Explicitly Correlating Agent's Daily Plans in a Multiagent Transport Simulation: Towards the Consideration of Social Relationships

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Motivation

- Leisure activities represent a growing share of travel in developed countries
- Location of leisure activities is difficult to predict
  - Depends on variety of unobserved factors
  - Best one can do in microsimulation: add random noise (Horni 2013)
- Most important motivation for leisure: social contact
- Other important behaviors rely on *joint decisions*, particularly inside the household
- Classical equilibrium formulation of transport systems do not allow to represent such behaviors

Aims

- Design a model to represent joint decisions in microsimulations
- Design a methodology to generate a *synthetic social network*
- Test the resulting model for travel to leisure locations
- Additionally in thesis:
  - Compare two *solution concepts* in the context of households
  - Estimate *car pooling potential*

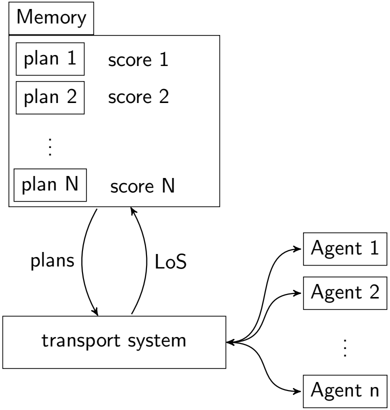
Equilibrium for Transport System

- Classical modeling assumption: rational agents
  - Preferences over routes/modes/daily plans, represented by utility
- Agents influence each other's utility (congestion, crowding)
  - Game theoretic view
  - need *Solution Concept*
- Classical way to model transport systems: some variant of Nash equilibrium
  - "no agent can *unilaterally* improve its utility"
  - Usual in traffic assignment: UE, SUE...
- MATSim: on the level of daily plans
  - Routes
  - Modes
  - Departure Time
  - (Sequence, Secondary Location...)

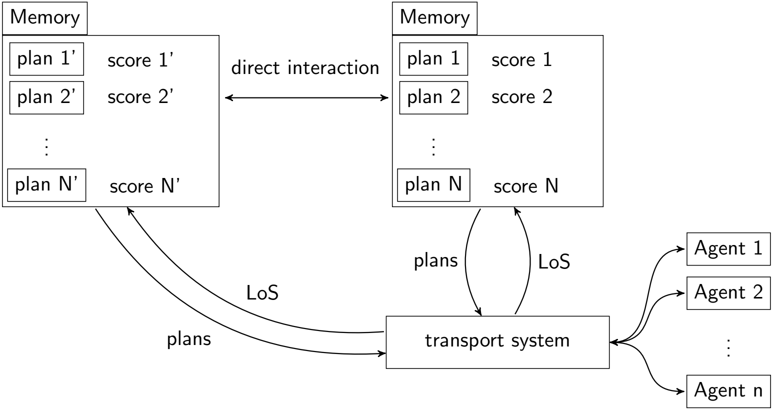
Joint Decisions

- Two kinds of co-dependence of plans' utilities
  - Field effect (congestion, crowding)
  - Direct effects (co-travelers)
- Two kinds of processes to take them into account (equilibrium):
  - Iterative learning
  - Binding agreement
- Intuitively, a decision that relies on *binding agreements*
  - for instance: going together to the cinema, sharing a ride...
- New concept in MATSim: Joint Plan
  - enforces binding agreements

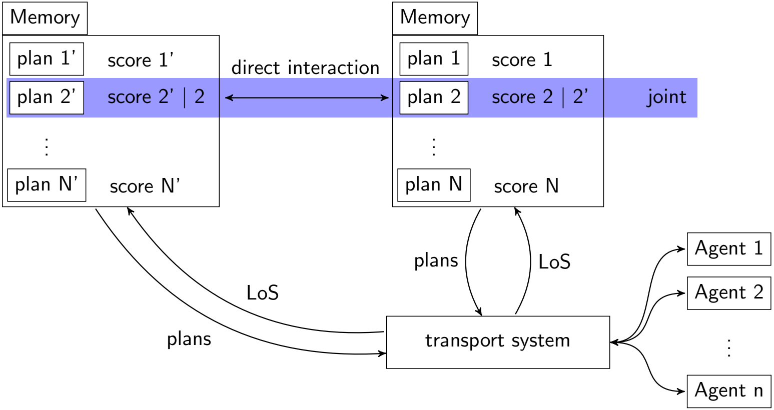
Joint MATSim: World of an Agent



Joint MATSim: World of an Agent



Joint MATSim: World of an Agent



Solution Concept for Joint Decisions

- Variants of Nash unrealistic
- Given an allocation of daily plans to agents, a group of agents represents a *blocking coalition* if:
  - they form a *clique*
  - they all can improve their (expected) utility by changing their daily plan *simultaneously*
- Includes Nash equilibrium as a special case (empty social network)

