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Reduced Mobility Transition Model

5.3.2024 spring school

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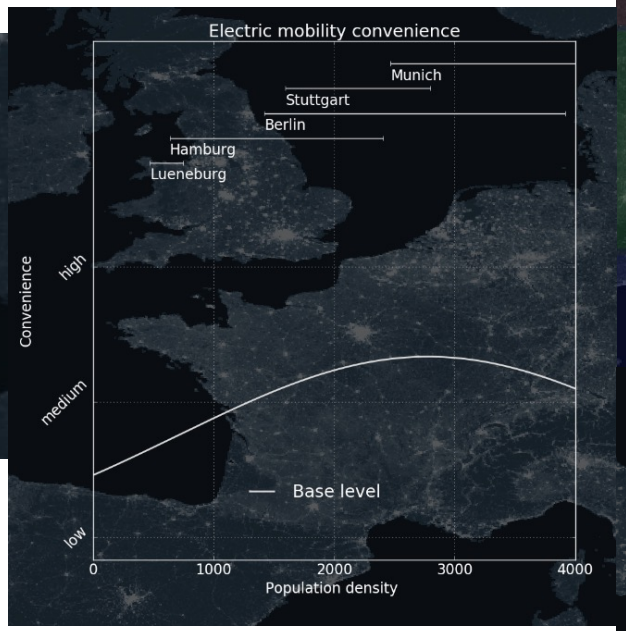
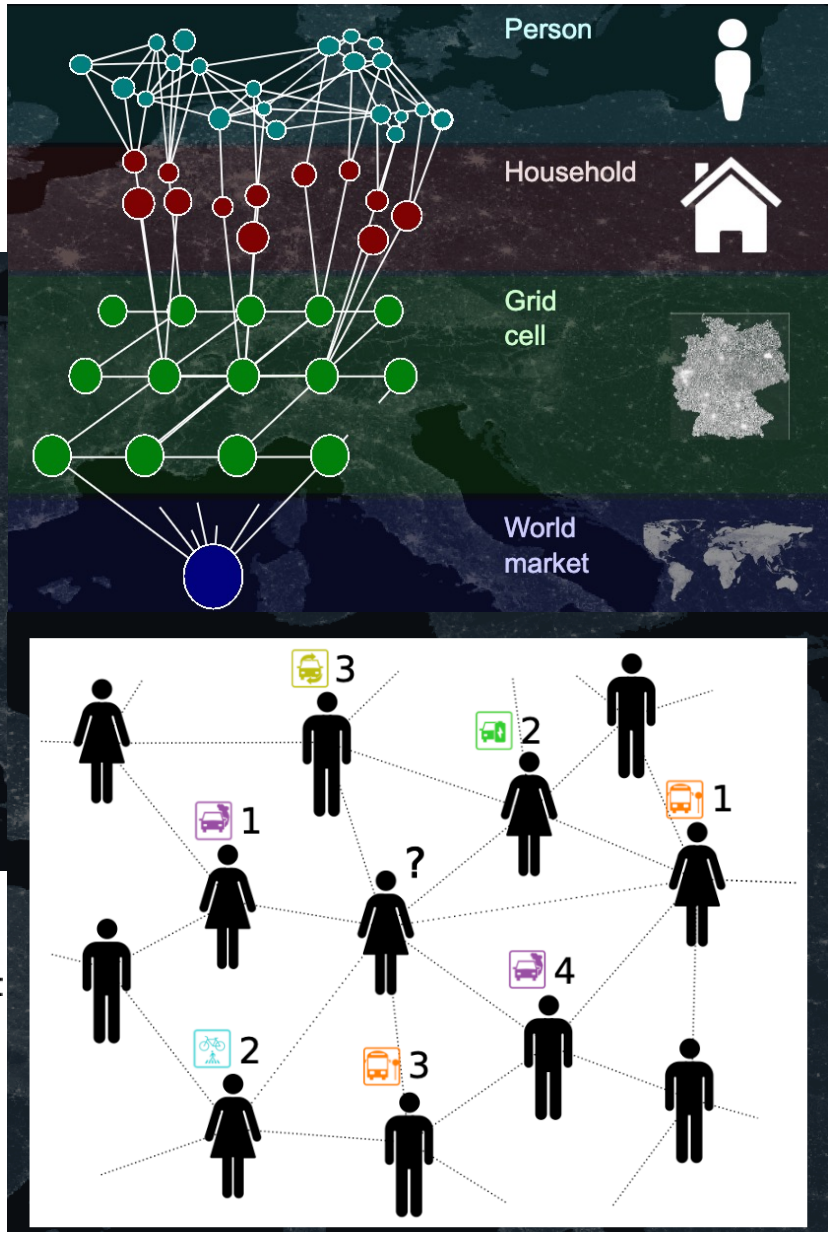
Mobility Transition Model





