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Iterated transport microsimulations

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Outline

Outline

Intuition

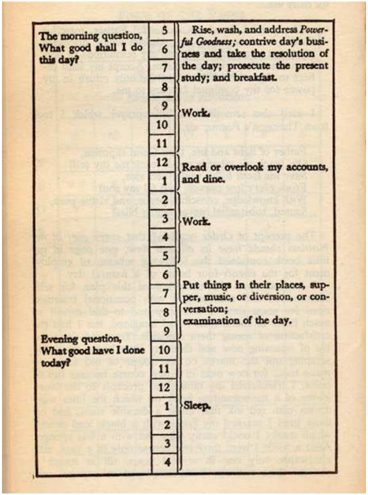
Modeling

Example

Summary

source: www.youtube.com

Activities and traveling



The morning question, What good shall I do this day?	5	Rise, wash, and address *Powerful Goodness;* contrive day's business and take the resolution of the day; prosecute the present study; and breakfast.
	6	
	7	
	8	Work.
	9	
	10	
	11	
	12	Read or overlook my accounts, and dine.
	1	
	2	Work.
	3	
	4	
	5	
	6	Put things in their places, supper, music, or diversion, or conversation; examination of the day.
	7	
	8	
	9	
Evening question, What good have I done today?	10	Sleep.
	11	
	12	
	1	
	2	
	3	
	4	

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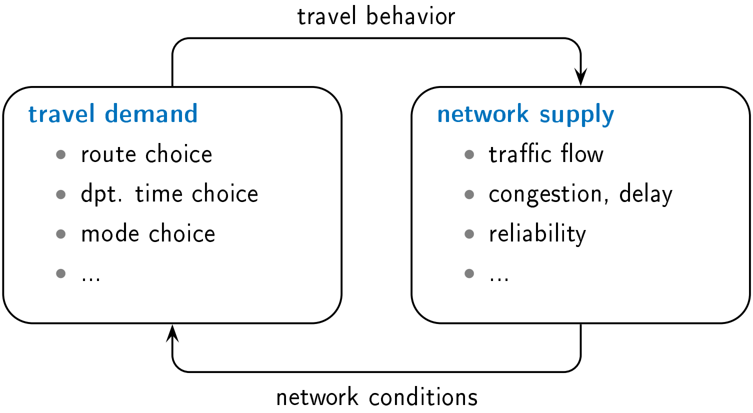
Network flows

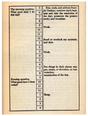
Transport model system



Multi-agent simulation

- create a synthetic population of individual travelers ("agents")
- resolve the demand/supply dependency iteratively
- in every iteration (simulated day):
    1. every traveler chooses some planned travel behavior
    2. all travelers execute their plans (i.e., they travel)
    3. all travelers observe the resulting network conditions

Outline



Discrete choice modeling

- decision maker n faces choice set C_n of discrete alternatives
- each alternative $i \in C_n$ is given a real-valued utility U_{ni}
- decision maker selects alternative of maximum utility

$$n \text{ selects } i \quad \Leftrightarrow \quad U_{ni} = \max_{j \in C_n} U_{nj}$$

- choice dimensions in transportation
  - **living:** activities (type, sequence, location)
  - **traveling:** route, departure time, mode
  - **driving:** gap acceptance, lane changing

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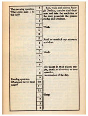
Discrete choice modeling



- fundamental modeling assumption: utility maximization
- decompose utility into systematic and stochastic term:

$$U_{ni} \quad = \quad V_{ni}(\mathbf{x}_{ni}; \beta) + \varepsilon_{ni}$$

  - $V_{ni}(\mathbf{x}_{ni}; \beta)$ depends on attributes $\mathbf{x}_{ni}$ and parameters β
  - random term ε_{ni} captures uncertainty in the modeling

- random utility leads to probabilistic choice model

$$\Pr(n \text{ selects } i) \quad = \quad \Pr(U_{ni} = \max_{j \in C_n} U_{nj})$$

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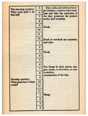
Discrete choice modeling



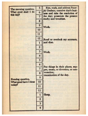
- some term distributions imply closed-form solutions, e.g.

