Continuous Demand Generation and Simulation

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Modeling Complex Socio-Economic Systems and Crises

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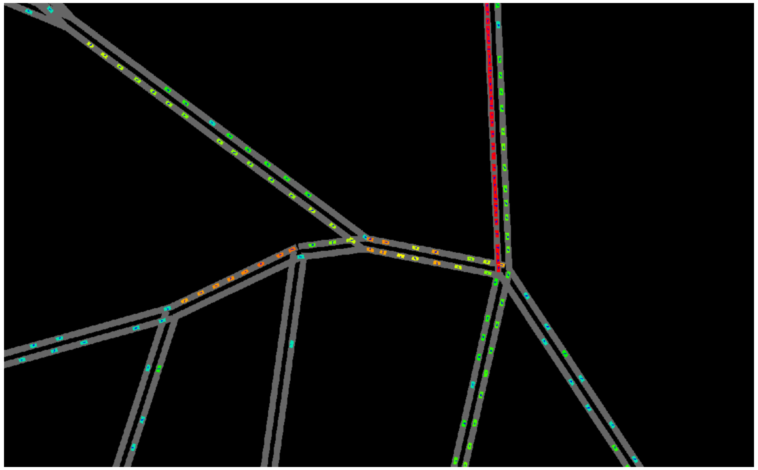
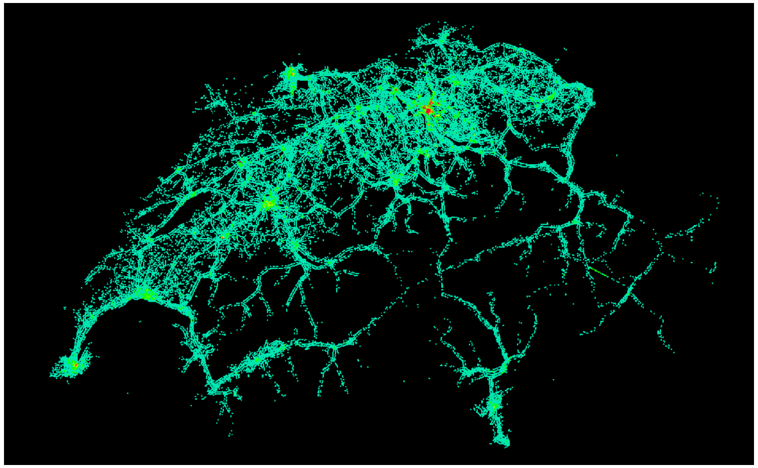
Institute for Transport Planning and Systems

Motivation

- Microscopic transport simulation ...
- ... for large-scale applications
- New Features
- Application to real-world problems
- What is next?
- What is missing?





Outline

- Current integrated demand model
- Next goals
- New framework
- Need-based planning
- Online routing
- Parallel performance

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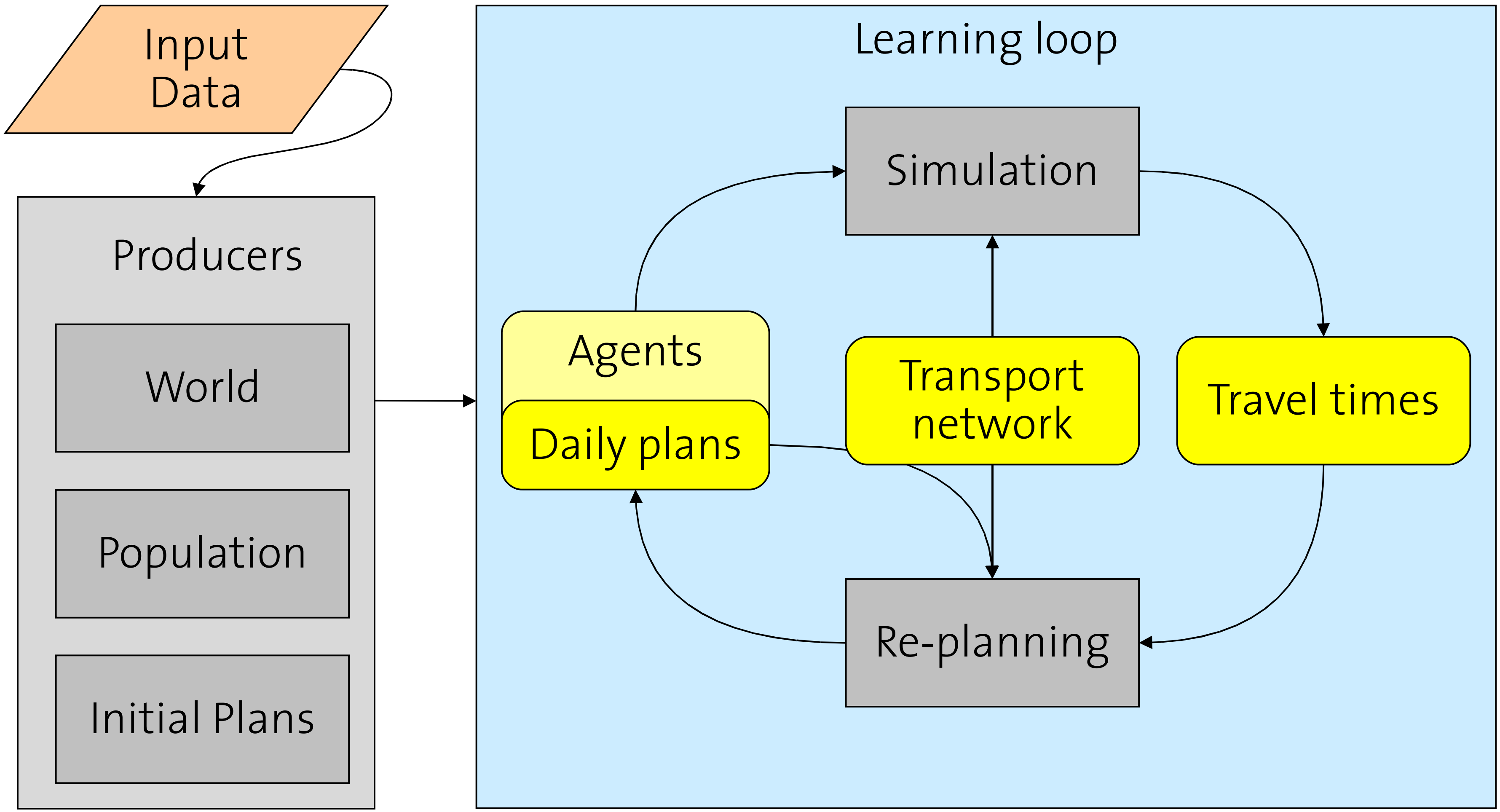
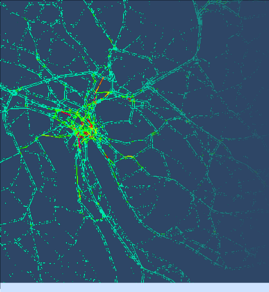
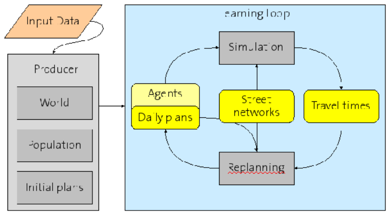
MATSim framework

