Including joint trips in a Multi-Agent transport simulation

Thibaut Dubernet

Institute for Transport Planning and Systems (IVT)
ETH Zurich
Introduction

Inclusion of joint trips in MATSim

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Introduction

- joint trip: several individuals traveling in the same private vehicle
- joint traveling: important behaviour
  - occurs frequently in households
  - some policies aim at encouraging such a behaviour
    - HOV lanes
    - car-pooling services
- currently, few means of predicting such a behaviour exist
- traffic simulation is an important tool for policy evaluation
- micro-simulation, by simulating individuals explicitly, allows to simulate a wide range of behaviours
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The MATSim software

- MATSim: Multi-Agent Transport Simulation
- open source software (GNU GPL)
- written in Java
- Mainly developed at ETHZ, TU Berlin, Senozon
The MATSim process in a nutshell

- state of traffic in an average day: (stochastic) user equilibrium
- a strategy (daily plan) can be modified by changing dimensions easy to change in the short-term (day-to-day)
- dimensions corresponding to long-term changes (e.g. home and work places) are exogenously determined (boundary conditions)
- search process: “co-evolutionary” algorithm
  - works with a population of heterogeneous agents
  - each agent $i$ tries to solve $\max_{p_i \in P_i} U(p_i|p_{-i})$
  - influence of $p_{-i}$: via congestion
The MATSim process steps

1. **Initial demand**
2. **Traffic simulation**
3. **Scoring**
4. **Analysis**
5. **Replanning**
   - Creation of new plan
   - Random mutation
   - Optimisation given the travel times in the previous iteration
   - Selection of a past plan based on experienced score
   - Probabilistic (RUM)
   - Deterministic (best past plan)
The MATSim process steps

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- **Traffic simulation**
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- **Analysis**

**Replanning**:
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MATSim and joint trips (1): MATSim

▶ remember the agent’s problem?
  ▶ max_{p_i \in P_i} U(p_i | p_{-i})
  ▶ |p_{-i}| estimated via “mobility simulation”
  ▶ |p_{-i}| actually differs between iterations

▶ remember MATSim’s process?
  ▶ agents actually “knows” U(p_i | p_{-i}) \approx U_I(p_i)
  ▶ |p_{-i}|: effect of experienced congestion in the last execution
    (iteration I): “empirical” knowledge
  ▶ this is usually valid enough:
    ▶ changing plans of few agents only has a minor influence on
      the state of traffic
    ▶ actually reproduces human learning
MATSim and joint trips (2): joint trips

- what about joint travel?
  - $p_{-i} = \{p_j\}_{j \in S_i} \cup \{p_k\}_{k \not\in S_i}$ with $S_i$ the set of co-travelers
  - $S_i$ typically very small
  - each $\{p_j\}_{j \in S_i}$ has a lot of influence
    - participation in joint travel
    - departure time for the joint trip
    - “utility transfers” (altruistic behaviour, monetary compensation)
  - individuals typically aware of (relevant part of) $\{p_j\}_{j \in S_i}$ (agreement): “theoretical” knowledge

- necessary to find a way to actually correlate plan selection based on $U(p_i|\{p_j\}_{j \in S_i})$
MATSim and joint trips (2+1): joint trips in MATSim

To solve those problems, the equilibrium is defined over groups of agents:

- new “aggregated” data structures are defined
  - Person → Clique
    - groups Persons which (can) travel together ($i \in C \Rightarrow S_i \subset C$)
    - maintains a set of JointPlans
  - Plan → JointPlan
    - groups individual plans, always selected together
    - is affected a score (currently, the sum of the scores of individual plans: full utility transfers)

- replanning modules work at the aggregated level (competing cliques)

- joint trip: access leg → pick-up → shared leg → drop-off → egress leg

- mobility simulation works with individuals
Remarks on joint trip generation

- most of the joint-trip generation approaches in the literature are specific to households
- in the context of MATSim, three approaches are possible:
  - generation *a priori* (exogeneous)
    - allows to adapt to different contexts (household, car-pool...)
    - joint trips not part of the equilibrium
  - generation during the iterations (endogeneous)
    - joint trips truly part of the equilibrium
    - increases the search space size
  - “hybrid”
    - a limited set of possible joint trips is identified beforehand
    - joint trips from this set can be selected/unselected during the optimisation
the replanning step in more details

At each iteration, for each clique, one of the following strategies is executed:

- optimisation of activity durations and mode
  - uses Tabu Search
  - estimates travel times based on the events of the previous simulation run
  - mode is optimised at the subtour level
- plans are synchronised by penalising unsynchronized plans
- (joint trips selection)
- re-routing
- best plan selection
  . . .
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▶ ...
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The Scenario

A scenario for the urban area of Zürich:

- 10% sample
- car-pooling matches computed by a partner
  - maximum detour time with time windows
- “default” (i.e. uncalibrated) utility parameters
Influence of constraints

- two major constraints implied by a joint trip:
  - synchronisation
  - mode chaining
- what influence do they have on the outcome?
- 3 runs:
  - no synchronisation, no mode chaining constraints
  - no synchronisation, mode chaining constraints
  - synchronisation, mode chaining constraints
Influence of constraints: synchronisation

no synchronisation, mode chaining constraints:

![Diagram showing influence of constraints with different scores and activities represented.]

- car
- car_passenger
- drop_off
- home
- leisure
- pt
- pu_28611
- pu_28612
- shop
- work_sector3
Influence of constraints: synchronisation

synchronisation, mode chaining constraints:
Influence of constraints: mode chaining

no synchronisation, no mode chaining constraints:

agent 4447907

score=159.11

agent 268740

score=215.61

- car
- car_passenger
- drop_off
- home
- leisure
- pt
- pu_54739
- shop
- work_sector2
Influence of constraints: mode chaining

no synchronisation, mode chaining constraints:

```
agent 268740
score=159.05
agent 4447907
score=190.76
```
Influence of constraints: scores
Travel time improvements
Score improvements

![Box plot showing score improvements with and without mode constraints.](image)
Score improvements

-4 -2 0 2 4
score improvement

2 3 4 5 6 7 8 9 10
clique size

with mode constraints
no mode constraints
What can we get from those results?

- major influence of mode chaining constraints on the attractiveness of joint trips
- need to consider other dimensions than travel time in attractiveness of joint trips vs other modes
  - monetary costs (fuel, tolls...)
  - car availability (household)
  - willingness to share time with social contacts
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- joint trip generation/selection
  - initial demand model
  - replanning-level (for small cliques, eg. households, or social-network-based)
- include monetary cost in utility function
- relaxation of the “utility transfers” hypothesis
  - actually use $U(p_i | \{p_j\}_{j \in S_i})$ to correlate plan choice
    - deterministic: iterative removal of dominated strategies
    - stochastic: joint choice probability
    - main issue: estimate efficiently conditional utility for all possible combinations
  - finer modeling of social contacts and willingness to help
  - allows more complex networks than isolated cliques
- extend the Clique concept to represent households
  - car availability
  - joint activities
- validation against aggregate data
Thank you for your attention

Any question?