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 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

- initial demand
- traffic simulation
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- 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?
  - \( p_{-i} = \{p_j\}_{j \in S_i} \cup \{p_k\}_{k \notin S_i} \) 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 → 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 \textit{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
- ...
the replanning step in more details

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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

(score=215.61) car
(score=159.11) car_passenger

home
leisure
pt
pu_54739
shop
work_sector2

time (h)
Influence of constraints: mode chaining

- Bike
- Car
- Car passenger
- Drop off
- Home
- Leisure
- PT
- PU 54739
- Shop
- Work sector 2

Score 190.76
Score 159.05
Influence of constraints: scores

- No synchronisation, unconstrained mode
- No synchronisation, constrained mode
- Synchronisation, constrained mode

The box plots illustrate the distribution of scores under different constraints. The dark grey box represents the scores with no synchronisation and unconstrained mode, the light grey box represents the scores with no synchronisation and constrained mode, and the white box represents the scores with synchronisation and constrained mode.
Score improvements

![Graph showing score improvements with and without mode constraints across different clique sizes. The graph displays box plots for score improvement with and without mode constraints, illustrating the distribution of improvements across various clique sizes.]
Score improvements
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?