LAAS - DO - ROC

Efficient multiobjective and multimodal path computation

Marie-José Huguet - Visite ENS - 7 janvier 2015

Introduction

Users mobility in multimodal transportation networks

- large size network
- new usages and new problems

Bi-Objective Shortest Paths

- Min path duration and Min number of mode transfers
- **Industrial transfer** - CIFRE thesis (12/2010)

Synchonized Itineraries

- Synchronized Paths between 2 users / 2-Way Shortest Path
  - ANR Project (lead TSF): use case on dynamic carpooling (2012-)
  - GdR OR Project (collaborations: LIPN, LI Tours, Heudiasyc) (2011-2012)
- **Open source software**

Introduction

Users mobility in multimodal transportation networks

- large size network
- new usages and new problems

Bi-Objective Shortest Paths

- Min path duration and Min number of mode transfers
- **Industrial transfer** - CIFRE thesis (12/2010)

Synchonized Itineraries

- Synchronized Paths between 2 users / 2-Way Shortest Path
  - ANR Project (lead TSF): use case on dynamic carpooling (2012-)
  - GdR OR Project (collaborations: LIPN, LI Tours, Heudiasyc) (2011-2012)
- **Open source software**

Introduction

Users mobility in multimodal transportation networks

- large size network
- new usages and new problems

Bi-Objective Shortest Paths

- Min path duration and Min number of mode transfers
- **Industrial transfer** - CIFRE thesis (12/2010)

Synchonized Itineraries

- Synchronized Paths between 2 users / 2-Way Shortest Path
  - ANR Project (lead TSF): use case on dynamic carpooling (2012-)
  - GdR OR Project (collaborations: LIPN, LI Tours, Heudiasyc) (2011-2012)
- **Open source software**

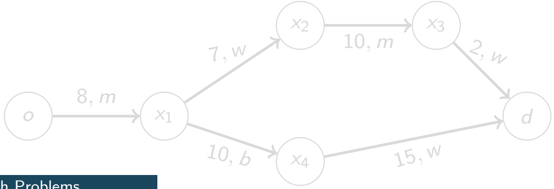
Shortest Path Problems (SPP)

Standard Shortest Path from o to d: Well-known Dijkstra Algorithm

- Two main variants
  - A* (guided by the destination d)
  - Bidirectional Search (forward from o and backward from d)
- Preprocessing technics

Multimodal Shortest Path

- Labelled graph: mode on arcs
- Constraints on mode: regular language



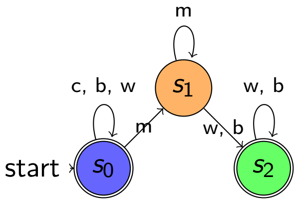
Shortest Path Problems (SPP)

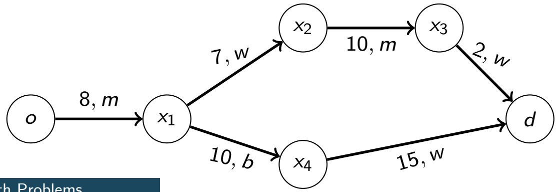
Standard Shortest Path from o to d: Well-known Dijkstra Algorithm

- Two main variants
  - A^* (guided by the destination d)
  - Bidirectional Search (forward from o and backward from d)
- Preprocessing technics

Multimodal Shortest Path

- Labelled graph: mode on arcs
- Constraints on mode: regular language





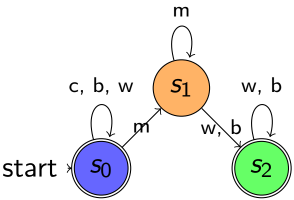
Shortest Path Problems (SPP)

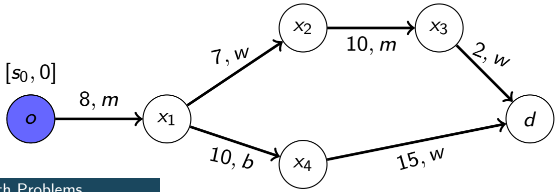
Standard Shortest Path from o to d: Well-known Dijkstra Algorithm

- Two main variants
  - A^* (guided by the destination d)
  - Bidirectional Search (forward from o and backward from d)
- Preprocessing technics

Multimodal Shortest Path

- Labelled graph: mode on arcs
- Constraints on mode: regular language





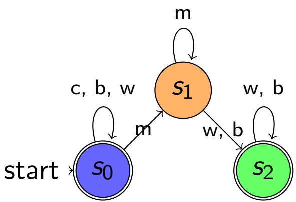
Shortest Path Problems (SPP)