MATSim Process Without Blocking Coalitions

- Field effects taken into account as usual
- Direct effects are solved *at each iteration*
  - Scores randomized
  - Joint plans selected such that there exists no blocking coalition given the randomized scores

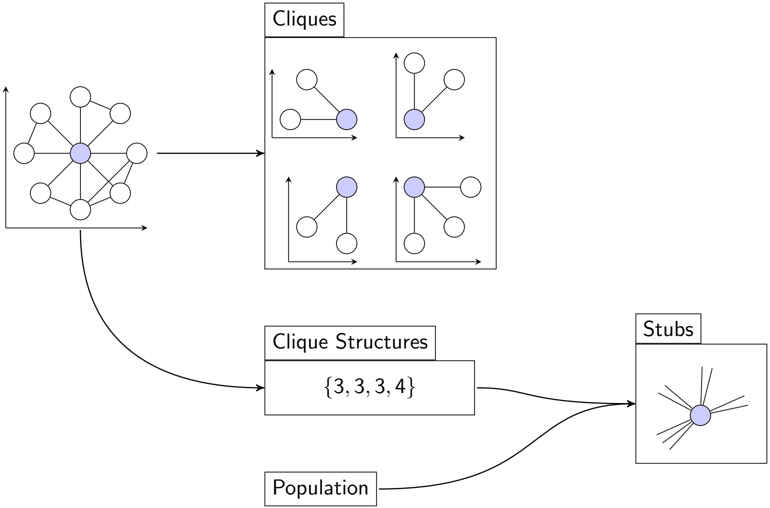
Generation of a Synthetic Social Network

- Simulating joint mobility behaviors requires *realistic synthetic social networks*
- Important characteristics:
  - Homophily (socio-demographic similarity of contacts)
  - Geography
  - Clustering (friends of friends tend to be friend)
    - in particular *clique size*
  - Large scale (several Mio agents)
- Lots of work on random networks, but no approach fulfills those requirements
  - Graph building procedures: no control
  - Statistical models: complex, poor and slow at generation

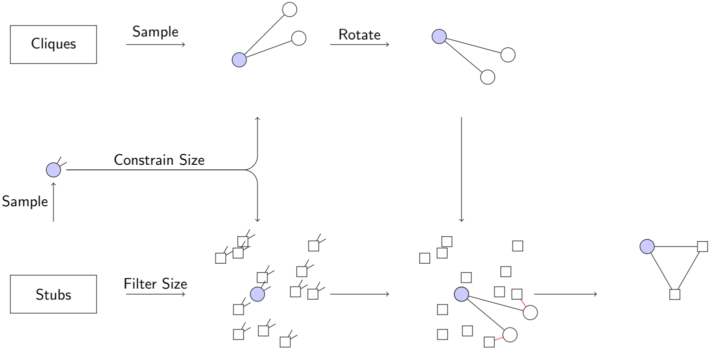
Cliques Sampling Algorithm

- Algorithm works on *ego-centric networks*
- The idea is to *sample from the observed distribution*
- Works on *positions* in a metric space, including space and socio-demographics
- Idea:
  - Sample *sets of positions* in this space
  - Link agents that are closest to those positions
- Exploits large scale of the population: there should be agents "relatively close" to most points of the space

Preparation



Cliques Sampling



Results

- Social network data from Swiss snowball sample (Kowald 2013)
- Algorithm applied to Swiss synthetic population (8,230,971 agents)
- 100 samples from 1% to 100% to test scalability
- Consider age in 5 years classes
- Consider gender
- Distance such that difference in socio-demographics more important than spatial distance

Results

- Controled parameters (distance, age difference, gender difference, clique size) well reproduced
- Degree well reproduced (not too much overlap in data)
- Global network statistics stable with sample size and realistic:
  - One giant connected component with more than 99% of agents
  - Average social distance close to 6
- Heterogeneity of ego-centric networks pretty well reproduced, except:
  - Under-estimate number of age-homogeneous networks
  - Under-estimate number of network with high share of friends 100 and 130km away
- Spatial concentration of social contacts well reproduced

