Including joint trips in a Multi-Agent transport simulation

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- joint trip: several individuals traveling in the same private vehicle
- joint traveling behaviour is an 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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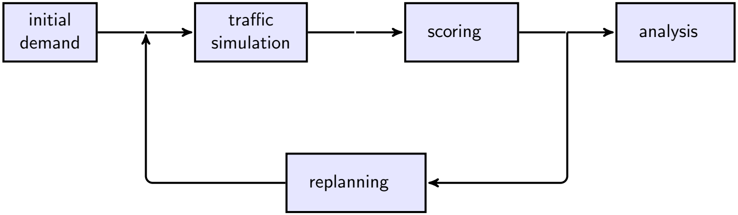
The MATSim software

- MATSim: Multi-Agent Transport Simulation
- open source software (GNU GPL)
- written in Java
- Mainly developped 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 (*eg.* home and work places) are exogenously determined (boundary conditions)
- search process: "co-evolutionary" algorithm
  - works with a population of heterogeneous agents
  - each agents 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



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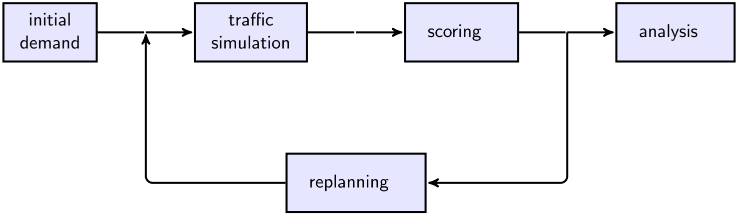

- replanning:
  - creation of new plan
    - random mutation
    - optimisation given the travel times in the previous iteration
  - selection of a past plan based on experienced score
    - probabilistic (RUM)
    - deterministic (best past plan)

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?
  - $p_{-i} = \{p_j\}_{j \in S_i} \bigcup \{p_k\}_{k \notin S_i}$ 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 $\rightarrow$ Clique
    - groups Persons which (can) travel together ($i \in \mathcal{C} \Rightarrow S_i \subset \mathcal{C}$)
    - maintains a set of JointPlans
  - Plan $\rightarrow$ 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* $\rightarrow$ *pick-up* $\rightarrow$ *shared leg* $\rightarrow$ *drop-off* $\rightarrow$ *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

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the replanning step in more details

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- optimisation of activity durations and mode
  - uses Tabu Search
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  - mode is optimised at the subtour level
  - plans are synchronised by penalising unsynchronized plans

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- best plan selection

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- best plan selection
- ...

The Scenario

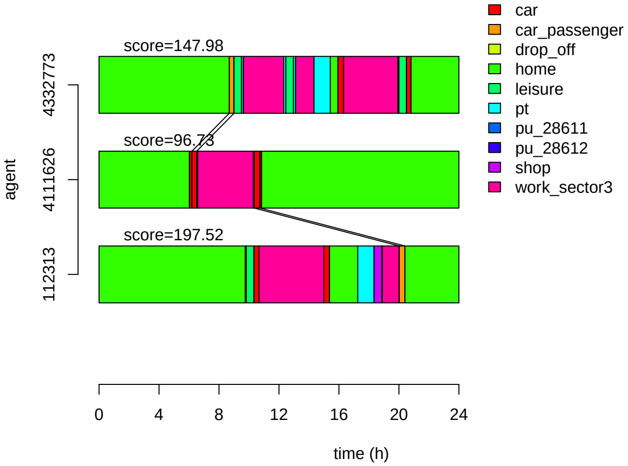
A scenario for the urban area of Zürich:

- 10% sample
- car-pooling matings computed by a partner
  - maximum detour time with time windows
- "default" (*i.e.* uncalibrated) utility parameters

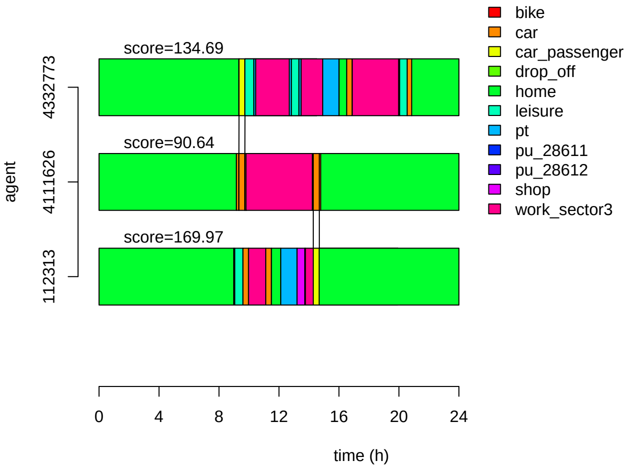
Influence of constraints

- 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

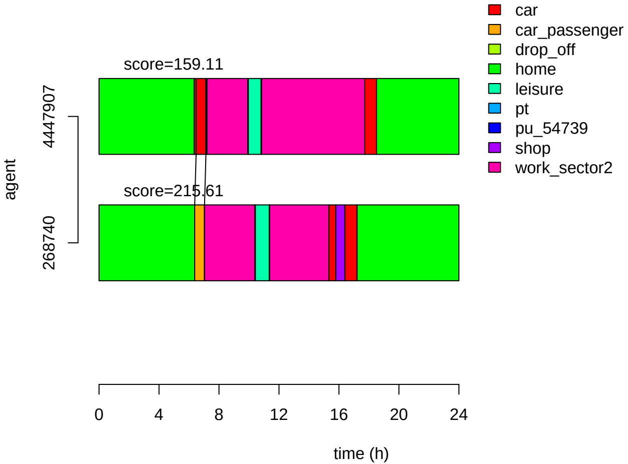
Influence of constraints: synchronisation