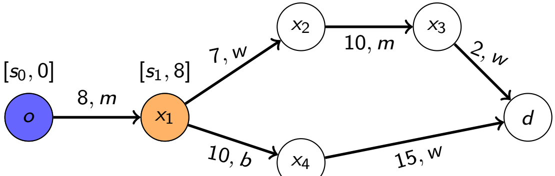
Standard Shortest Path from o to d: Well-known Dijkstra Algorithm

- Two main variants
  - A^* (guided by the destination d)
  - Bidirectional Search (forward from o and backward from d)
- Preprocessing technics

Multimodal Shortest Path

- Labelled graph: mode on arcs
- Constraints on mode: regular language





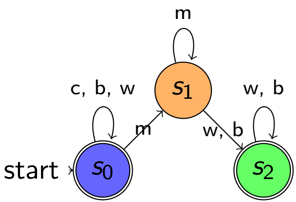
Shortest Path Problems (SPP)

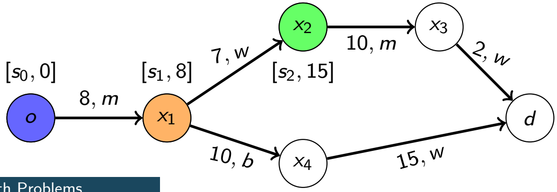
Standard Shortest Path from o to d: Well-known Dijkstra Algorithm

- Two main variants
  - A* (guided by the destination d)
  - Bidirectional Search (forward from o and backward from d)
- Preprocessing technics

Multimodal Shortest Path

- Labelled graph: mode on arcs
- Constraints on mode: regular language





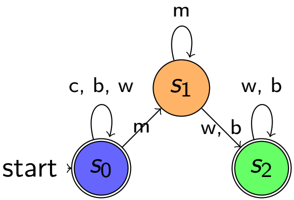
Shortest Path Problems (SPP)

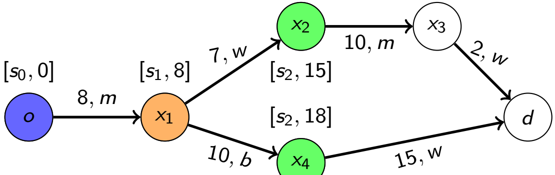
Standard Shortest Path from o to d: Well-known Dijkstra Algorithm

- Two main variants
  - A^* (guided by the destination d)
  - Bidirectional Search (forward from o and backward from d)
- Preprocessing technics

Multimodal Shortest Path

- Labelled graph: mode on arcs
- Constraints on mode: regular language





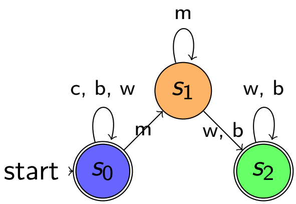
Shortest Path Problems (SPP)

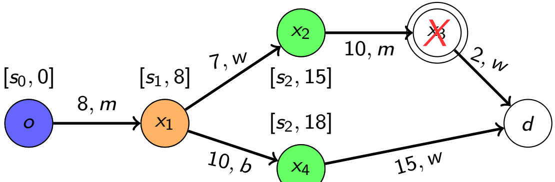
Standard Shortest Path from o to d: Well-known Dijkstra Algorithm

- Two main variants
  - A* (guided by the destination d)
  - Bidirectional Search (forward from o and backward from d)
- Preprocessing technics

Multimodal Shortest Path

- Labelled graph: mode on arcs
- Constraints on mode: regular language





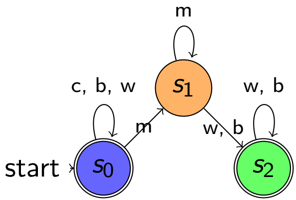
Shortest Path Problems (SPP)

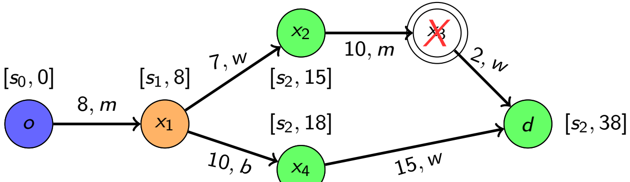
Standard Shortest Path from o to d: Well-known Dijkstra Algorithm

- Two main variants
  - A* (guided by the destination d)
  - Bidirectional Search (forward from o and backward from d)
- Preprocessing technics