$\alpha_1 \cdot \alpha_2 \cdot \alpha_3 \cdot \alpha_4$

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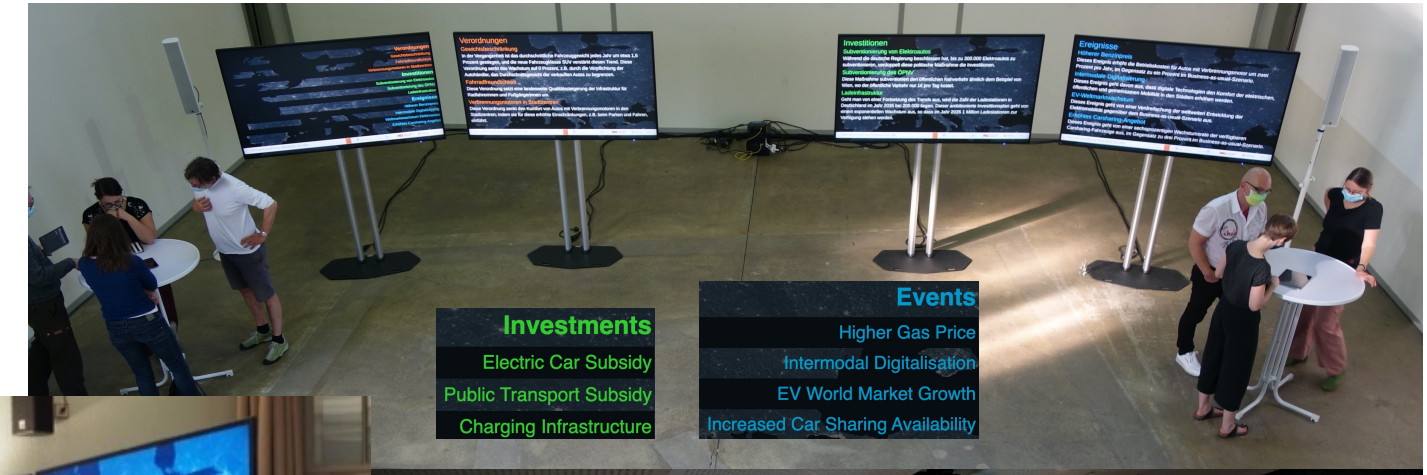
MoTMo in Decision Theatres

Policies

Car Weight Restriction

Bike Friendliness

Urban Combustion Restrictions



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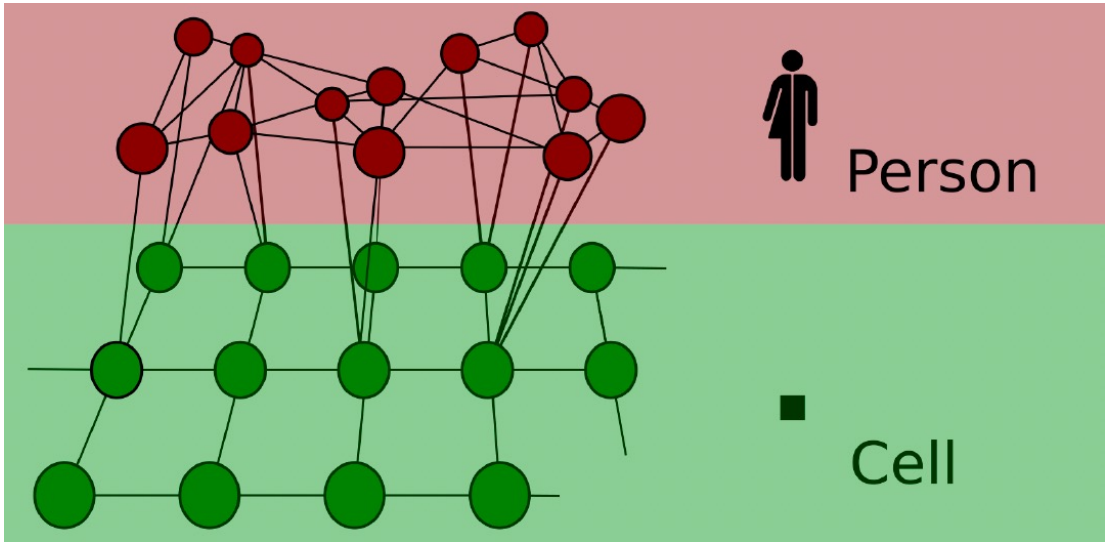
R-MoTMo

- 2 mobility options m: car $(m = 0)$, public transport $(m = 1)$
- $\mathcal{M}(t) = (\mathcal{M}_i(t))_{i=1,\ldots,N} \in \mathbb{M}^N, t \in \mathbb{N}_0$

agents (i) live in a fixed cell (c_i)

set of friends $\mathbb{F}(i)$



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underlying idea

- decision making as an evolutionary process: imitation
- MoTMo also has mutation, here left out
- co-evolution of two elements with this decision process:
  - network of friends (social structure)
  - utility of infrastructure (common environment)