$$P_n(i \mid C_n) = \frac{e^{V_{ni}(\mathbf{x}_{ni};\beta)}}{\sum_{j \in C_n} e^{V_{nj}(\mathbf{x}_{nj};\beta)}}$$

- general distributions require to resort to simulation

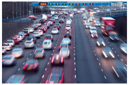
$$\text{draw from } P_n(i \mid C_n) \Leftrightarrow \begin{cases} 1.\,\text{draw error terms } \varepsilon_{ni} \\ 2.\,\text{select } \arg\max_{i \in C_n} V_{ni}(\mathbf{x}_{ni};\beta) + \varepsilon_{ni} \end{cases}$$

Discrete choice modeling



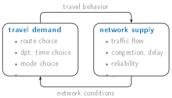
- estimating the model parameters β requires Monte Carlo evaluation of $P_n(i \mid C_n)$ and $\nabla_\beta P_n(i \mid C_n)$: simulated Maximum Likelihood, Bayesian techniques ...
- choice sets C_n get intractably large (all possible travel behaviors)
  - (importance) sampling of alternatives
  - correct simulated behavior using sampling probabilities
- example: Metropolis-Hastings sampling of paths

Traffic flow modeling



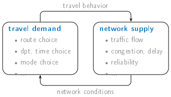
- **microscopic:** car-following models
  - driver selects acceleration based on immediate environment
  - see talk of Vincenzo and Biaggio
- **macroscopic:** continuum models, incompatible with agents
- **mesoscopic:** middle ground between micro and macro
  - move individual vehicles based on aggregate velocity fields
  - fairly realistic and compatible with the agent-based approach

Iterations



- represent a **day-to-day learning process**
  - very intuitive, easy to communicate
  - implicitly assumes a learning process
  - actual "learning model" is *very ad hoc*
- are **computational means to an end**
  - stationary process distribution is model solution
  - stationarity = consistency between demand and supply
  - justified if travelers learn *expected* network conditions

Iterations



- iterations (hopefully) attain a unique, stationary distribution
- very limited understanding of this distribution
- continuous limit perspective sometimes helps
  - assume continuum of travelers
  - approximate network flow dynamics with smooth equations
  - obtain analytical approximations of stationary mean values

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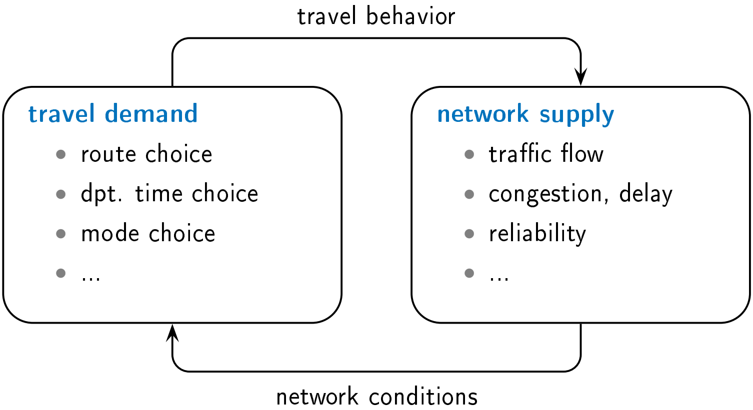
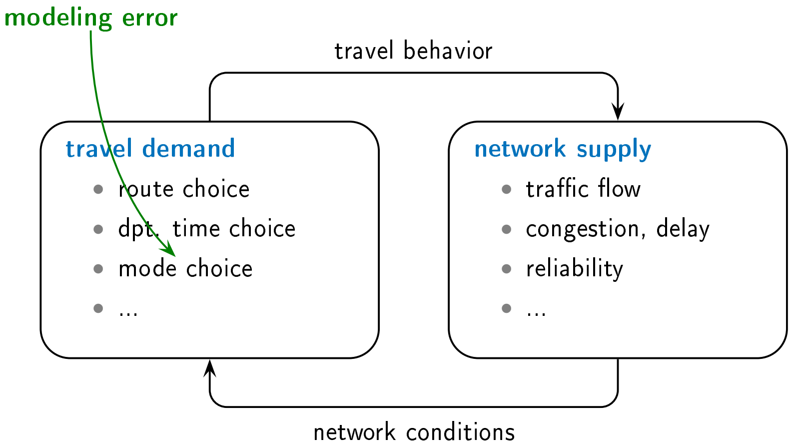
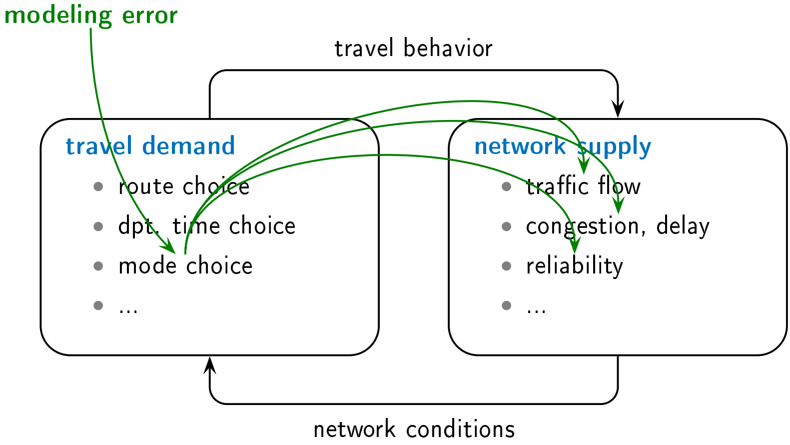
Behavioral calibration from network data



