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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Introduction: Social Contacts in Transportation Systems

A Framework to Simulate Joint Decisions

Simulation of Joint Leisure Destination Choice

Conclusion and Next Steps
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
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Conclusion and Next Steps
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
    - Absence 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
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Conclusion and Next Steps
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 chosen
- 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
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

![Mode shares chart]

- car
- car_driver
- car_passenger
- pt
- bike
- walk
- other

Trip Length:
- < 0.5 km
- < 2 km
- < 10 km
- < 30 km

Share distribution across different trip lengths and modes.
Distance Distributions per Mode
Distance Distributions per Purpose

![Distance Distributions Chart]

- Leisure
- Other

Run ID
Trip Length (m)
0
2000
4000
6000
8000

NTS
No tog
Log tog
Lin tog

Leisure
Other
**Passenger Mode Share per Purpose: NTS**

<table>
<thead>
<tr>
<th>Destination Type</th>
<th>education</th>
<th>home</th>
<th>leisure</th>
<th>shop</th>
<th>work</th>
<th>all</th>
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<td>5.3 %</td>
<td>15.7 %</td>
<td>6.8 %</td>
<td>12.0%</td>
<td>6.5%</td>
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<td></td>
<td></td>
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<tr>
<td>leisure</td>
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<td>14.9 %</td>
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<td>4.8 %</td>
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<tr>
<td>shop</td>
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<td>work</td>
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<td>5.1 %</td>
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<tr>
<td>all</td>
<td>6.5 %</td>
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<td>13.7 %</td>
<td>8.0 %</td>
<td>5.0 %</td>
<td>9.2 %</td>
</tr>
</tbody>
</table>

**Destination Type**

- education
- home
- leisure
- shop
- work
- all

**Origin Type**

- education
- home
- leisure
- shop
- work
- all

**Passenger Mode Share**

- 6.5%
- 9.9%
- 13.7%
- 8.0%
- 5.0%
- 9.2%
- 6.7%
- 5.1%
- 7.6%
- 3.7%
- 4.8%
- 5.3%
- 0.0%
- 8.3%
- 10.4%
- 13.1%
- 4.0%
- 8.2%
- 6.7%
- 5.1%
- 7.6%
- 3.7%
- 4.8%
- 5.3%
- 8.4%
- 16.8%
- 17.6%
- 8.0%
- 7.0%
- 15.0%
- 6.5%
- NA
- 14.9%
- 9.2%
- 4.8%
- 9.0%
- 7.3%
- 5.3%
- 15.7%
- 6.8%
- 12.0%
- 6.5%
Passenger Mode Share per Purpose: Log
## Passenger Mode Share per Purpose: Linear

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<th>Origin Type</th>
<th>Destination Type</th>
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<td>2.1%</td>
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<tr>
<td>leisure</td>
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<td>4.2%</td>
<td>3.4%</td>
<td>2.2%</td>
<td>3.1%</td>
<td>2.6%</td>
<td>3.1%</td>
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<tr>
<td>home</td>
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<td>2.5%</td>
<td>2.1%</td>
<td>3.5%</td>
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<td>2.5%</td>
<td>2.9%</td>
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<tr>
<td>education</td>
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<td>2.2%</td>
<td>1.9%</td>
<td>3.1%</td>
<td>2.1%</td>
<td>2.7%</td>
<td>2.1%</td>
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</tbody>
</table>
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
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Conclusion and Next Steps
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?