Ag.-based simulation and economic evaluation
– or –
The quest for *quantitatively* valid models
Outline

- Where we come from and where we are (= intellectual heritage of MATSim)

- Including an excursion into the "bar problem"

- From toy models to quantitative predictions

- (Economic) interpretation of selected MASim studies
Where we come from
(= intellectual heritage of MATSim)
Fractals: look similar at different scales.

Need to be able to look at 100x100 gridcells "windows" of a 1000x1000 gridcells object.

→ each cell an "agent"
→ simple computational "rules" → fast computation
→ Model "correct"/useful if correct fractal dimension
From fractals to "true" agents

The "cells" became more and more "intelligent" (and mobile).
Emergence

Computational techniques such as CA or MASim developed ... (in part) to ... observe/understand "emergence".

Emergence ...

... something like "macroscopic properties that do not exist at the micro-level". E.g. ocean waves, fractals, intelligence. Also: traffic jams, urban system.

So this is where we come from: Understanding the emergent properties of urban systems.
The bar problem

[[screenshots from paper, with certain texts highlighted]]
Morale

Do not need full econometric rational choice behavior to get coordination.

Instead, coordination emerging from "alphabet soup of predictors".

On the other hand, agent-based scoring/fitness functions, and agents that climb uphill.
Where we are
(MATSIm = Multi-Agent Transport Simulation)

www.matsim.org
Each agent (= synthetic traveler) has multiple plans:

<plan>
  <act type="home" ... link="5834" end_time="07:00" />
  <leg mode="car" trav_time="00:25">
    <route>1932 1933 1934 1947</route>
  </leg>
  <act type="work" ... link="5844" end_time="16:00" />
  <leg mode="car" trav_time="00:14">
    <route>1934 1933</route>
  </leg>
  <act type="shop" ... link="123" />
...
</plan>
Co-evolutionary approach

1) active plans simultan'ly **executed** in synthetic reality [[show pt]]
2) plans **scored** based on how they performed
3) bad plans are **removed**
4) some agents copy a plan, **modify** it, make it "active"
4) other agents **select** according to logit model out of existing plans
5) goto 1)

Plan = "genotype"
Perf. of plan = "phenotype"
Score = "fitness"
New route

<plan>
  <act type="home" ... link="5834" end_time="07:00" />
  <leg mode="car" trav_time="00:25">
    <route>1932 1933 1934 1947</route>
  </leg>
  <act type="work" ... link="5844" end_time="16:00" />
...
</plan>
New mode

<plan>
  <act type="home" ... link="5834" end_time="07:00" />
  <leg mode="car" bicycle" trav_time="00:25">
    <route>1932 1933 1934 1947</route>
  </leg>
  <act type="work" ... link="5844" end_time="16:00" />
  ...
</plan>
Plans modification

E.g.:

- new route
- new mode (+ new route)
- new departure times
- new locations for secondary activities

- (change of mobility tools)
- new locations for primary activities (work)
- new residential locations
Score

Use econometric "utility" for "score"

Where does utility come from?

E.g. Random Utility Modelling:

\[ U = \beta_{tt.car} \times tt_{car} + \beta_{tt.pt} \times tt_{pt} + \beta_{cost} \times cost + ... \]

Again:

The attributes for the scoring come from executing the plan, not from some prediction about it.
Darwinian selection

Removal of bad plans
- worst
- inverse logit model
- inverse path size logit model

Selection of good plans
- select best
- logit model
- path size logit model
"Toy" models vs. quantitative predictions
Toy models

Originally:

- model should show "emergence", if possible based on simple rules (to facilitate insight)
- model should show correct fractal dimension

→ "Toy models" sufficient

Our current work:

- correct quantitative prediction (e.g. of traffic volumes, number of passengers, economic gains)

→ "Toy" models no longer sufficient.
ABM and RUM

- Use random utility model for decision-makers (e.g. paper by Takama & Preston, TR-A, 2008)

- Or alternative behavioral model (prospect theo, regret min.)
Calibration of choice "from outside in"

Option 1:
Manual search for good parameters to match macro data.

Option 2:
Cadyts = Calibration of dynamic traffic simulations (G. Flötteröd). Automatic calibration of ...

• ... plan-specific additive utility corrections ...
• ... (person-specific?) utility coefficients (future) ...
... to match macroscopic data.
Calibration of choice set generation

Do we need calibrated choice set generation?

- **routes, times, modes**: "random" choice set generation seems ok
- **locations**: random choice set generation not sufficient (work with A. Horni, K.W. Axhausen)

→ For routes, times, modes, we may be getting away without calibrating choice set generation.

(consistent with Brian Arthur)
(Economic) interpretation
So we have ...

... (at least for routes, times, modes):
- "random" choice set generation
- execution-based scoring of each alternative
- (path size) logit choice based on score
- ways to get the utility functions "right".

What can we do with this?
Downstream analysis (e.g. emissions)
NO2 exhaust emissions (w/ B. Kickhöfer)

*see http://www.matsim.org/scenario/munich*
Winners and losers
Winners and losers

Since we have every agent's utility ...

... we can search for agents who gain or lose a lot by a measure.
Seattle viaduct removal top 10% affected
Locations winning from freeway ring extension

Areas along ring do not benefit

benefits go to suburban commuters
Brussels cordon toll accessibility changes

Accessibility increase inside cordon (reduced congestion)

Reduced accessibility outside cordon (toll part of travel cost)

(with D. Röder, I. Cabrita)
Winner/loser analysis

Winner/loser analysis *very* straightforward with ABM.

More important than one may think: identify support/opposition for projects.
Internalization of external effects
Emissions-specific toll

Let each driver pay vehicle-specific toll that corresponds to the external costs of its emissions
Emissions effects (compared to zone 30, left)

Zone 30 reduces emissions inside zone, but increases them everywhere else

Internalization reduces emissions everywhere

(with B. Kickhöfer)
Zone 30: Changes in emissions

(with B. Kickhöfer)
Economic benefit

Agent-specific utility:

\[ U = ... + \beta_{tt} \times tt + \beta_{money} \times cost + ... \]

Now assume that \( \beta_{money} \) is income-dependent ...

(+/- 100Eu different to non-affluent vs. affluent people)

WTP for measure = \( \Delta U / \beta_{money} \)
Income-dependent benefit of measure

(10% pt speed +, Zrh scenario)

→ Equity analysis of policy measures possible with MASim

Affluent people happy.

Less affluent people would be more happy about paying out the construction cost.
Summary
Conclusion

Can (and should)

- build "toy" ABMs to illustrate.
- build calibrated ABMs to quantify.
- calibrate "from the inside out"
  -(e.g. calibrated Random Utility Models for behavior)
- calibrate "from the outside in"
  -(e.g. calibrate behavior to match aggregated data)
- investigate if we really need to calibrate choice set generation in MASim
- understand connection to cost-benefit-analysis/economic theory
- "tell stories".