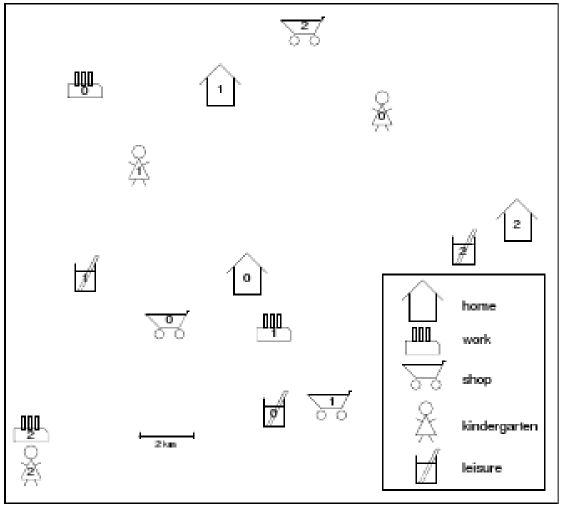




Activity planning

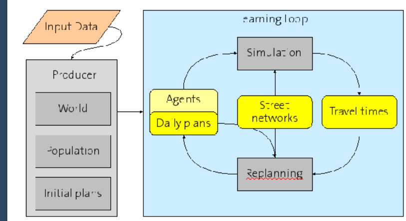


- Input
  - Available activities
  - Time budget
  - World



- Desired: Optimal daily plan
  - Activity pattern (selection and order)
  - Activity duration
  - Location per activity
  - Routes between successive locations

Positive utility of activity duration



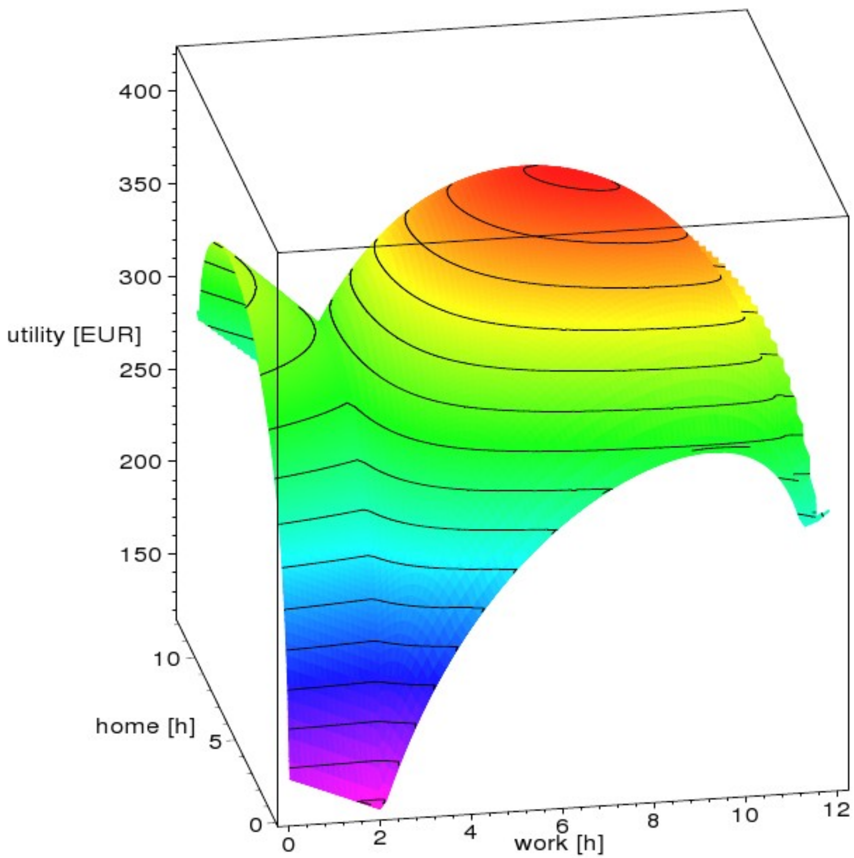
- Positive diminishing marginal utility of activity duration
- Linear penalty terms for travel times, waiting times, delays, etc.

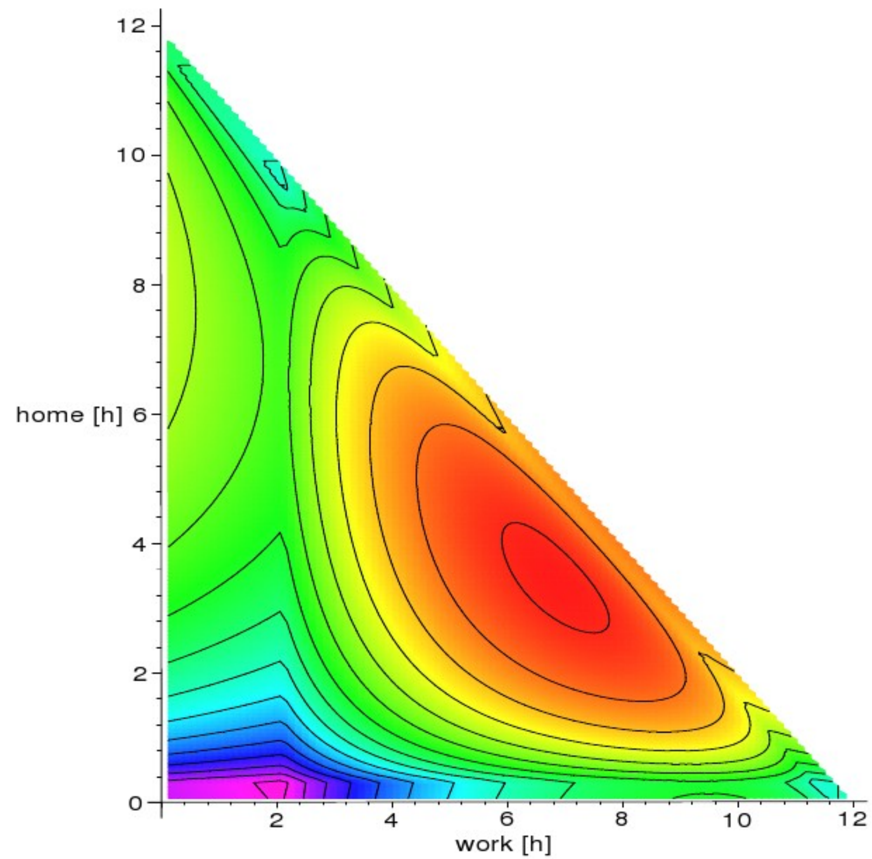
$$U_{perf} = \beta_{dur} t^* \ln \frac{t_{dur}}{t_0} \qquad U_{wait} = -\beta_{wait} t_{dur}$$

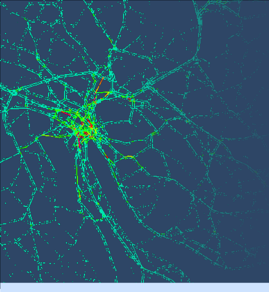
$$U = \max(U_{perf}, U_{wait}) - \beta_{trav} t_{trav} - \beta_{wait} t_{wait} - \beta_{late} t_{late} - \beta_{early} t_{early} - \beta_{short} t_{short}$$

$$\beta_{dur} = 20 \text{ Euro/h} \qquad \beta_{late} = 18 \text{ Euro/h}$$
$$\beta_{trav} = 12 \text{ Euro/h} \qquad \beta_{early} = 6 \text{ Euro/h}$$
$$\beta_{wait} = 6 \text{ Euro/h} \qquad \beta_{short} = 6 \text{ Euro/h}$$