Behavioral calibration from network data



Behavioral calibration from network data



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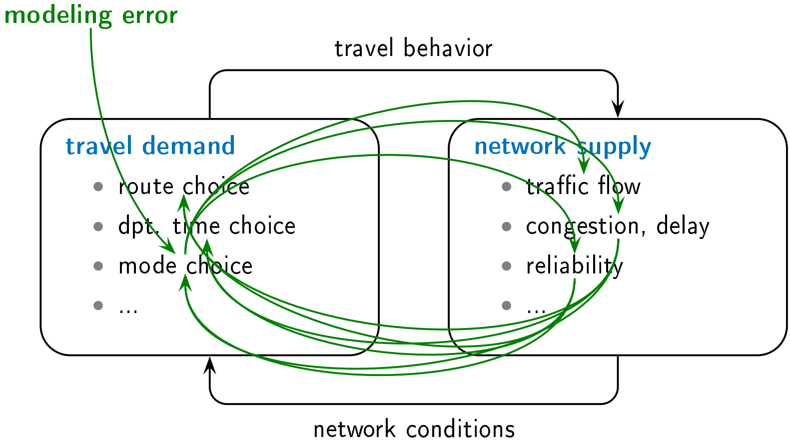

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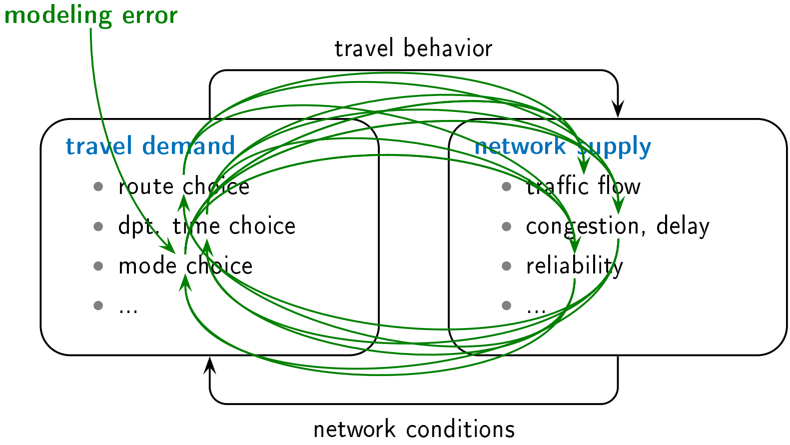