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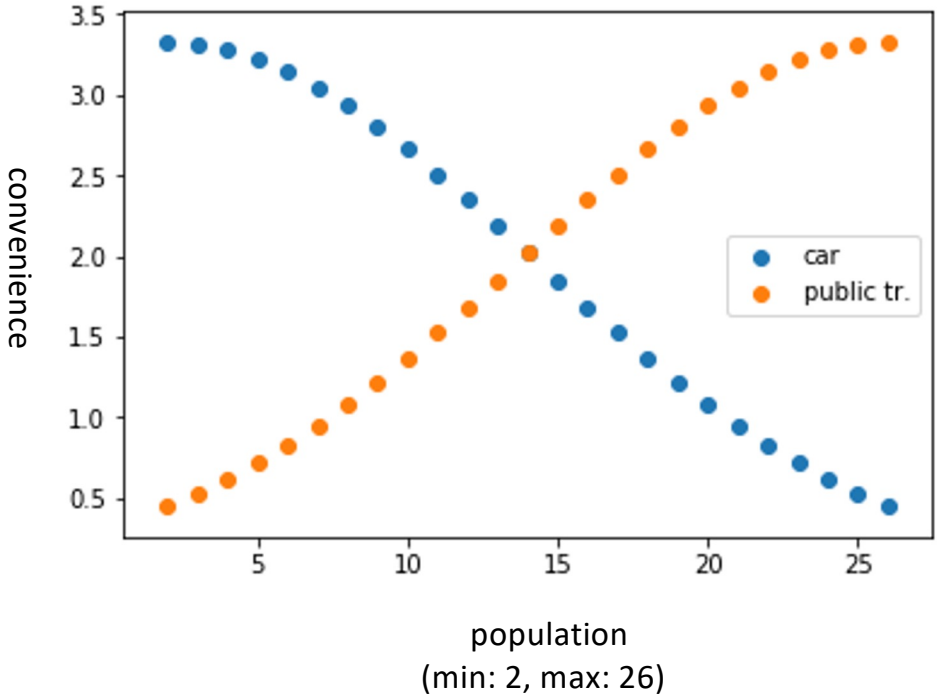
utility = convenience



$$\left(\frac{100}{\sqrt{2\pi}\sigma}\exp\left(-\frac{(N_c-\mu_m)^2}{2\sigma^2}\right)\right)$$

$$\sigma = \frac{1}{2}(p_{max}-p_{min})$$

$$\mu_0 = p_{min}$$

$$\mu_1 = p_{max}$$

car is 0
public transport is 1

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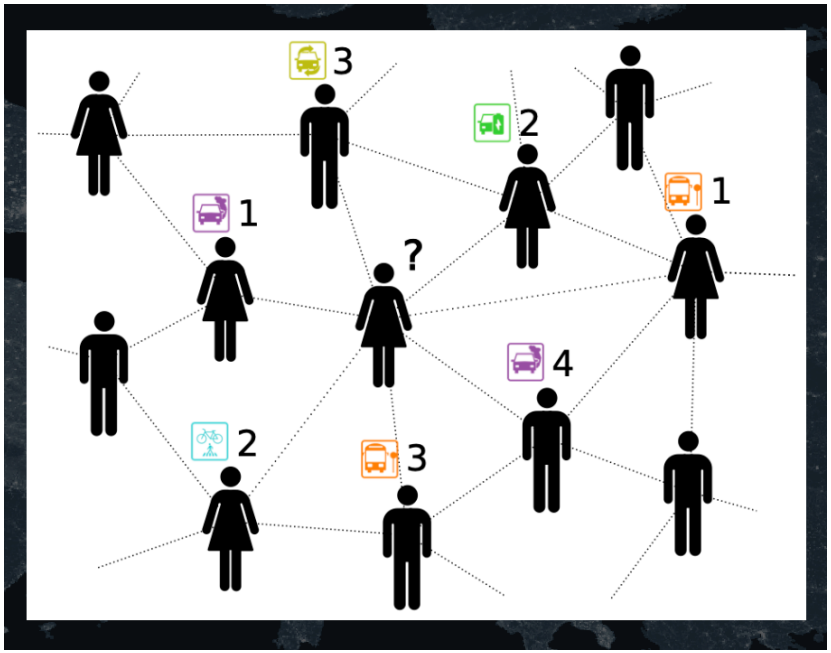
decision



- weighted network of friends

$$\mathcal{W}_{i,j}(0) = \begin{cases} 1, & \text{if } j \in \mathbb{F}(i), \\ 0, & \text{otherwise} \end{cases}$$

- weights evolve (see below)
- imitation:

$$\text{Prob}(\mathcal{J}_i(t) = j) = \frac{\mathcal{U}_j(t) \cdot \mathcal{W}_{i,j}(t)}{\sum_{k \in \mathbb{F}(i)} \mathcal{U}_k(t) \cdot \mathcal{W}_{i,k}(t)}$$

$$\mathcal{M}_i(t+1) = \begin{cases} \mathcal{M}_j(t), & \text{if } j = \mathcal{J}_i(t) \text{ and } \mathcal{U}_j(t) > \mathcal{U}_i(t), \\ \mathcal{M}_i(t), & \text{otherwise.} \end{cases}$$

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feedbacks in R-MoTMo

“infrastructure bonus”: the more people use a mobility choice, the better it gets in the long run

counting process: $\mathcal{X}_{c,m}(t) := \sum_{i \in \mathbb{I}_c} 1_m(\mathcal{M}_i(t)) \in \mathbb{N}_0$

bonus process $\mathcal{B}_{c,m}(t) = \frac{1}{3} \cdot \frac{\mathcal{X}_{c,m}(t)}{N_c} + \frac{2}{3} \cdot \mathcal{B}_{c,m}(t-1)$

recursively defined, starting with $\mathcal{B}_{c,m}(-1) := 0$

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infrastructure feedback

short-term malus: $$a_{c,m}(x) := 1 - \frac{1}{3} \cdot \frac{x}{N_c}$$

utility of a mobilitv choice in a cell:

$$u_{c,m}(x, b) := a_{c,m}(x) \cdot \left(\frac{100}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(N_c - \mu_m)^2}{2\sigma^2} \right) \right) + b,$$

utility of a mobility choice for a person:

$$\mathcal{U}_i(t) := u_{c_i,\mathcal{M}_i(t)}\left(\mathcal{X}_{c_i,\mathcal{M}_i(t)}(t), \mathcal{B}_{c_i,\mathcal{M}_i(t)}(t)\right)$$