Multimodal Shortest Path

- Labelled graph: mode on arcs
- Constraints on mode: regular language

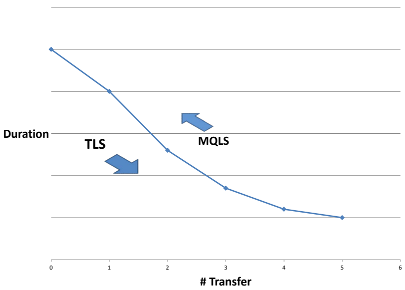




Bi-Objective Multimodal SPP

Objectives

- Minimize the travel time
- Minimize the number of transfers
- Pareto set of solutions



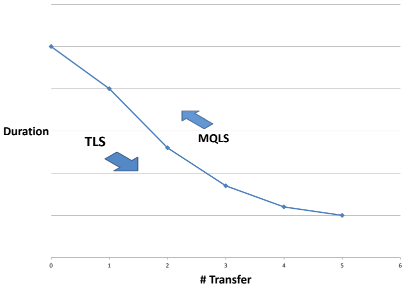
Contributions

- Complexity: polynomial
- Two main algorithms
- Dominance rule based on automata
- A* and bidirectional variants

Bi-Objective Multimodal SPP

Objectives

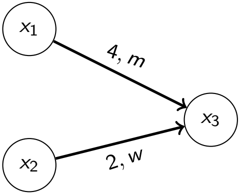
- Minimize the travel time
- Minimize the number of transfers
- Pareto set of solutions

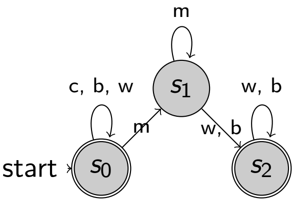


Contributions

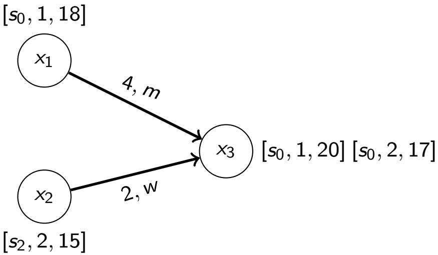
- Complexity: polynomial
- Two main algorithms
- Dominance rule based on automata
- A^* and bidirectional variants

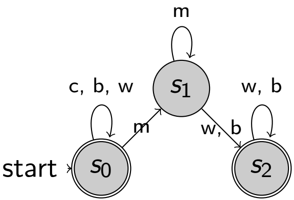
Bi-Objective Multimodal SPP: Algorithm and Dominance Rule



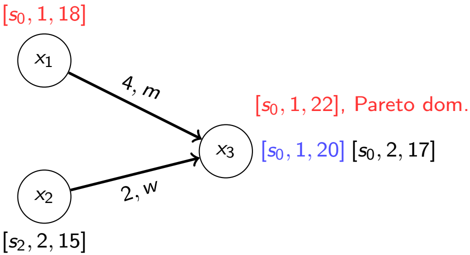


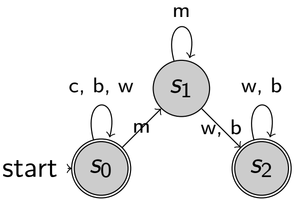
Bi-Objective Multimodal SPP: Algorithm and Dominance Rule



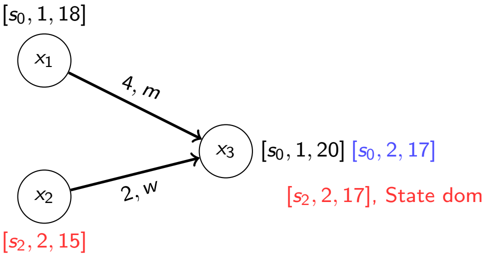


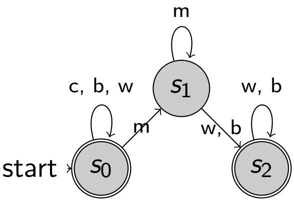
Bi-Objective Multimodal SPP: Algorithm and Dominance Rule



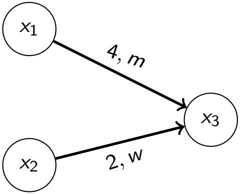


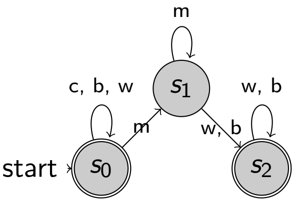
Bi-Objective Multimodal SPP: Algorithm and Dominance Rule





