Using a Multi-Agent Transport Simulation to Study the Impact of the Preference for Joint Activities on Leisure Trip Distance Distribution

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Social Contacts in Mobility Behavior

- Most modeling approaches consider individuals making decisions given characteristics of the environment
- Important part of mobility behavior also conditioned by *social interactions*
  - Social activities (meeting friends at a restaurant)
  - Intra-household interactions (who will do the groceries?)
  - Joint travel
- Comes with additional challenges for modeler
  - Bargaining
  - Strong dependency of choices of different individuals

Game Theoretic View of Social Interaction

- Game Theory: mathematical modeling of *strategical interaction* of *rational agents*
- Game Theoretic *Solution Concept*: definition of which states are "solutions" of the game
  - Stability condition
  - *e.g.* Nash Equilibrium
- Social interactions: group of individuals with private preferences attempting to *agree* on a joint outcome.
  - Corresponds to the object of game theory
  - *Communication* dimension
  - Requires specific solution concept

Game Theoretic View of the Transportation System

- Even without social interactions, game theoretic view of transportation systems standard
  - Wardrop Equilibrium: Nash Equilibrium of a specific "congestion game"
- Individuals compete for use of the infrastructure
- Solution Concepts: variants of the Nash Equilibrium
- Particularly well suited in the activity-based framework
  - Strategy of an individual: daily plan
  - Satisfaction depends on travel times, facility crowding...
  - Individuals try to maximize their satisfaction
  - Example: MATSim

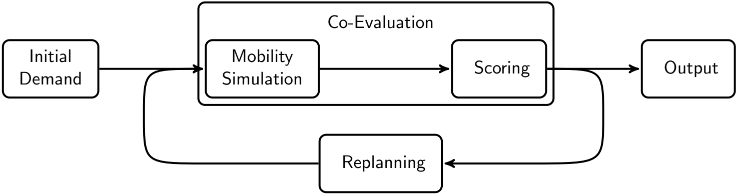
Solution Concept for Social Interaction

- Nash Equilibrium lacks communication
  - Example of the House Allocation Problem
    - *n* houses, *n* players
    - Players have preference ordering over houses
    - Players prefer the worst house than having to share
    - Any one-to-one allocation of player to houses is a Nash Equilibrium!
    - More realistic solution concept: Absence of Blocking Coalition
- Solution Concept with Communication: "Absence of Improving Coalition"
  - Improving Coalition: group of agents that can *all* be better off by *simultaneously* changing their daily plan

Simulation Framework: Overview

- Design a *co-evolutionary* algorithm embedding the *absence of improving coalition* concept for the daily plan scheduling game
- Joint decisions can be undertaken with:
  - Household members
  - Social contacts
- Multi-agent, game theoretic setting
- Idea: allow agents to conclude binding agreements, and represent their influence on utility

The Simulation Framework in a Nutshell



- Binding agreements represented by *joint plans*
  - Score allocated to a plan takes into account the fact that other plans of the joint plan are selected
  - Several copies of a daily plan can each pertain to different joint plans
  - $\Rightarrow$ agreement structure part of the evolution
- MATSim process modified to allow enforcement of those constraints

Selection Operators

- Solution Concept defined by the selection operators
  - Selection for interaction
    - Influences scores
    - Determines output
    - Abscence of Improving Coalition with randomized scores
  - Selection for removal
    - Defines choice set
    - Pushes memory of agents towards improvement
    - Uses lexicographic ordering, keeping at least one plan per "joint plan composition"
  - Result: logit choice between coalition structures

Motivation

- Leisure trip distance distribution difficult to forecast
- Empirical work shows a strong influence of social contacts on choice of leisure location and time
- Most joint travel is observed for leisure purpose — modeling the choice of joint leisure location choice is necessary to be able to represent joint travel

Including Joint Leisure Location Choice

- Search space defined by *replanning operators*
- Need to adapt leisure locations for social contacts such that
  - High probability to have social contacts performing activities at the same location
  - "Good" locations have high probability to be choosen
- Procedure:
  - Select social contacts with leisure activities in the same time frame
  - Approximate space-time prisms by ellipses
  - Select a location in the intersection of the prisms