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friend network feedback

initial network

$$\mathcal{W}_{i,j}(0) = \begin{cases} 1, & \text{if } j \in \mathbb{F}(i), \\ 0, & \text{otherwise} \end{cases}$$

update to increase weight if imitating was useful, and vice versa

$$\mathcal{W}_{i,j}(t+1) = \begin{cases} \mathcal{W}_{i,j}(t) \cdot \frac{\mathcal{U}_i(t+1)}{\mathcal{U}_i(t)}, & \text{if } j = \mathcal{J}_i(t) \text{ and } \mathcal{U}_j(t) > \mathcal{U}_i(t), \\ \mathcal{W}_{i,j}(t), & \text{otherwise.} \end{cases}$$

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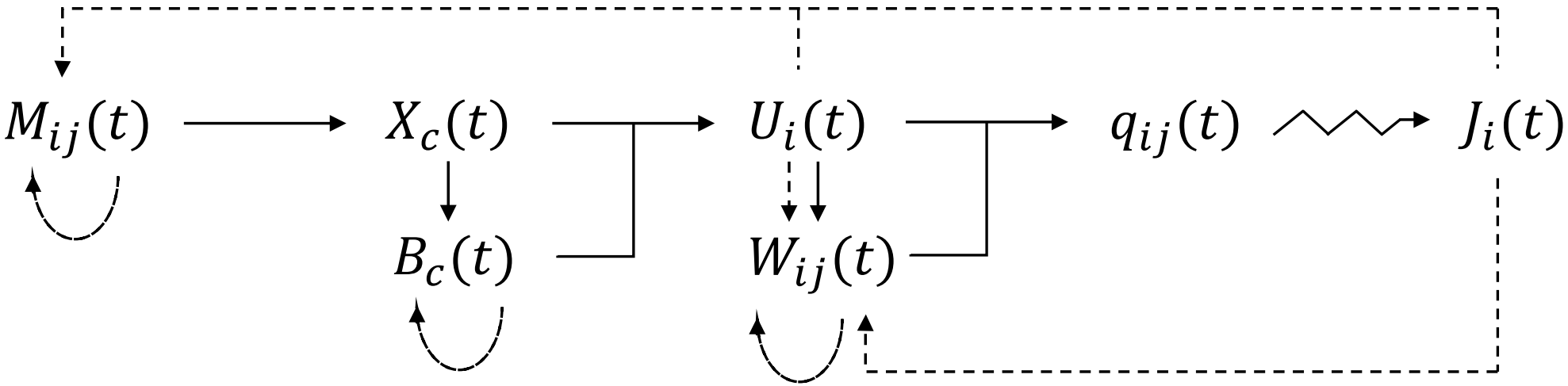
complex feedback loops



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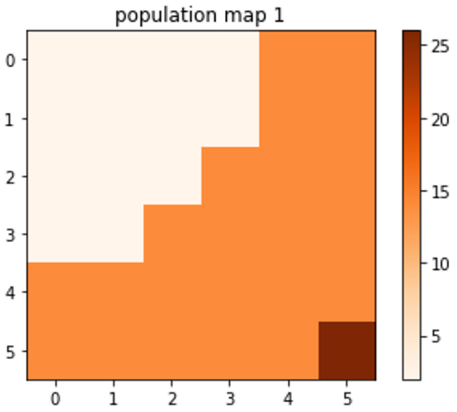
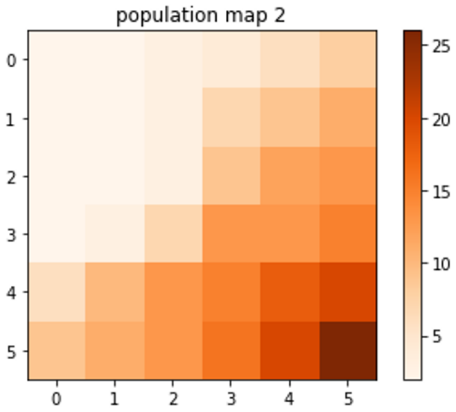
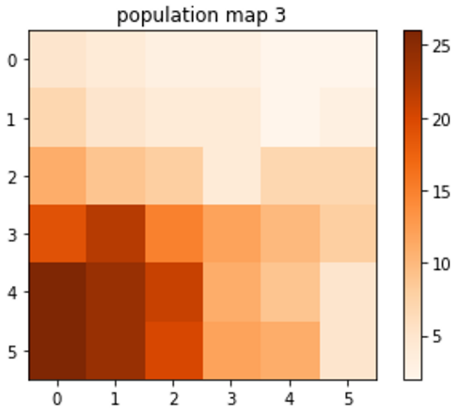
Population Densities