Location Choice with Preference for Group Activities

- Can social networks help reduce the amount of noise needed to get realistic travel distance to leisure?
- Use the elements presented until now
- “Proof-of-concept” simulation for joint leisure in Switzerland
- “Simplified MATSim framework”: no iteration, no externalities, only direct influence

Leisure Travel in Switzerland

Most important leisure activity types (National Travel Survey 2010, in % of leisure activities):

Activity Type	Day of the Week			
	Mon. – Fri.	Sat.	Sun.	All
Restaurants	24.8	20.7	13.5	22.2
Outdoor (non sport)	19.2	17.2	26.0	20.0
Visits	17.7	21.5	22.4	19.2
Sports	13.0	8.6	8.8	11.5
Total	74.7	68.0	70.7	72.9

Setting

- 1% Swiss sample, with social network
- Each agent "knows" 30 random locations in a radius of 30km around home, plus home
- Agents choose one of the following plans:
  - go alone at one known location (including home)
  - go as a group of 2 to one of the locations known to the participants (including home)
  - go as a group of 3 to one of the locations known to the participants (including home)
- Search for a state without blocking coalition

Preferences

- Preferences of agents represented by utility including:
  - cost of distance
  - personal preference for location $\varepsilon_{e,l} \sim \mathcal{N}(0, \sigma)$
  - preference for social contact α
  - personal preference for particular contacts $\eta_{e,a} = \eta_{a,e} \sim \mathcal{N}(0, \vartheta)$

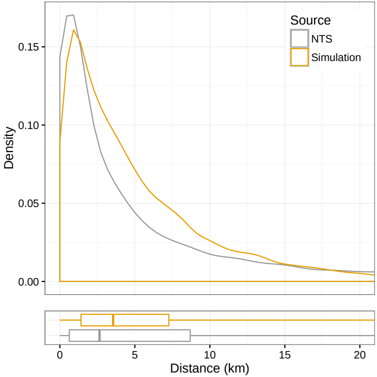
$$U(e, l, \mathcal{A}) = -d_{e,l} + \varepsilon_{e,l} + \sum_{a \in \mathcal{A}} (\alpha + \eta_{e,a})$$

- Use the following values:
  - $\alpha \in \{0\,\mathrm{km}, 5\,\mathrm{km}, 10\,\mathrm{km}\}$
  - $\vartheta \in \{0\,\mathrm{km}, 1\,\mathrm{km}, 5\,\mathrm{km}, 10\,\mathrm{km}\}$
  - $\sigma \in \{0\,\mathrm{km}, 1\,\mathrm{km}, 5\,\mathrm{km}, 10\,\mathrm{km}\}$

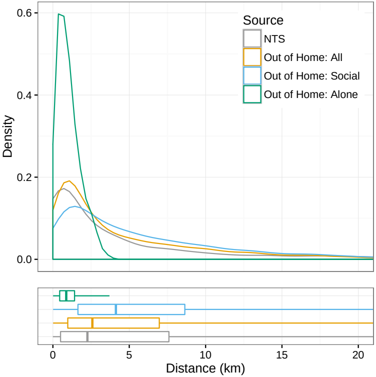
Summary Results

- Given positive α, traveled distance for visit very insensitive to parameters
- Traveled distance for Out-of-Home gets larger with σ and θ
- For higher α or θ, σ has little influence on traveled distance, but on the number of out-of-home activities
- Complex interactions between θ and σ: increasing σ makes it more difficult to find an agreement, until it is so large it is possible to find solutions acceptable for all

Traveled Distance, Visit, $\alpha = 10, \theta = 5, \sigma = 1$



(a) Visits



(b) Out of Home/Restaurant (WE)

Discussion

- Proposed algorithm able to generate realistic social network in reasonable time
  - Important non-controlled for characteristics well reproduced
  - Difficult to do better without a more "semantic" model
  - Satisfying for our purpose
- Realistic social network results in realistic traveled distances for visits
  - Not very sensitive to parameters
- Desire to meet social contact allows to reduce the level of noise needed on top of utility of facility
- Additional work to do to include it in practical simulation
  - Who performs leisure (Feil, Ordoñez, Balac)
  - Calibration / Validation of full simulation
  - Combine with household activity model

Conclusions

- A realistic social network does help to predict leisure travel distance
- Fair amount of additional complexity
- Contributions:
    - Model for joint decisions in generic social network
    - Effective algorithm to generate realistic social network
    - Demonstration of viability of using social contacts to steer leisure location choice