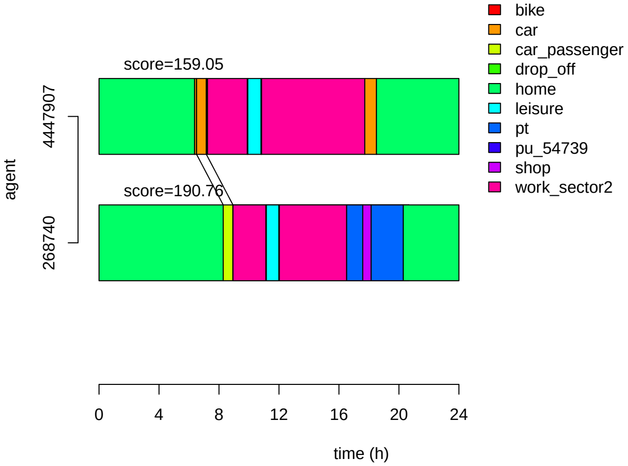
Influence of constraints: synchronisation



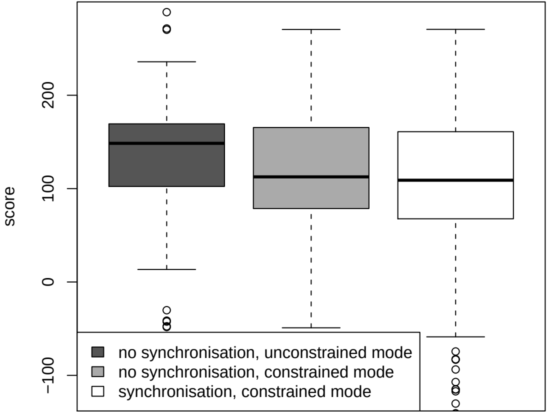
Influence of constraints: mode chaining



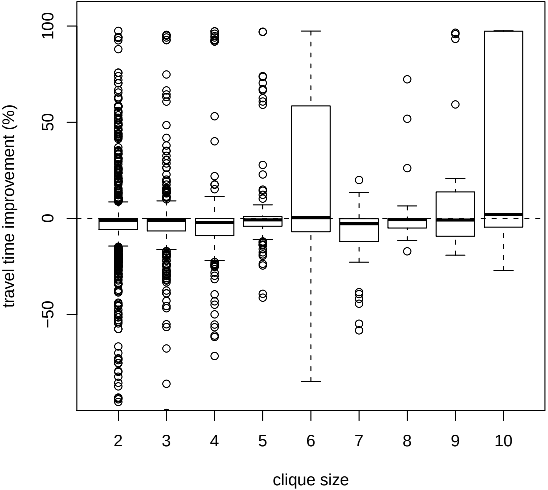
Influence of constraints: mode chaining



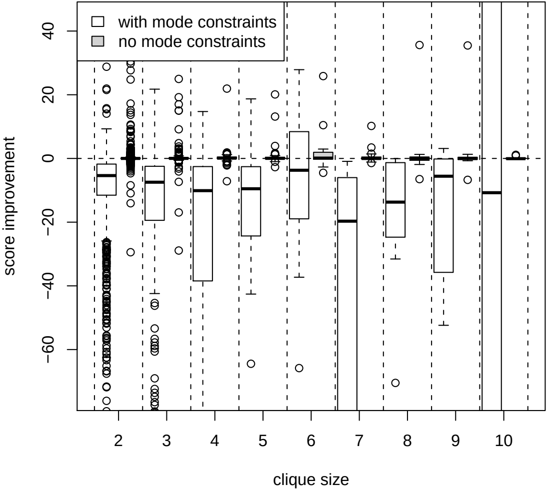
Influence of constraints: scores



Travel time improvements



Score improvements



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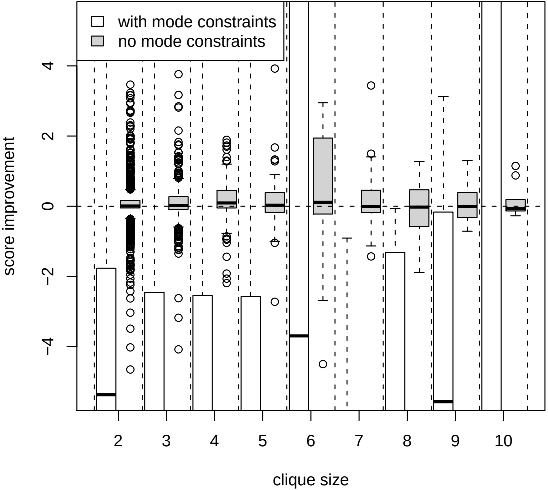

What can we get from those results?

- 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?