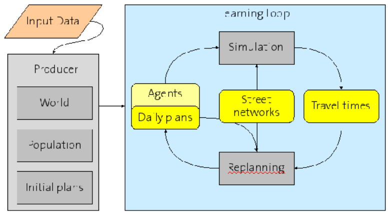
Utility landscapes H-W

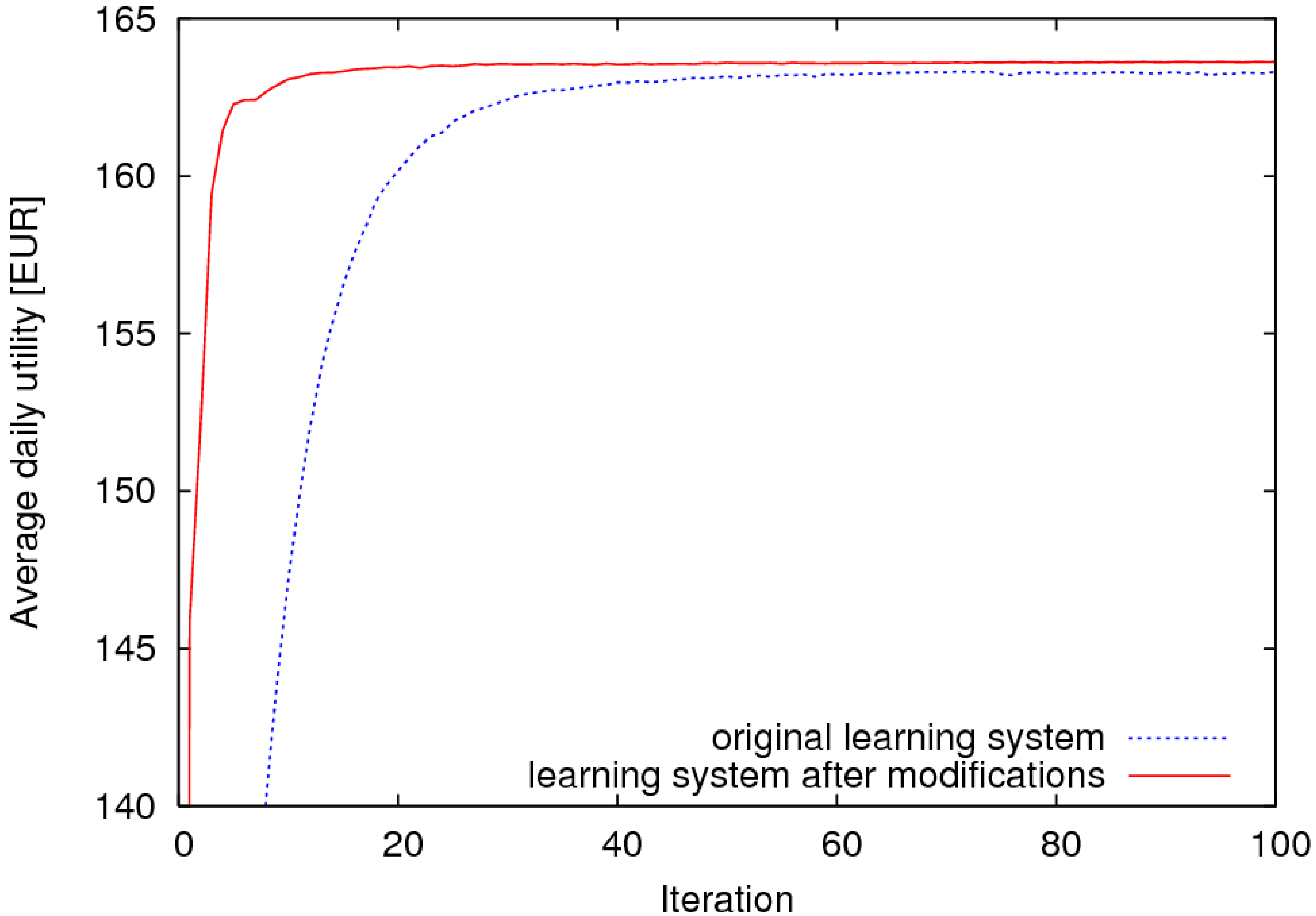


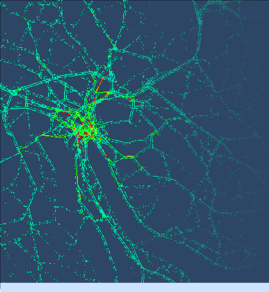




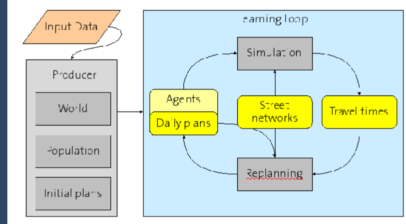
Iterative Learning

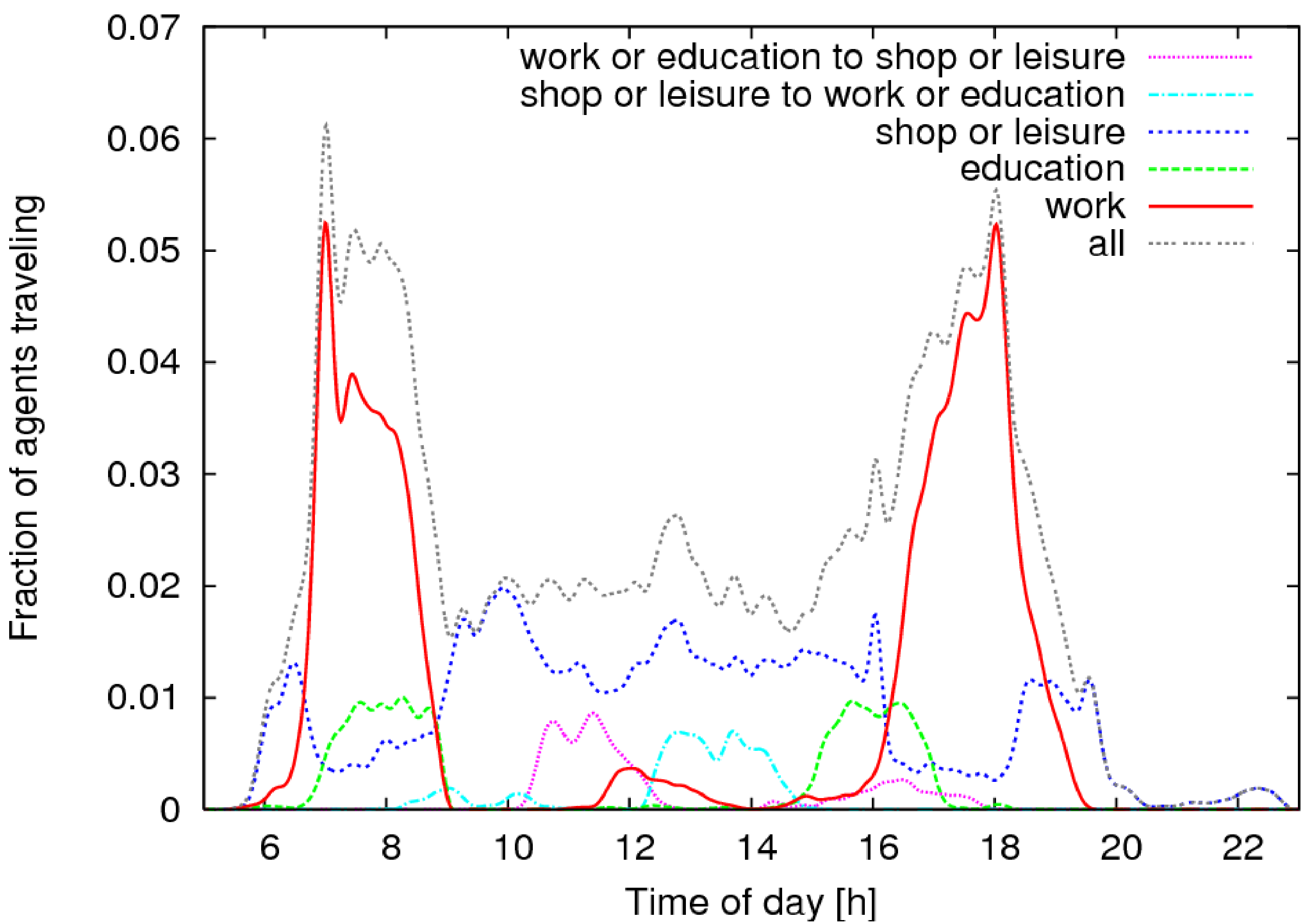






Result: Network load





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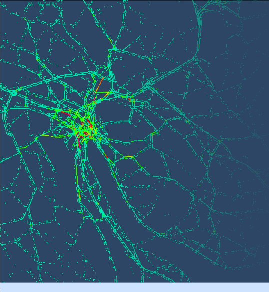
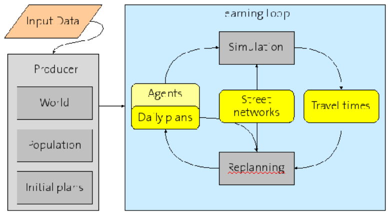
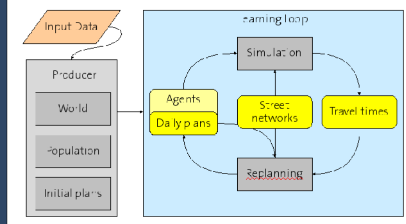


Next goals



- Reactions to changes
  - Changes in infrastructure
  - Changes in load
- Simulation of longer periods (weeks)
- Plausible explanation for utility landscapes
- Reduction of computing times

Changes, transients



- Current state: MATSim is an equilibrium model

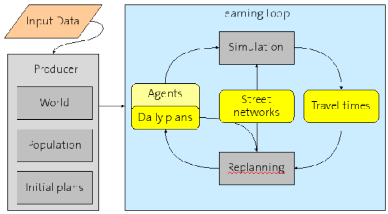
  -> Produces meaningful repeated utilization of a given world

- Problem: Reactions to unforeseen, nonrecurring events?

  -> Need a model explaining (travel) behavior relatively far away from equilibria.