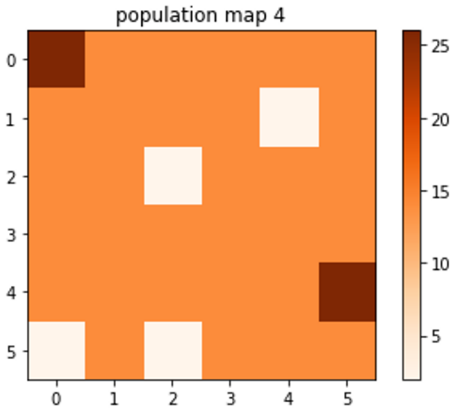

```
inhabitants: 360
urban: 1 cells, 26 persons
rural: 13 cells, 26 persons
```




```
inhabitants: 330
urban: 7 cells, 130 persons
rural: 29 cells, 200 persons
```




```
inhabitants: 370
urban: 9 cells, 197 persons
rural: 27 cells, 173 persons
```




```
inhabitants: 480
urban: 2 cells, 52 persons
rural: 4 cells, 8 persons
```

Maximum per cell: 26, minimum per cell: 2 (for all maps)
Rural: cell with < 14 inhabitants
Urban: cell with > 14 inhabitants

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Simulation options

```
parameters ={'timeSteps’: 70,
             'density': 1,
             'nFriends': 15,
             'friendsLocally': True,
             'weightFriends': True,
             'convenienceBonus': True,
             'convenienceMalus': True}
```

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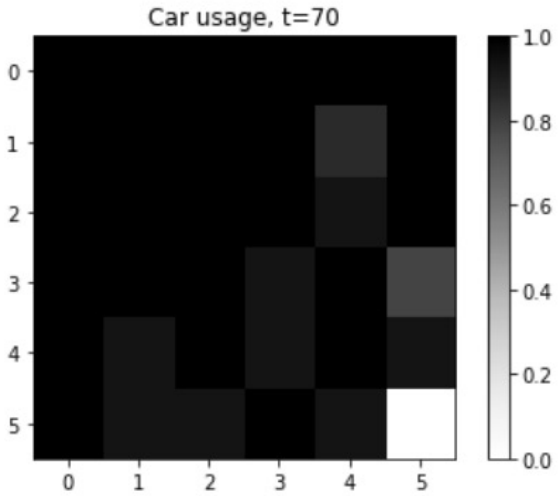
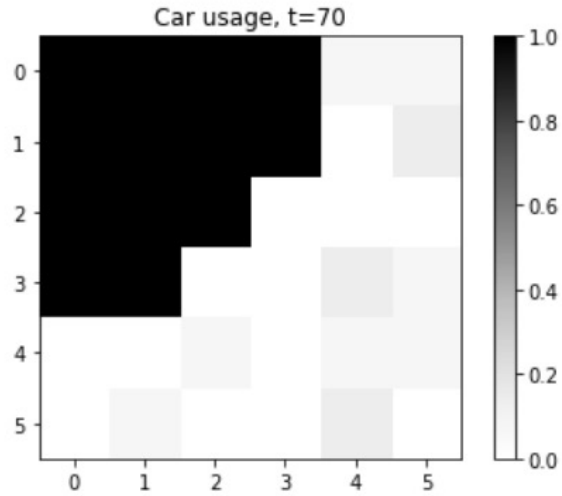
Some results: example runs infrastructure

