A general methodology and a free software for the calibration of DTA models

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Motivation

- joint estimation of
  - path flows
  - demand parameters
  - supply parameters

  combining all available data sources
- formulation without equilibrium constraints
- applicable to microsimulations

Outline

Methodology

Simple example

Complex example

Summary & outlook

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Stochastic user equilibrium (SUE)

n	origin/destination (OD) pair, $n = 1 \ldots N$
d_n	number of trips between OD pair n
C_n	set of available routes for OD pair n
d_{ni}	number of trips on route $i \in C_n$

- path flows $\mathbf{d} = (d_{ni})$ are in SUE if

$$d_{ni} = P_n(i|\mathbf{x}(\mathbf{d};\gamma);\beta)d_n \quad n = 1 \ldots N,\ i \in C_n$$

  where

  - $\mathbf{x}(\mathbf{d};\gamma)$ is network loading model (with parameters γ)
  - $P_n(i|\mathbf{x};\beta)$ is the route choice model (with parameters β)

Equivalent optimization problem

- maximum of **prior entropy function** yields an SUE

$$\max_{\mathbf{d}=(d_{ni})} W(\mathbf{d}|\beta,\gamma) = \sum_{n=1}^{N} \sum_{i \in C_n} d_{ni} \ln \frac{P_n(i|\mathbf{x}(\mathbf{d};\gamma);\beta)}{d_{ni}}$$

$$\text{s.t.} \sum_{i \in C_n} d_{ni} = d_n \ \forall n = 1 \ldots N,$$

- $W(\mathbf{d}|\beta,\gamma)$ is logarithm of probability that path flows $\mathbf{d}$ occur
- SUE generates most probable path flow pattern

Maximum a posteriori estimator

- exploit additional measurements **y** (e.g., counts)
- maximize **posterior entropy function**

$$
\begin{aligned}
\max_{\mathbf{d},\beta,\gamma} W(\mathbf{d},\beta,\gamma|\mathbf{y}) &= \ln p(\mathbf{y}|\mathbf{x}(\mathbf{d};\gamma)) + W(\mathbf{d}|\beta,\gamma) + W(\beta,\gamma) \\
\text{s.t.} \sum_{i\in C_n} d_{ni} &= d_n \ \forall n = 1\ldots N. \\
d_{ni} &\geq 0 \ \forall n = 1\ldots N,\ i \in C_n
\end{aligned}
$$

- single-level optimization problem, no equilibrium constraints
- independent of model specification

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Setting

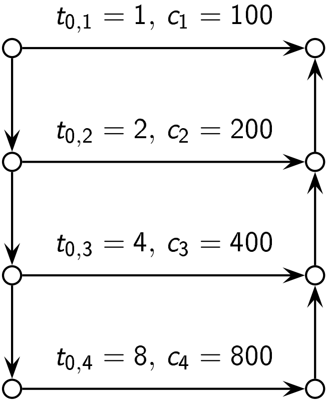
- route travel time

$$t_i = t_{0,i} + \left(\frac{d_i}{c_i}\right)^{\gamma}$$

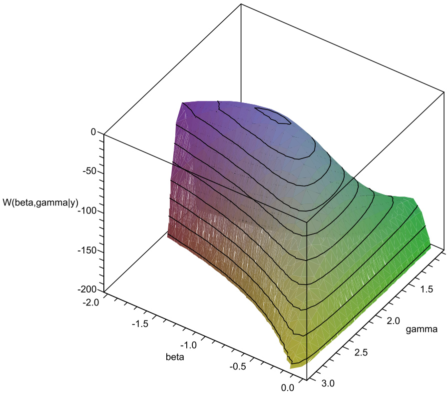
- route choice

$$P(i) = \frac{e^{\beta t_i}}{\sum_j e^{\beta t_j}}$$

- estimate β, γ, $\mathbf{d} = (d_i)$ from counts



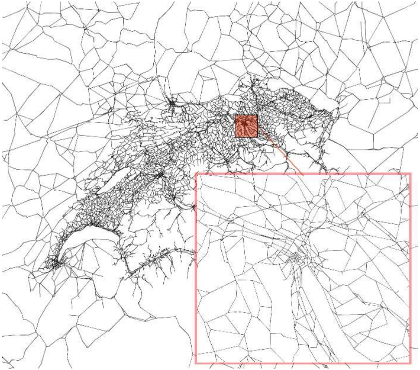
Objective function



- sensor data on all routes from $\beta = -1$, $\gamma = 2$
- figure shows $W(\mathbf{d}, \beta, \gamma | \mathbf{y})$ around estimated $\mathbf{d}$

Outline

Zurich case study

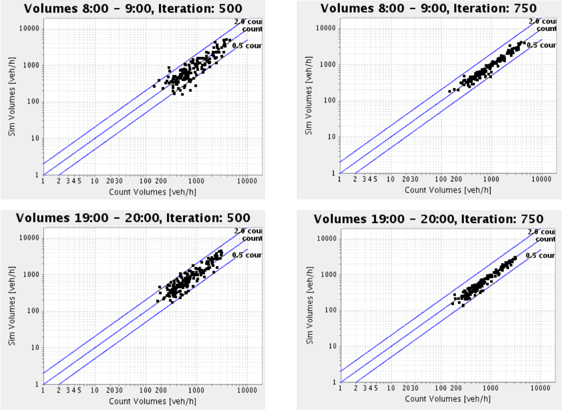


- network with 60 492 links and 24 180 nodes
- microsimulation with 187 484 agents
- hourly counts from 161 counting stations
- jointly estimate route + dpt. time + mode choice (generalized path flows)

Results: qualitatively

plain simulation | with calibration

morning | evening



Results: quantitatively

	reproduction $(\cdot)^2$ error	validation $(\cdot)^2$ error	comp. time until stationarity
plain simulation	103.6	103.6	$18^1/_2$ h
estimated simulation	20.9	75.1	$20^1/_4$ h
relative difference	- 80 %	- 28 %	+ 9 %

- 10-fold cross-validation
- no overfitting; but not all agents are adjusted
- single-level formulation yields excellent computing times

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- integrated path flow and parameter estimation
  - single-level optimization problem
  - transferable to microsimulations
- Cadyts – "Calibration of dynamic microsimulations"
  - ongoing implementation of methodology
  - applications: MATSim, DRACULA, SUMO
  - free code: `transp-or2.epfl.ch/cadyts`
- ongoing and future work
  - disaggregate sensors (vehicle re-identification, smartphones)
  - improve approximations, specifically of network loading