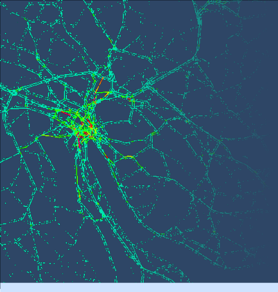
- Moreover: People do react quickly to the state of the system. How can we model that?

Simulation of longer periods (weeks)

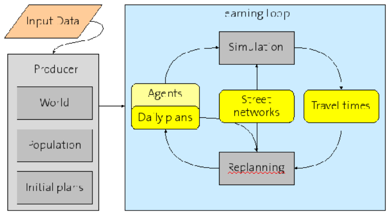


Goal: Simulation of travel behavior over multiple days (weeks)

- Problem 1: Curse of dimensionality
  - Number of activities proportional to length of plan
  - Number of possible activity patterns grows exponentially
  - Computing time and (to some extent) memory consumption increase indefinitely



Simulation of longer periods (weeks)



- Problem 2: Chaotic nature of complex systems
  - Small fluctuations grow quickly
  - Plans must be ever more exact to predict longer periods
  - More, longer simulation runs
  - Is there a stable state at all?

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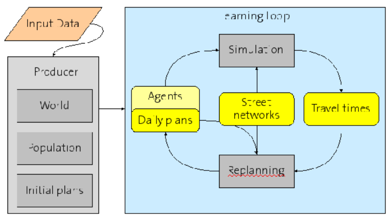
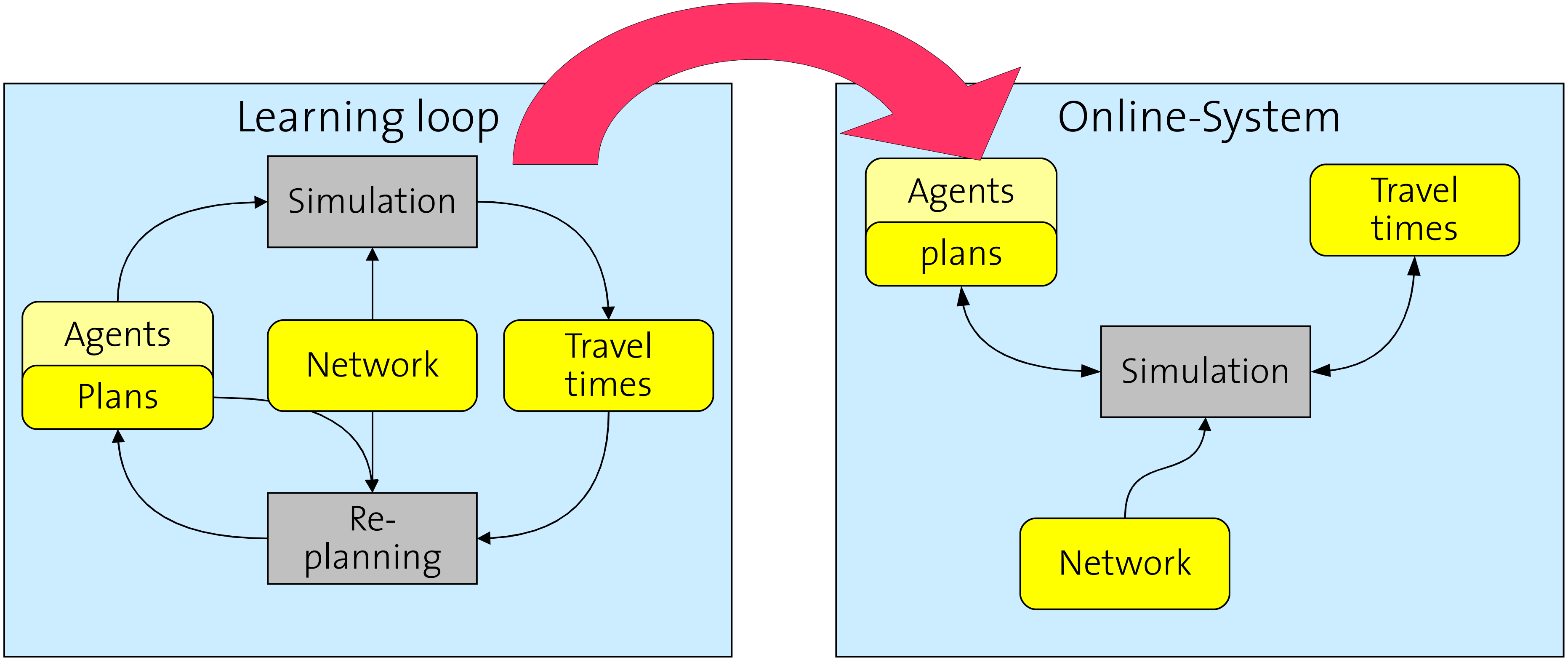
Performance