map 1

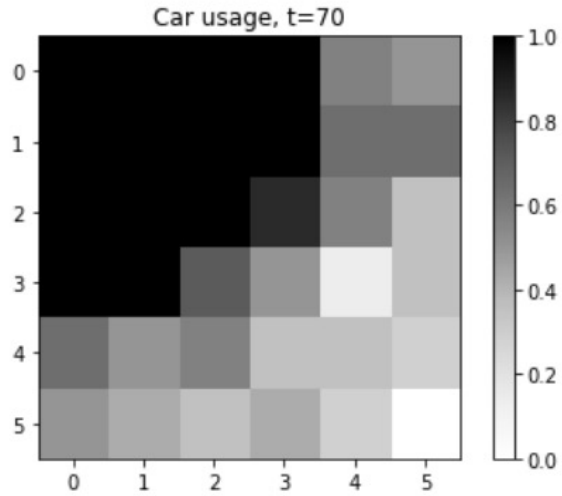
infrastructure process on





coordination on one of the two mobility types in the initially indifferent area

off



no coordination

-> niche construction

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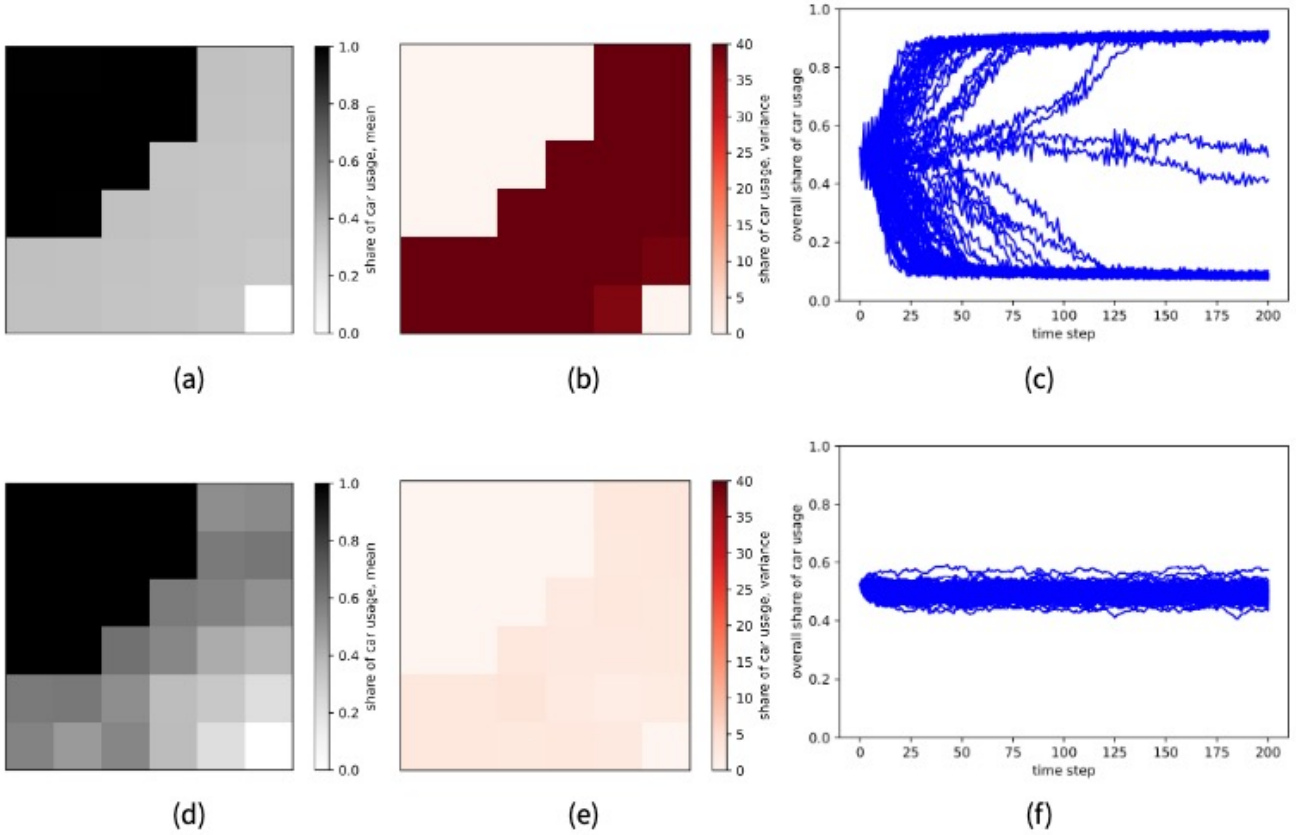
statistics: influence of the bonus process



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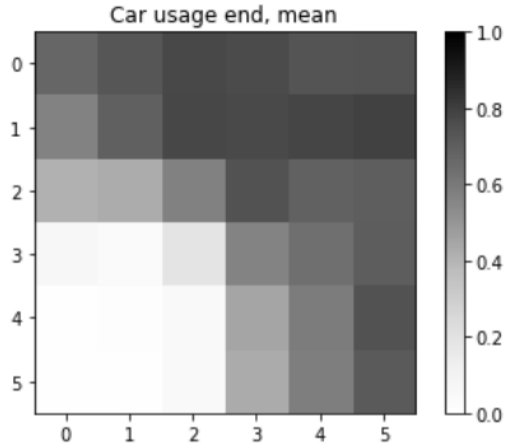
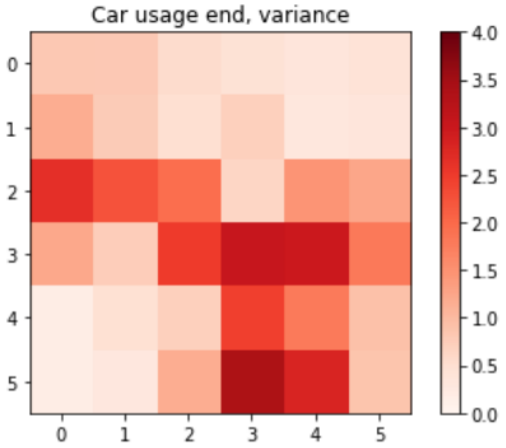
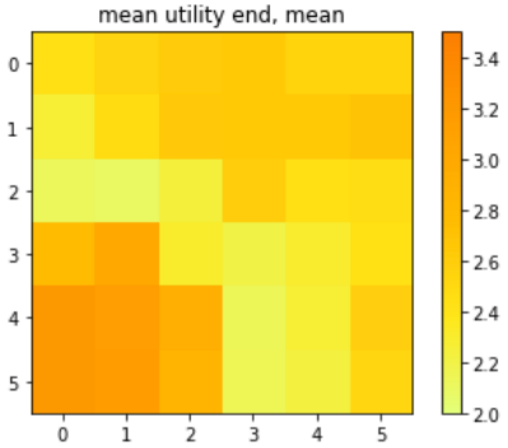
Updating of weights

