Conference Poster

Fleet control algorithms for automated mobility
A simulation assessment for Zurich

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### Problem Statement

**Autonomous Mobility on Demand (AMoD) service**

Customers can request rides from the AMoD operator, who dispatches an empty automated taxi to the requested pick-up location. The taxi then drives to the drop-off point. The operator decides which vehicles to assign to which request (dispatching strategy) and where to move unsaturated vehicles (rebalancing strategy).

**Operator objective**

The goal is to minimize total customer waiting times and idle time of vehicles. Given a static demand, find optimal dispatching and rebalancing strategies that minimize the total empty-pickup distance and empty-rebalancing distance, respectively.

### Algorithms

**A1) Load-balancing heuristic**

For every dispatching time step, check whether there are enough available vehicles. If so, route the requests and assign the closest available vehicle. Otherwise, create a list of available vehicles and assign the closest available one. Once assigned, dispatched vehicles cannot be reassigned.

**A2) Global Euclidean Bipartite Matching**

Determine an optimal bipartite matching between all open requests and available vehicles in every dispatching step. Based on the Euclidean distance. Assignments may be changed in the next dispatching step.

**A3) Feedforward Linear Program**

Formulates a linear program to simultaneously compute travel times and transition probabilities. For every dispatching step, solve the linear program and assign the closest available vehicle. Once assigned, dispatched vehicles cannot be reassigned.

**A4) Feedback Linear Program**

Instead of prescribing route times and transition probabilities, the Feedback Linear Program uses continuously measured counts of open requests as the desired distribution. Solve the linear program and assign the closest available vehicle. Once assigned, dispatched vehicles cannot be reassigned.

### Simulation Setup

**MATSim**

- Agent- and activity-based transport simulation framework
- Simulates daily travel plans of a population in a queue-based network
- Extension for Automated Vehicles by Blott (2017)

**Baseline Scenario: City of Zurich**

- Cut from 8M agents Swiss Baseline Scenario (Bösch et al. 2016)
- 1% sample of agents that interact with the study area (City of Zurich, Figure 1)
- Detailed multi-stage daily activity chains

**Demand generation for the AMoD service**

- Consider structural constraints (agents entering the area by car must leave by car)
- Detailed multi-stage daily activity chains
- K-median clustering of the requests (Map: OpenStreetMap)

**Study area**

- Covers the 12 districts of Zurich and the nodes Virtual Nodes

**Simulation results**

- For almost any analyzed waiting time, there is at least one advanced algorithm with a competitive advantage over the simple heuristic (A1).
- For longer waiting times (> 5min) the non-rebalancing bipartite matching (A2) outperforms the rebalancing ones.
- For almost any analyzed waiting time, there is at least one advanced algorithm with a competitive advantage over the simple heuristic (A1).
- Considering the full costs of a private vehicle in Switzerland (0.7 CHF/km, TCS, 2016) the analyzed operators would be able to offer a waiting time of about four minutes.

### Fleet Operation Results

**Waiting time (Figure 2)**

- The Load-balancing heuristic (A1) yields consistently the longest waiting times.
- The Feedback Linear Program (A4) performs best, but close to the other algorithms based on Linear Programming.
- A wait time of 5 minutes (which is assumed to be acceptable) is reached with a fleet size of 14,000 vehicles for the heuristic, but with only 4,700 vehicles for the feedback dispatcher.

**Fleet distance**

- Customer distance (left, dark) stays constant since demand is kept constant
- Empty pickup distance (middle, light) increases with larger fleet sizes and higher vehicle availability
- Empty rebalancing distance (right, dark) adds substantial mileage to the fleet. The total mileage is almost kept constant with rebalancing.

### Financial Analysis

Cost Calculation (Bösch et al., 2017)

- Considered fleet occupancy (idle time) and utilizations (empty miles)
- Price per passenger kilometer in Swiss Francs (CHF) for a profit margin of 3%

**Results (Figure 4)**

- The Feedback Linear Program (A4) is able to offer the cheapest rides if very low waiting times (<=5 min) are desired.
- For longer waiting times (>5 min) the non-rebalancing bipartite matching (A2) outperforms the rebalancing ones.
- For almost any analyzed waiting time, there is at least one advanced algorithm with a competitive advantage over the simple heuristic (A1).

**Conclusion & Outlook**

We show that, in our scenario, an operator with an intelligent dispatching and rebalancing algorithm has a competitive advantage over others. To what extent the optimal strategy, however, depends on the willingness to pay (WTP) of the customer.

For future studies, we will use the possibility of MATSim to perform dynamic mode choice decisions. By incorporating survey results we will be able to further explore the trade-off between WTP, customer waits times and AMoD supply. Furthermore, larger population samples will be used.