Behavioral calibration of a large-scale travel behavior microsimulation

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Introduction and motivation

• Dynamic traffic assignment (DTA) captures interactions of
  – a travel demand model (typically route choice)
  – a supply model (mobility simulation)
• DTA *microsimulations* have the potential to
  – equilibrate more than route choice (e.g., dpt. time, mode)
  – capture arbitrary demand heterogeneity
  – handle complex and very large systems
• however
  – little mathematical framework available
  – calibration has been fairly ad hoc

This article presents real-world results using a mathematically consistent calibration methodology.
Outline

Outline of DTA microsimulation

Outline of calibration

Zurich case study

Summary, conclusion, outlook
General DTA microsimulation structure

- travel behavior
  - demand simulator
    - route choice
    - dpt. time choice
    - location choice
    - ...
  - supply simulator
    - traffic flow dynamics
    - congestion
    - travel times
    - ...

- network conditions

[Diagram of a flowchart showing the relationships between travel behavior, demand simulator, supply simulator, and network conditions.]
The MATSim DTA microsimulation

• all-day travel behavior of an agent is captured in its plan
• equilibrates route + departure time + mode choice
• runs in two stages
  1. choice set generation: update choice set during iterations
  2. choice: run demand simulator based on stable choice set
• choice stage deploys multinomial logit model where

\[ P_n(i) \sim \exp(V_n(i)) \]

is probability that agent \( n \) chooses plan \( i \) with utility \( V_n(i) \)
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Cadyts – Calibration of dynamic traffic simulations

- calibration framework for iterated DTA microsimulations
- calibrates arbitrary choice dimensions from traffic counts
- compatible with many demand and supply simulators
- freely available under GPL:³ transp-or2.epfl.ch/cadyts

³GNU General Public License
Basic functioning

- simulator implements plan choice distribution $P_n(i)$
- account for measurements observed in the network
  - $y_a(k)$ is traffic count on link $a$ in time step $k$
  - $\sigma_a^2(k)$ is the variance of the according error
- plan choice distribution given the measurements is

$$P_n(i|\{y_a(k)\}_{ak}) \sim P_n(i) \prod_{ak \in i} \exp \left( \frac{y_a(k) - q_a(k)}{\sigma_a^2(k)} \right)$$

where $q_a(k)$ is the simulated flow on link $a$ in time step $k$
- assumes normal error and low congestion
- more general solution exists but is less intuitive
- the above works intuitively like a controller
Application to MATSim (1/2)

- insert MATSim choice model $P_n(i) \sim \exp(V_n(i))$ into the calibrated choice distribution:

$$P_n(i\{y_a(k)\}_{ak}) \sim \exp \left( V_n(i) + \sum_{ak \in i} \frac{y_a(k) - q_a(k)}{\sigma_a^2(k)} \right)$$

- increases the utility of plans that improve the measurement reproduction (and vice versa)
Application to MATSim (2/2)

MSC one iteration of calibrated simulation
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- network with 60,492 links and 24,180 nodes
- 187,484 agents
- hourly counts from 161 counting stations
- jointly estimate route + dpt. time + mode choice
Cross-validation

- mean weighted square error MWSE

\[
MWSE = \left\langle \left( \frac{(y_a(k) - q_a(k))^2}{2\sigma_a^2(k)} \right) \right\rangle_{ak}
\]

- split counting stations into 10 disjoint sets
- run 10 experiments, in each experiment
  - use 9 out of 10 sensor sets for estimation
  - use remaining sensors for validation
Measurement reproduction results

relative MWSE

iteration

0 100 200 300 400 500

0 0.2 0.4 0.6 0.8 1.0
Cross-validation results

relative MWSE

iteration
Scatterplots

**plain simulation**

*Volumes 8:00 – 9:00, Iteration: 500*

*Volumes 16:00 – 17:00, Iteration: 500*

**calibrated simulation**

*Volumes 8:00 – 9:00, Iteration: 1000*

*Volumes 16:00 – 17:00, Iteration: 1000*
Computational performance

• experiments were run on a heterogeneous cluster
• raw running times are *not comparable*
  – 500 iterations of **plain simulation** took 72 h on a Dual-Core AMD Opteron Processor 2222 machine with 32 GB RAM
  – 500 iterations of **calibrated simulation** took 36 h on a Intel Xeon CPU X5550 with 48 GB RAM

• calibration takes place *within* the iterations of the simulation
• speculation: calibration *may even accelerate* simulation in that it induces drift to plausible system state
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- joint calibration of route + dpt. time + mode choice for 190k agents on 60k link network with low computational overhead
- analytical DTA models do not have an edge over simulation-based ones in terms of calibration any more
- also adjust the parameters of the choice model – likely to require additional data sources