map 3

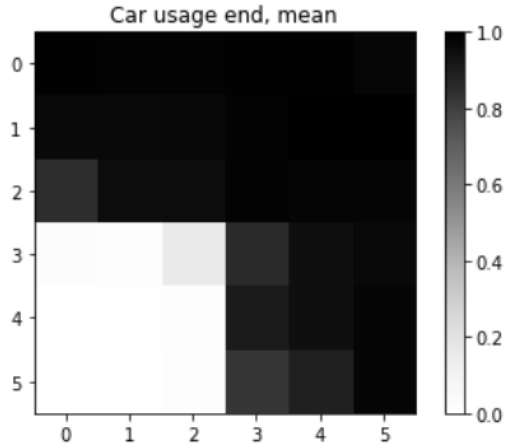
updating of weights off

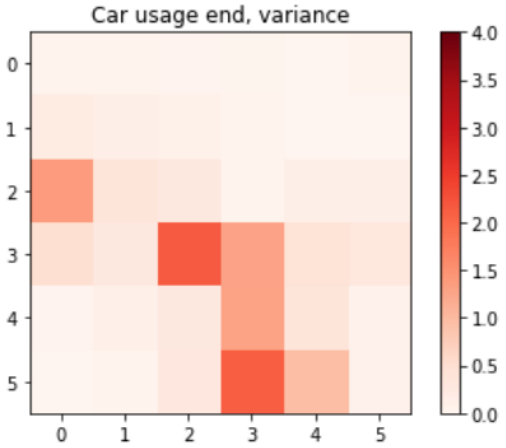


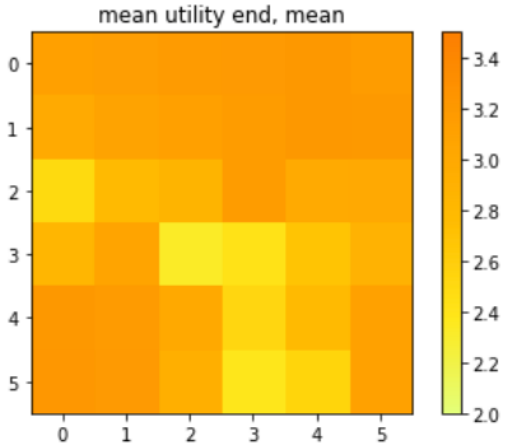




on







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open questions

- what are indicators for ending up with few / many car users?
- model extensions / changes
  - add costs as a second dimension to the utility function
  - instead of imitating a friend, let agents maximize expected utility, where expectations derive from interaction with friends in the network
- how does the model behaviour change?

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backup

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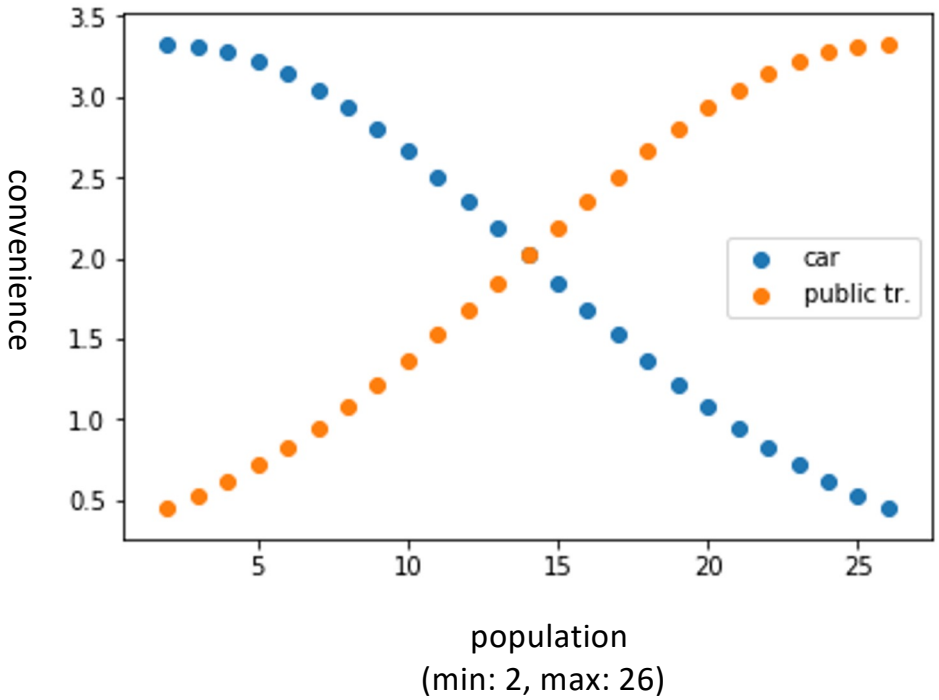
Convenience = Utility



$$U_{c,m}(t) = A_{c,m}(t) \cdot \left(\frac{100}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(p_c - \mu_m)^2}{2\sigma^2}\right)\right) + B_{c,m}(t)$$

$$\sigma = \frac{1}{2}(p_{max} - p_{min})$$

$$\mu_0 = p_{min}$$ car is 0

$$\mu_1 = p_{max}$$ public transport is 1

Usage dependent convenience components:

1. usage malus (immediate; e.g. traffic jams)
2. usage bonus (building up over time; e.g. infrastructure):

$$A_{c,m}(t) = 1 - \frac{1}{3} \cdot \frac{p_{c,m}(t)}{p_c}$$

$$B_{c,m}(t) = \frac{1}{3} \cdot \frac{p_{c,m}(t)}{p_c} + \frac{2}{3} \cdot B_{c,m}(t-1)$$

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Imitation of Friends

Person *i* may copy a friend's mobility choice. At time step *t*:

1) Probability for choosing friend j $$q_{i,j}(t) := \frac{\mathcal{U}_j(t) \cdot \mathcal{W}_{i,j}(t)}{\sum_{k \in \mathbb{F}(i)} \mathcal{U}_k(t) \cdot \mathcal{W}_{i,k}(t)}.$$

2) j's mobility choice is copied only if $U_j(t) > U_i(t)$

3) Connection weight update

$$\mathcal{W}_{i,j}(t+1) = \begin{cases} \mathcal{W}_{i,j}(t) \cdot \frac{\mathcal{U}_i(t+1)}{\mathcal{U}_i(t)}, & \text{if } j = \mathcal{J}_i(t) \text{ and } \mathcal{U}_j(t) > \mathcal{U}_i(t), \\ \mathcal{W}_{i,j}(t), & \text{otherwise.} \end{cases}$$