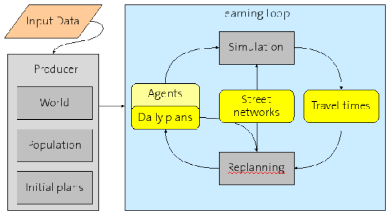


Current figures: 8 million person days on ca. 1 million links in ca. 7 days on 16 cores(8 processors) and 64 GiB of memory

Multi-week simulation must not take longer

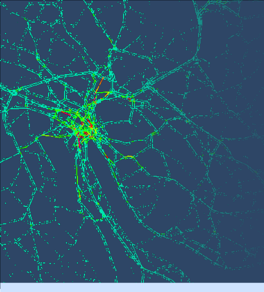


Continuous replanning

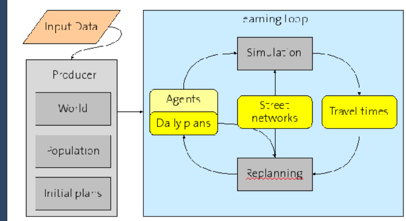


Concept:

- Permanent (re-)generation of short time horizon activity plans based on needs
- Route generation based on all-knowing navigation device able to answer routing request efficiently
- State of the system is continuously updated and available for planning processes

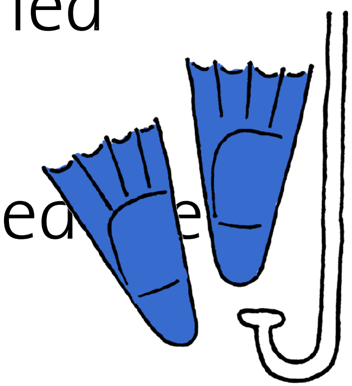


Need-based planning



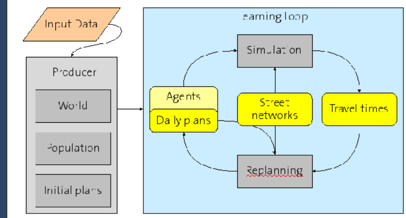
Approach:

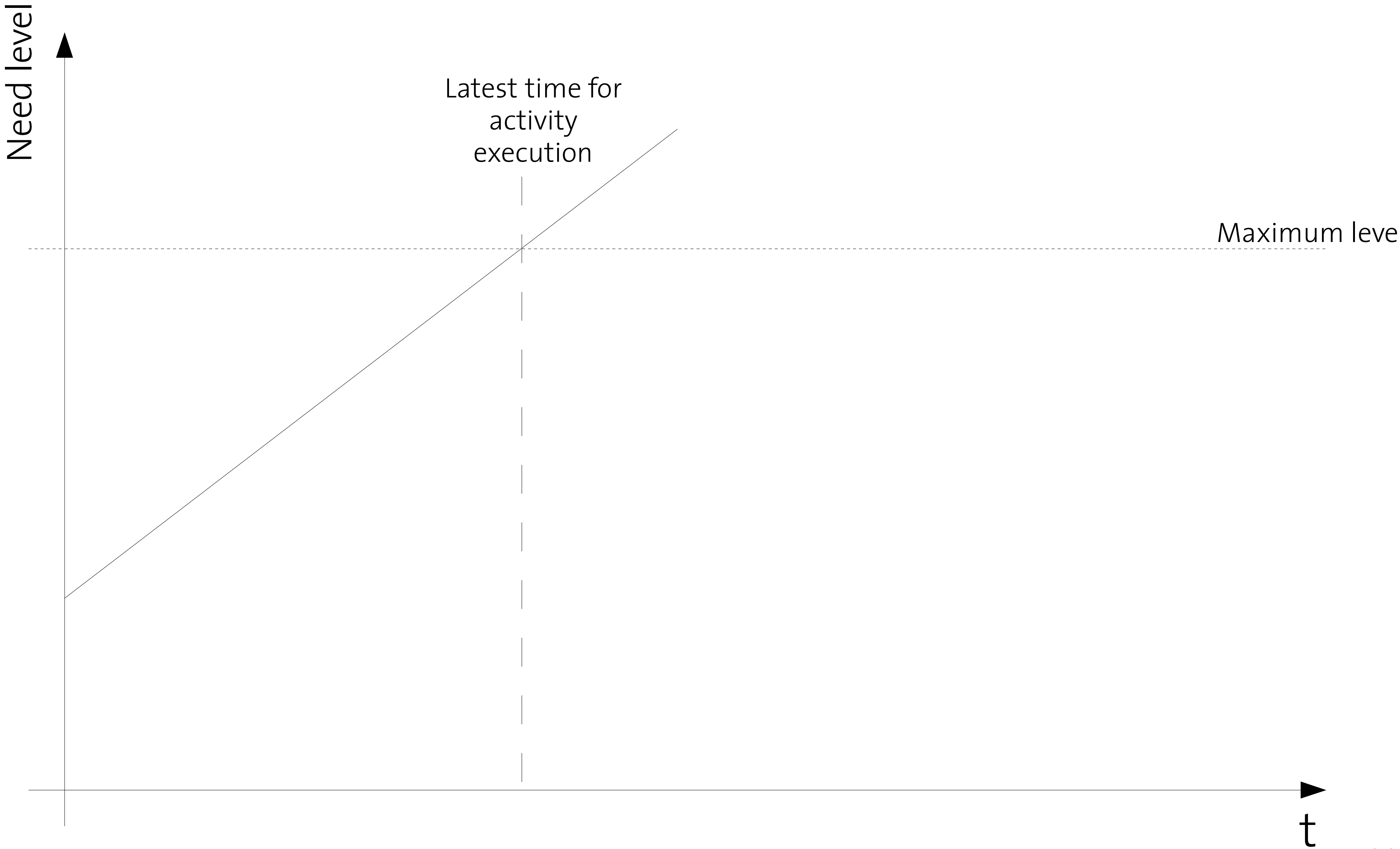
- Each agent has endogenous needs
  - Food, sleep, work, shop, leisure, etc.
- Needs build up continuously and can be satisfied th... gh
  - e ... t be ... rmed ... e



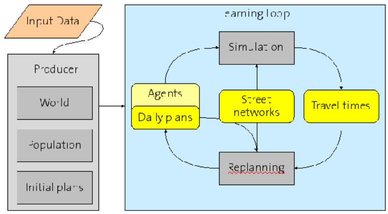
- Main behavioral rule is to avoid starved needs
- Satisfaction of needs can be interpreted as utility