Bi-Objective Multimodal SPP: Algorithm and Dominance Rule





Impact of Dominance Rule for TLS-A*

- Graph: 60 000 nodes; 160 000 edges
- CPU time: from 300 to 150 ms
- Pareto dom.: speed-up around 38% vs TLS-A* without dominance
- State dom.: speed-up around 48% vs TLS-A* without dominance

Bi-Objective Multimodal SPP: Outcomes

Publications

- Artigues, Huguet, Gueye, Schettini, Dezou. State-based accelerations and bidirectional search for bi-objective multi modal shortest paths. *Transportation research Part C*, 27:233-259, 2013.
- Gueye, Artigues, Huguet, Schettini, Dezou. Bi-objective multimodal time-dependent shortest viable path algorithms. *In Seven Triennial Symposium on Transportation Analysis (TRISTAN 2010)*, Tromso (Norway), June 20-24, 2010

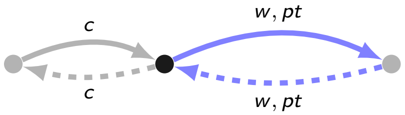
DEMO

- MobiAnalyst Software
- PhD (CIFRE) - MOBIGIS

SPP with Synchronization Points

2-Way Multimodal SPP

- Minimize the total travel time
  - from o to d and d to o
  - through a synchronization point to be determined (parking)



2-Synchronisation Points SPP

- A driver and a pedestrian
- Minimize the arrival time for both user
  - through 2 synchronization points: pick-up and drop-off to be determined

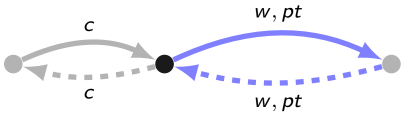
Polynomial Problems

- Several Dijkstra algorithms
  - Enumeration of synchronization points ($>$ 30 min for 80 parking nodes)
- Proposed Approach: several forward and backward algorithms ($\approx$ 4s without limit on parking)

SPP with Synchronization Points

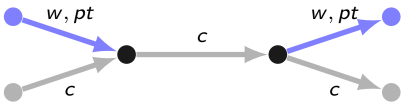
2-Way Multimodal SPP

- Minimize the total travel time
  - from o to d and d to o
  - through a synchronization point to be determined (parking)



2-Synchronisation Points SPP

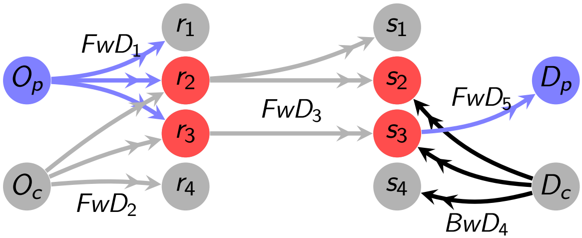
- A driver and a pedestrian
- Minimize the arrival time for both user
  - through 2 synchronization points: pick-up and drop-off to be determined



Polynomial Problems

- Several Dijkstra algorithms
  - Enumeration of synchronization points ($>$ 30 min for 80 parking nodes)
- Proposed Approach: several forward and backward algorithms ($\approx$ 4s without limit on parking)

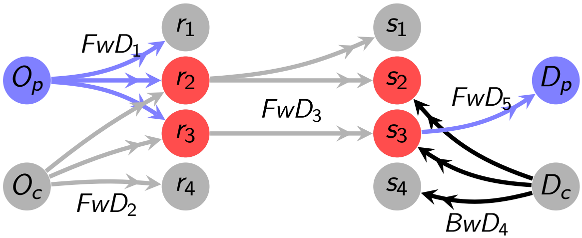
Solving the 2-Synchronisation Points SPP



The Best Origin Problem

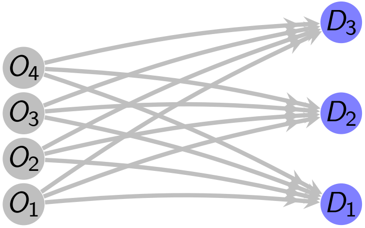
- Set of origins and destinations
- Find the Best Origin for each destination
- Dijkstra algorithm in static case

Solving the 2-Synchronisation Points SPP



The Best Origin Problem

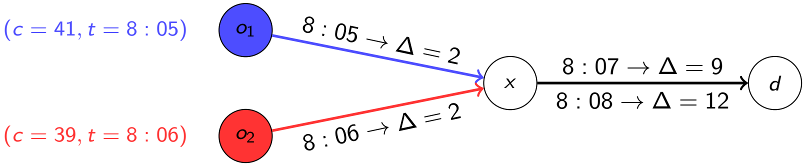
- Set of origins and destinations
- Find the Best Origin for each destination
- Dijkstra algorithm in static case