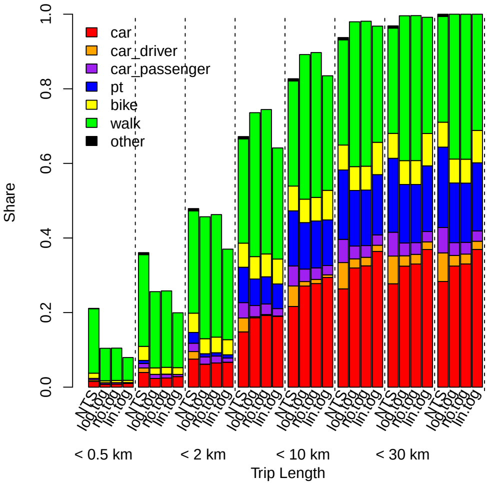
Scenario

- Based on the 2010 Zurich area scenario
  - Population, network, public transport
- Synthetic leisure contact network
  - Based on swiss snowball sample
  - Social network generation model: Arentze *et al* (2013)

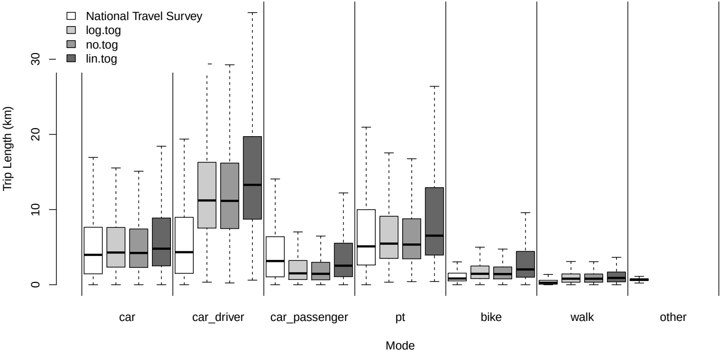
Specific elements

- Utility of being together
  - Logarithmic
  - Linear
- Positive ASC for driving somebody
  - Represents willingness to help
  - *De facto* acts as a threshold of driver detours

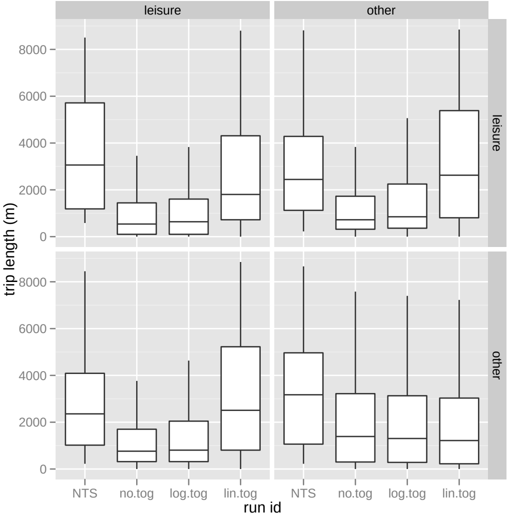
Mode shares


car
car_driver
car_passenger
pt
bike
walk
other
Share
0.0
0.2
0.4
0.6
0.8
1.0
NTS
log.tog
no.tog
lin.tog
< 0.5 km
< 2 km
< 10 km
< 30 km
Trip Length

Distance Distributions per Mode



Distance Distributions per Purpose



Passenger Mode Share per Purpose: NTS

Passenger Mode Share per Purpose: Log

Passenger Mode Share per Purpose: Linear

Discussion

- Results of first runs for the case of leisure contact network
- Reasons for the patterns observed in the data still to find
- Simply using parameters that worked well for households for the case of leisure contacts results in very high driver detours
  - Joint calibration with both households and leisure contacts seem necessary…
- Desire to perform joint leisure activities can be made to have strong impact on distance distribution
  - Not clear how to calibrate part of social coordination and unobserved heterogeneity
- Desire to perform joint activities did not result in joint travel to leisure activities

Conclusion

- Considering leisure contacts seem to be necessary for simulating leisure trips
  - Location choice
  - Joint travel
- New challenges in representing individual's decisions
- Joint decision problem can be formulated in game theoretic terms

Next Steps

- Investigate in more details the impact of the location sampling heuristic
  - Tradeoff between variability and size of the search space
- Finalize calibration
- Solve detours
- Integrate with household simulation

Questions?