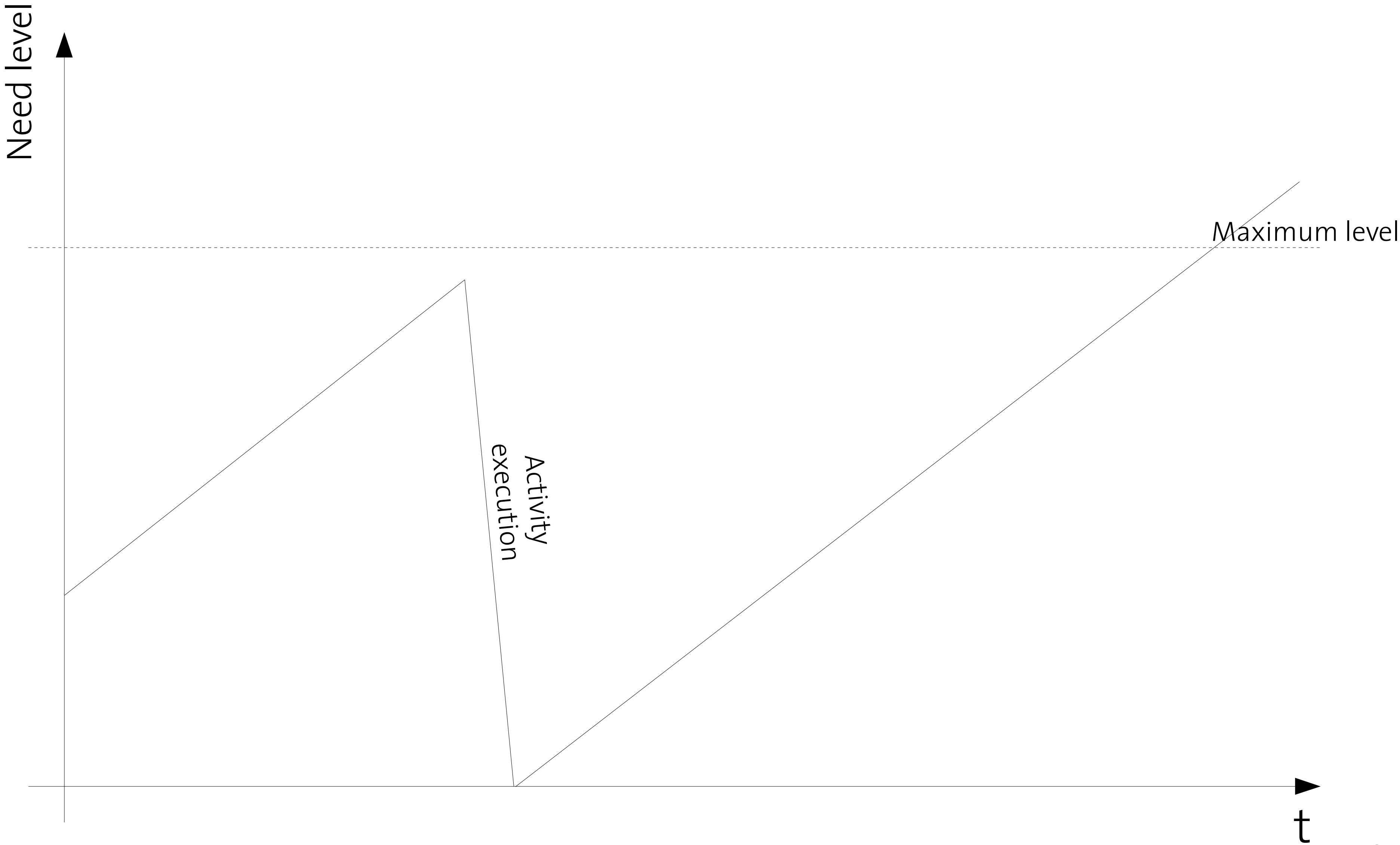
Need buildup

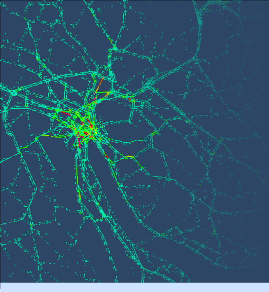




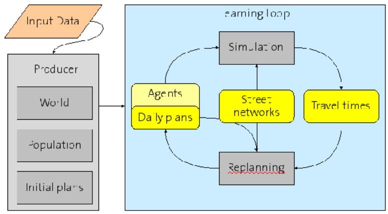
Activity execution

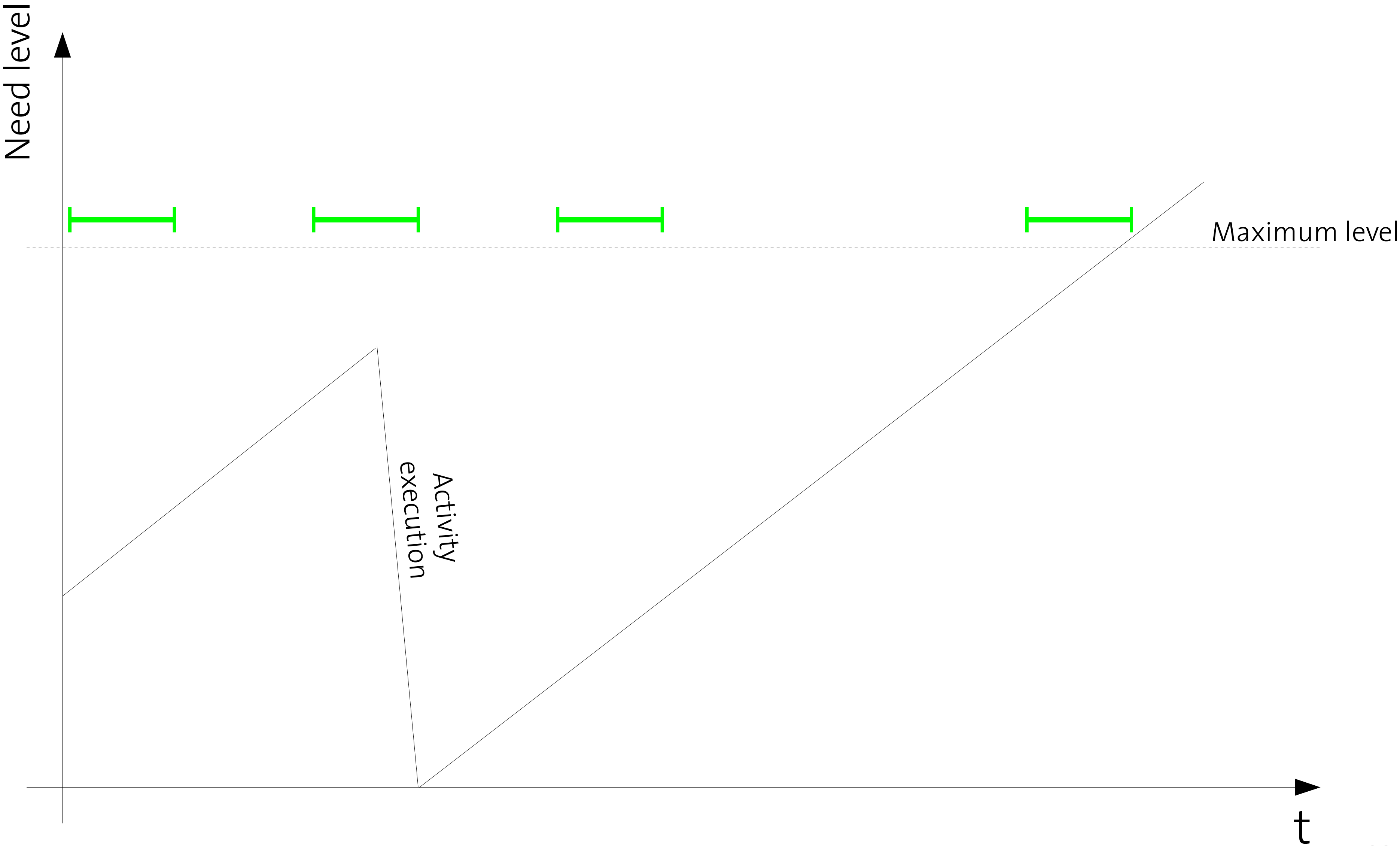




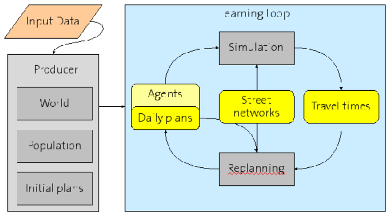


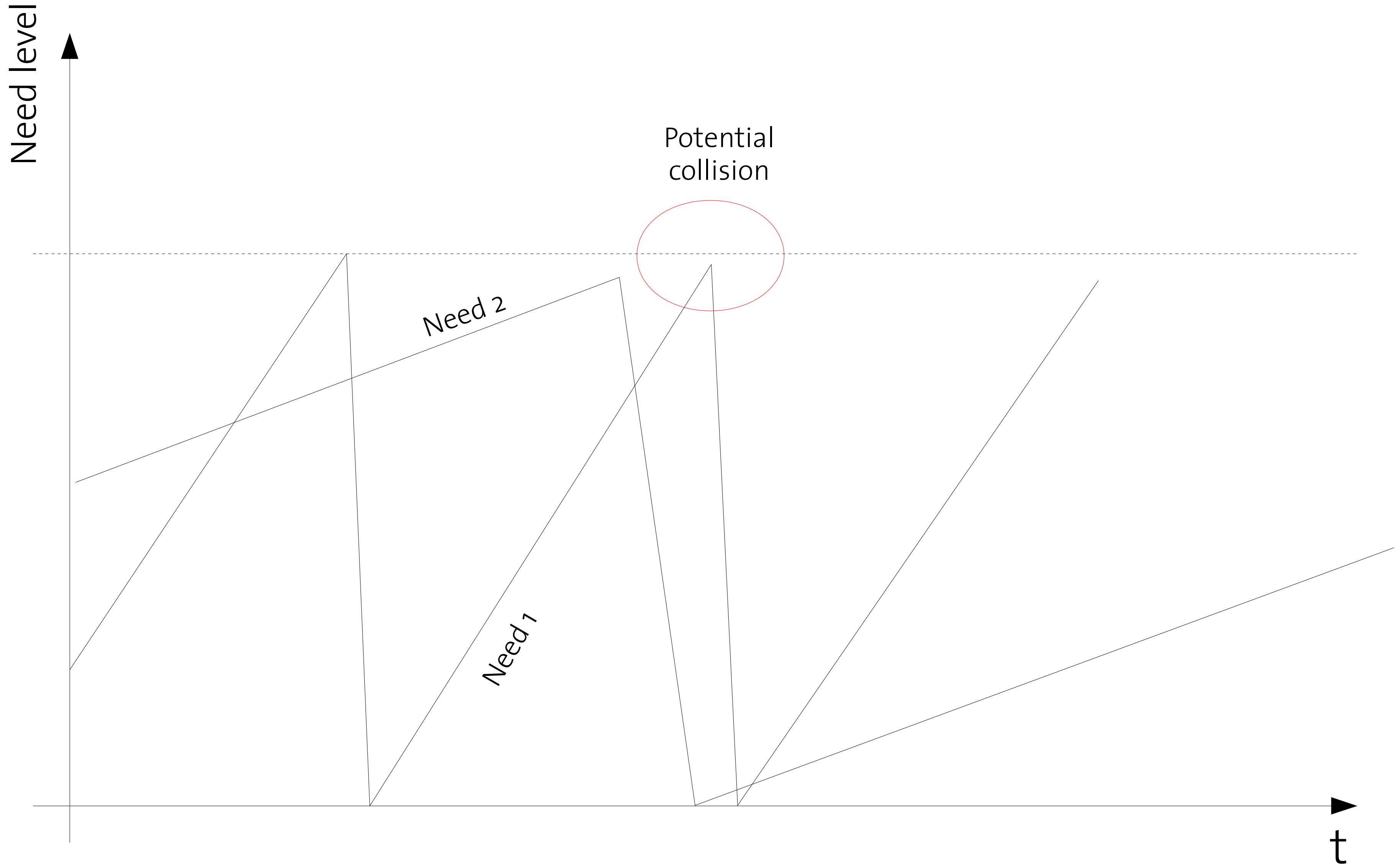
Shop hours


Input Data
Producer
Agents
Travel times
Replanning


Need level
Maximum level
Activity execution
t

Multiple needs





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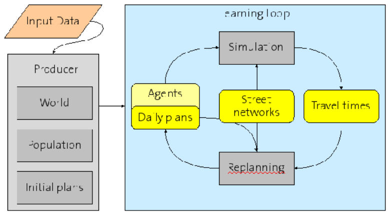
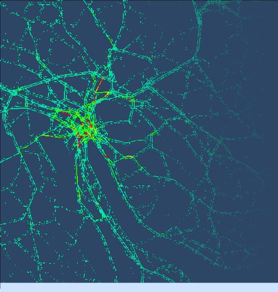
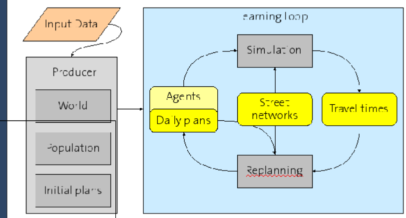
Online Routing