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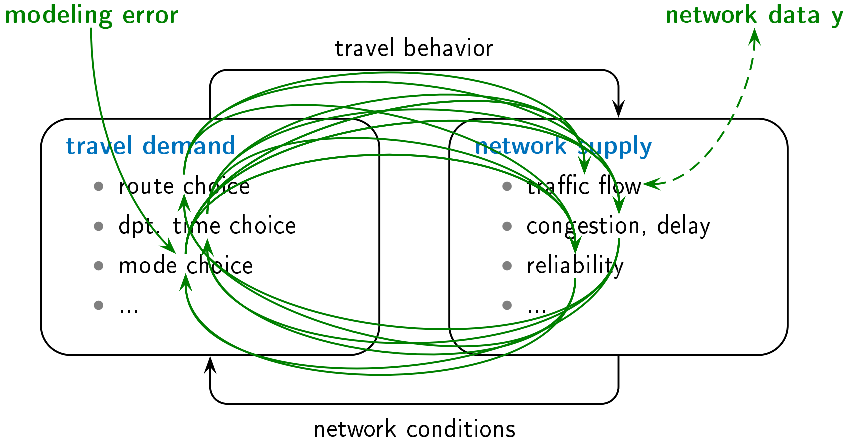


Some notation

- population of synthetic individuals $n = 1 \ldots N$
- individual n has a choice set C_n of travel plans
- Π_{ni} is probability that person n chooses travel plan $i \in C_n$
- $\mathbf{x}(\boldsymbol{\Pi})$ are average network conditions resulting from $\boldsymbol{\Pi} = (\Pi_{ni})$
- individual n chooses plan i according to model $P_n(i|\mathbf{x})$

Continuous limit approximation

- iterative simulation is maximizer of **prior entropy**

$$W(\boldsymbol{\Pi}) = \sum_{n=1}^{N} \sum_{i \in C_n} \left[\Pi_{ni} \ln P_n(i|\mathbf{x}(\boldsymbol{\Pi})) - \Pi_{ni} \ln \Pi_{ni} \right]$$

- interpretation: the system attains its most likely state

Calibration of simulated behavior

- objective: condition simulated behavior $\mathbf{\Pi}$ on network data $\mathbf{y}$
- approach: maximize **posterior entropy**

$$W(\mathbf{\Pi}|\mathbf{y}) = \mathcal{L}(\mathbf{y}|\mathbf{x}(\mathbf{\Pi})) + W(\mathbf{\Pi})$$

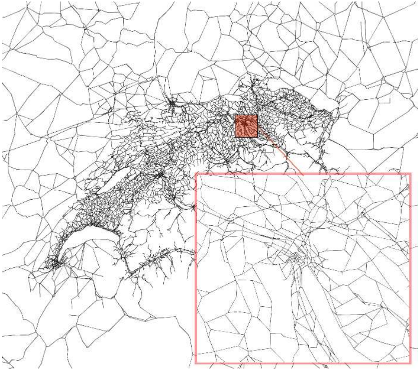
where $\mathcal{L}(\mathbf{y}|\mathbf{x}(\mathbf{\Pi}))$ is log-likelihood of $\mathbf{y}$

- this can be solved analytically:

$$\Pi_{ni} \sim \exp\left(\frac{\partial \mathcal{L}(\mathbf{y}|\mathbf{x}(\mathbf{\Pi}))}{\partial \Pi_{ni}}\right) P_n(i|\mathbf{x}(\mathbf{\Pi}))$$

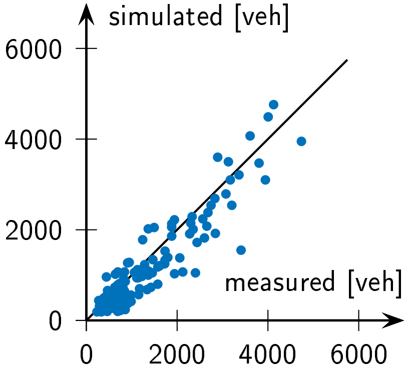
- implemented at *individual* level, *within* simulation loop

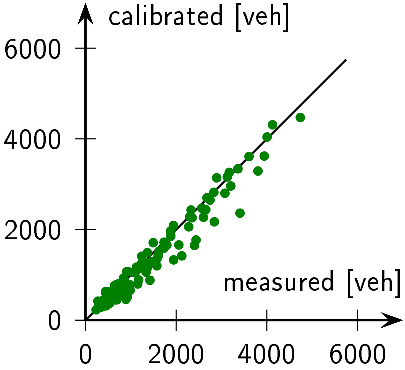
Zurich case study: setting



- 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

Zurich case study: evening peak





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- there exist credible models of human travel behavior
- these can be put into models of the physical environment
- the resulting model system is iteratively solved ("learning")
- MCMC ... one *realization* from this model takes *one day*