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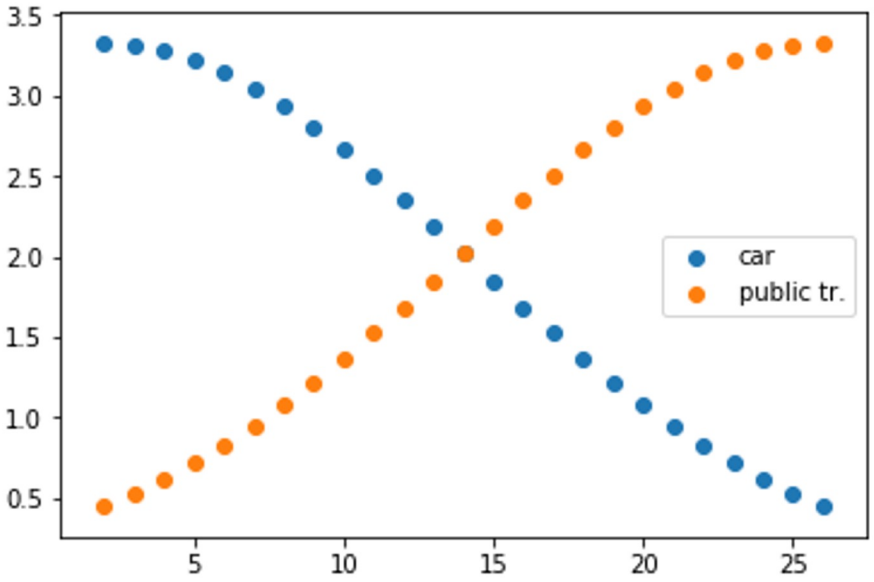
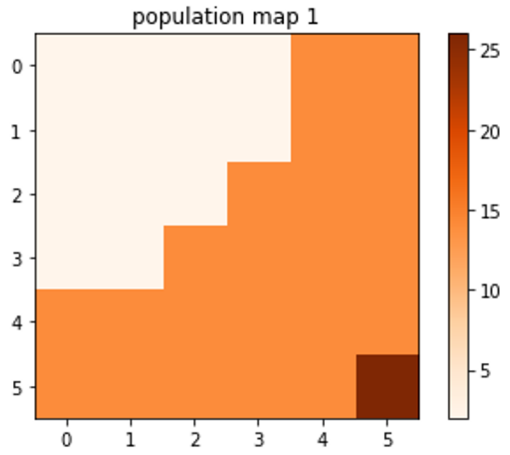
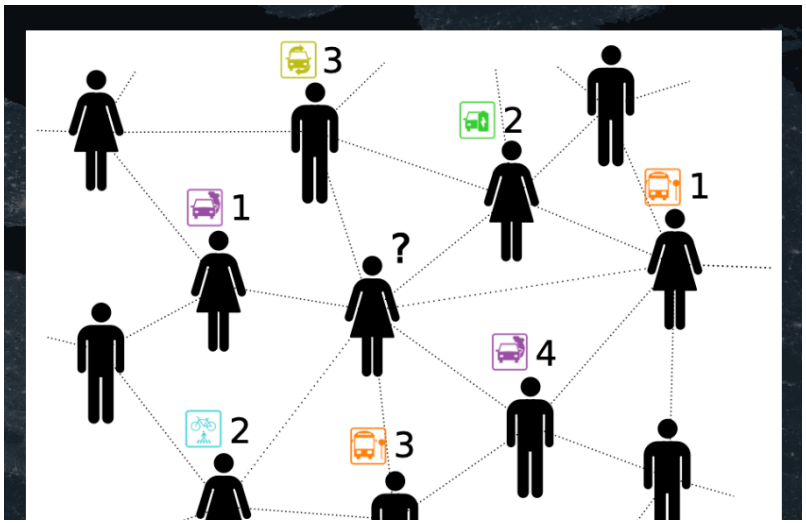
R-MoTMo







- 300-400 **persons** decide in each step
- **utility equals convenience**
- convenience evolves **depending on usage**
- **friend** imitated if their utility greater
- update network **weights** after copy

▶ 2 mobility options m: car $(m = 0)$,

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Social Network

Network creation: draw friends for person *i*:

1) $d_{i,j} = \frac{1}{dist_{j,i} + 0.1}$ with $dist_{j,i}$ Euclidean distance between the cells persons *i* and *j* are located in.

2) normalize: $p_{i,j} = \frac{d_{i,j}}{\sum_j d_{i,j}}$

3) draw *n* friends for person *i* with probabilities $p_{i,j}$

4) friends are fixed but links to them are weighted, connection weights evolve; initial weights are all $w_{i,j}(t=0)=1$.

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models

- Modern wage dynamics:

https://github.com/jmapplegate/ASU-MATH-Spring-School-2023

- Cooperation

https://www.comses.net/codebases/4510/releases/1.2.0

Papers:

https://www.dropbox.com/scl/fo/7drlpsyycj8yiyff752dx/h?dl=0&rlkey=6slrn1vlkx5c7t56t1q9dlkt0

- Opinion

github.com/luzieh/socialmediamodelpy

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