Sub-Problem: The Best Origin Problem

In Time-Dependent Case

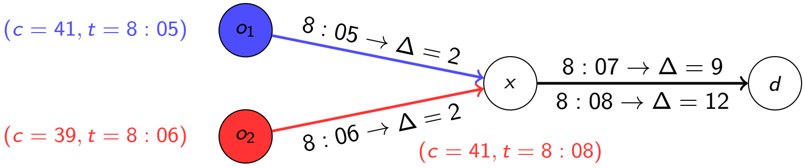
- No consistency between costs and arrival times



Sub-Problem: The Best Origin Problem

In Time-Dependent Case

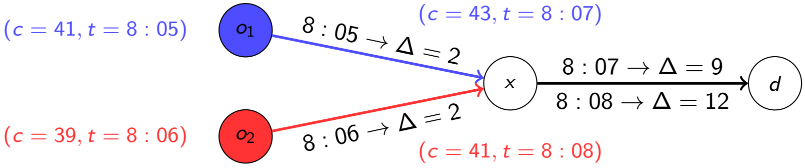
- No consistency between costs and arrival times



Sub-Problem: The Best Origin Problem

In Time-Dependent Case

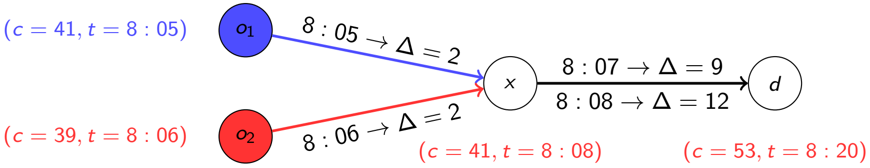
- No consistency between costs and arrival times



Sub-Problem: The Best Origin Problem

In Time-Dependent Case

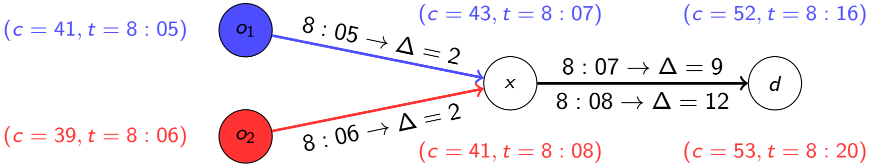
- No consistency between costs and arrival times



Sub-Problem: The Best Origin Problem

In Time-Dependent Case

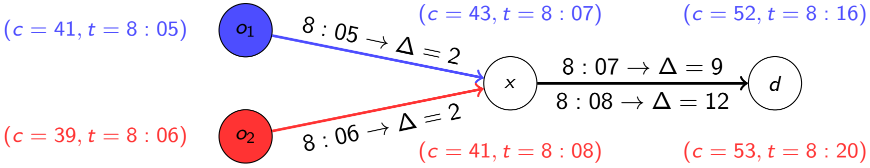
- No consistency between costs and arrival times



Sub-Problem: The Best Origin Problem

In Time-Dependent Case

- No consistency between costs and arrival times



Multi-Label Dijkstra

- Dominance rule: (c_x, t_x) dominates (c'_x, t'_x) if and only if:
  - **Exact:** $t_x \leq t'_x$ and $c_x - c'_x \leq t_x - t'_x$
  - **Heuristic:** $t_x \leq t'_x$ and $c_x \leq c'_x$
- Impact of heuristic dominance
  - CPU time: decr. 91.6%; Sol cost: incr. 0.6%

SPP with Synchronization Points: Outcomes

Publication

- Bit-Monnot, Artigues, Huguet, *Killijian*. Carpooling: the 2 Synchronization Points Shortest Paths Problem. *Workshop on Algorithmic Approaches for Transportation Modelling, Optimization, and Systems, ATMOS'2013*, Sophia Antipolis France, pp150-163, September, 2013
- Huguet, Kirchler, Parent, Wolfler Calvo. Efficient algorithms for the 2-Way Multi Modal Shortest Path Problem. *Electronic Notes on Discrete Mathematics, (International Network Optimization Conference)*, 41:431-437, May, 2013 May 2013), 2013

DEMO

- MuPaRo (Multi-Participant Routing)
- Open source (`http://projects.laas.fr/MuPaRo/MuPaRo/`)

Future works

- Alternative and Multi-Objective itineraries
- Synchronization points (multi-users) and Privacy preserving
- Robustness of itineraries in agile transportation networks