J))$.
- Then: Higher-scored journeys are more significant.

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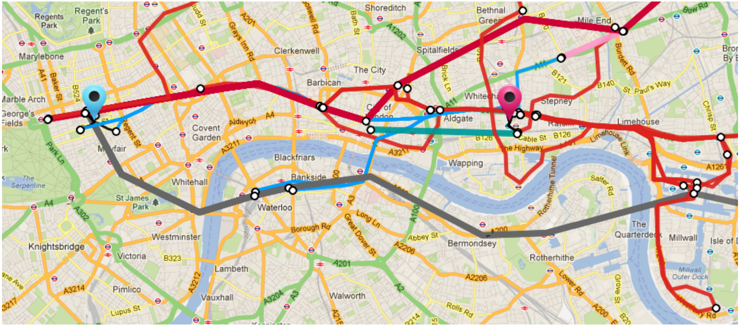

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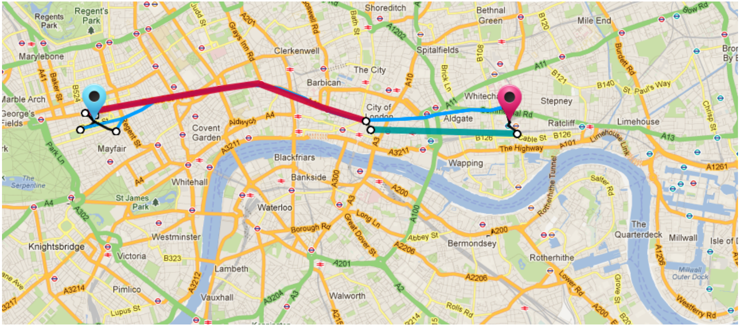

Three highest-scored journeys.

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Exact Algorithm: MCR

Observations

- Modal transfers occur at limited set of locations.
- One trip always made up by single transport mode.

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Round-based Framework

- Run one round per trip.
- Maintain Pareto set of labels for each location and round.
- In each round: Run subalgorithm per *transport mode*.
  - Public Transit: RAPTOR.
  - Walking, Taxi, Cycle: LC-Dijkstra & UCCH.
- ... read labels from round $i - 1$, write to round i.

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Heuristic Approaches

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Problem: Queries take too long (several seconds).

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Relax Domination Rules

- MCR-hf: Fuzzy domination between labels during algorithm.
- MCR-hb: Strict domination with discretized criteria.

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- MCR-tx-ry: Max walking x between trips and y at source/target.

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Restict Walking

- MCR-t*x*-r*y*: Max walking *x* between trips and *y* at source/target.

Reduce Number of Criteria

- MR-*x*: Count every *x* minutes of walking as trip.

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Measuring Quality of Heuristics

Motivation: Service running alg. $\mathcal{A}$ presents top-k journeys from $P_{\mathcal{A}}$.

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Similarity of two Journeys

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- Total similarity: minimum similarity over all criteria.

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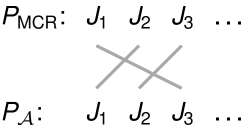
Quality of Solution

- Consider P_{MCR} as *ground truth*.
- Keep only top-k journ. in $P_{\mathcal{A}}, P_{\text{MCR}}$.
- Compute (greedy) maximum matching between $P_{\mathcal{A}}$ and P_{MCR} with similarity.

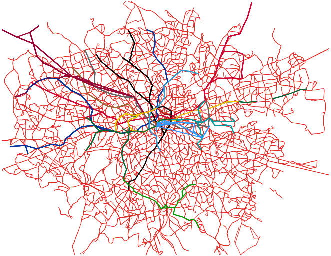


Output average similarity of matched journeys.

The London Instance

Complete Public Transit Network

- Contains Tube, Bus, DLR, Tram. . .
- 20 k stops, 2.2 k routes,
- over 5 M daily departures,
- and 564 cycle hire stations.



Road and Pedestrian Networks

- $\approx$ 260 k vertices (27 k uncontracted)
- and 1.4 M edges, each.

Scenario without Taxi

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Criteria: Arrival time, # transfers, walking duration.

Algorithm	# Rnd.	# Jn.	Time [ms]	Quality-6 Avg.	Quality-6 Sd.
MCR	13.8	29.1	1 438.7	100 %	0 %
MCR-hf	15.6	10.9	699.4	89 %	11 %
MCR-hb	10.2	9.0	456.7	91 %	10 %
MCR-t10-r15	10.7	13.2	885.0	30 %	31 %
MR-10	20.0	4.3	39.4	45 %	29 %

One core of Intel Xeon E5-2670, 2.6 GHz, 64 GiB DDR3-1600 RAM

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Scenario with Taxi

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Criteria: Arrival time, # transfers, walking duration, cost.

Algorithm	Wlk.	# Rnd.	# Jn.	Time [ms]	Quality-6 Avg.	Sd.
MCR	●	16.3	1 666.0	1 960 234.0	100 %	0 %
MCR-hf	●	17.1	35.2	6 451.6	92 %	6 %
MCR-hb	●	9.9	27.6	2 807.7	92 %	6 %
MCR-hb	○	9.0	11.6	996.4	74 %	12 %

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Wlk. ○: Combines walking duration into cost.

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Conclusion

- Multicriteria approach to multimodal route planning.
- Optimizes arrival time plus convenience criteria.
- Fuzzy set theory helps identify significant solutions.
- Heuristics quickly find solutions of good quality,
- if convenience criteria not dropped.

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Literatur I

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