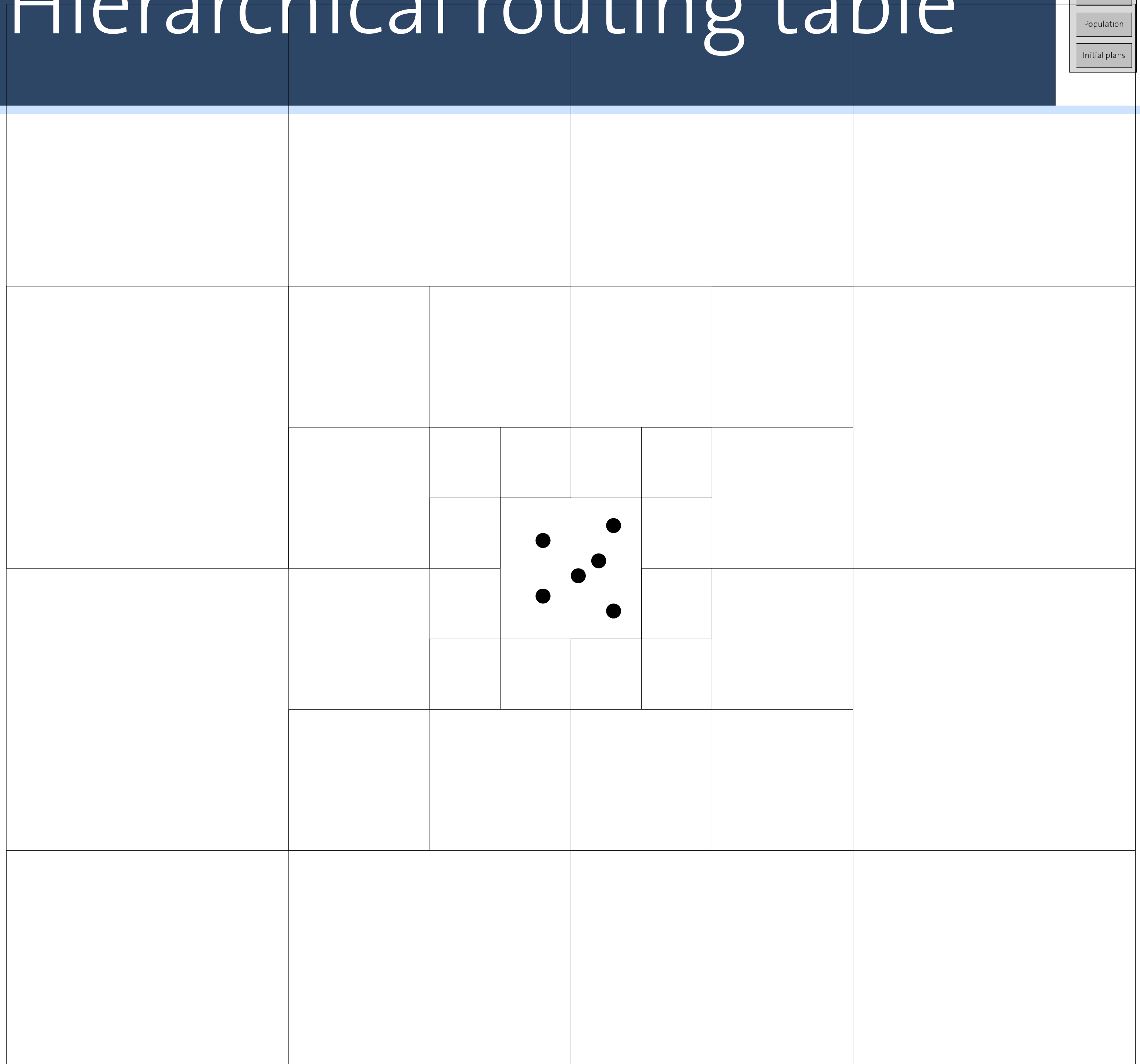


- No pre-computing of routes
- Agents rely on direction signs at each node
- Each network node holds a hierarchical map of possible destinations
- For each element of this map, the first link of the shortest route leading there is available (Routing table)
- Routing hierarchy can be efficiently stored
- Travel times (and hence routes) permanently updated using tt-messages between nodes.

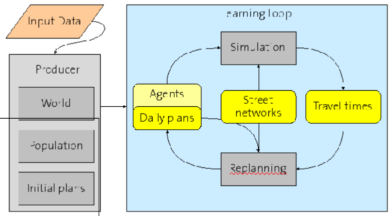


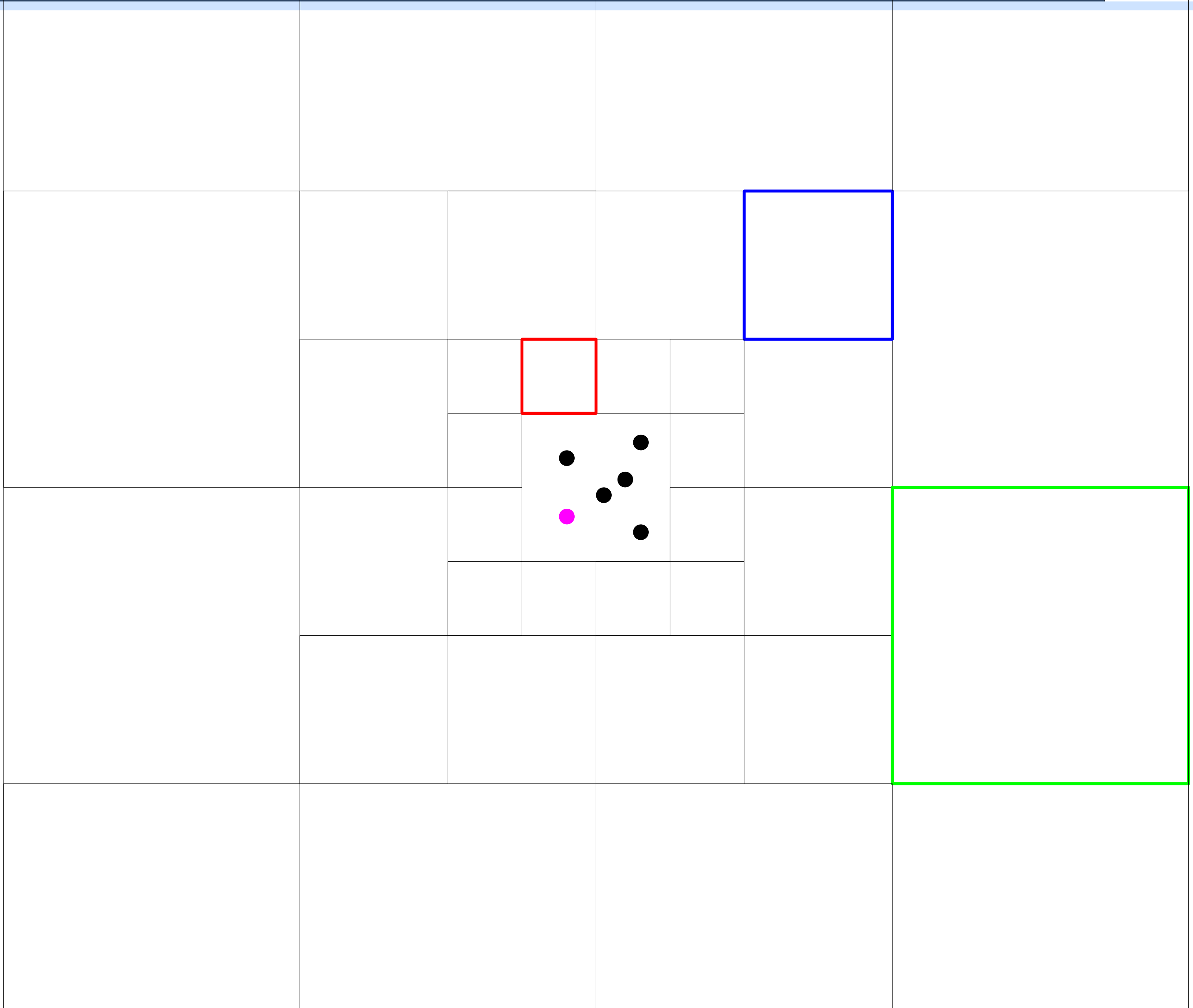
Hierarchical routing table

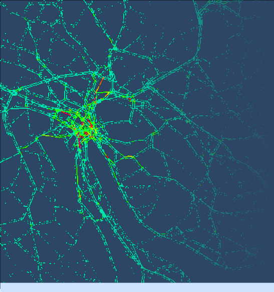




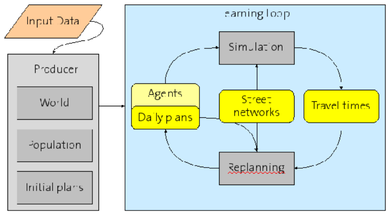
Elements of equal amount of information







Routing: exchange of information



- Routing tables sent periodically to neighboring nodes
- Limited travel speed of such information
- Merging of received with local information to create new routing table
- Redundancy reduction (compression) according to a precise criterion (e.g. 10% travel time difference)

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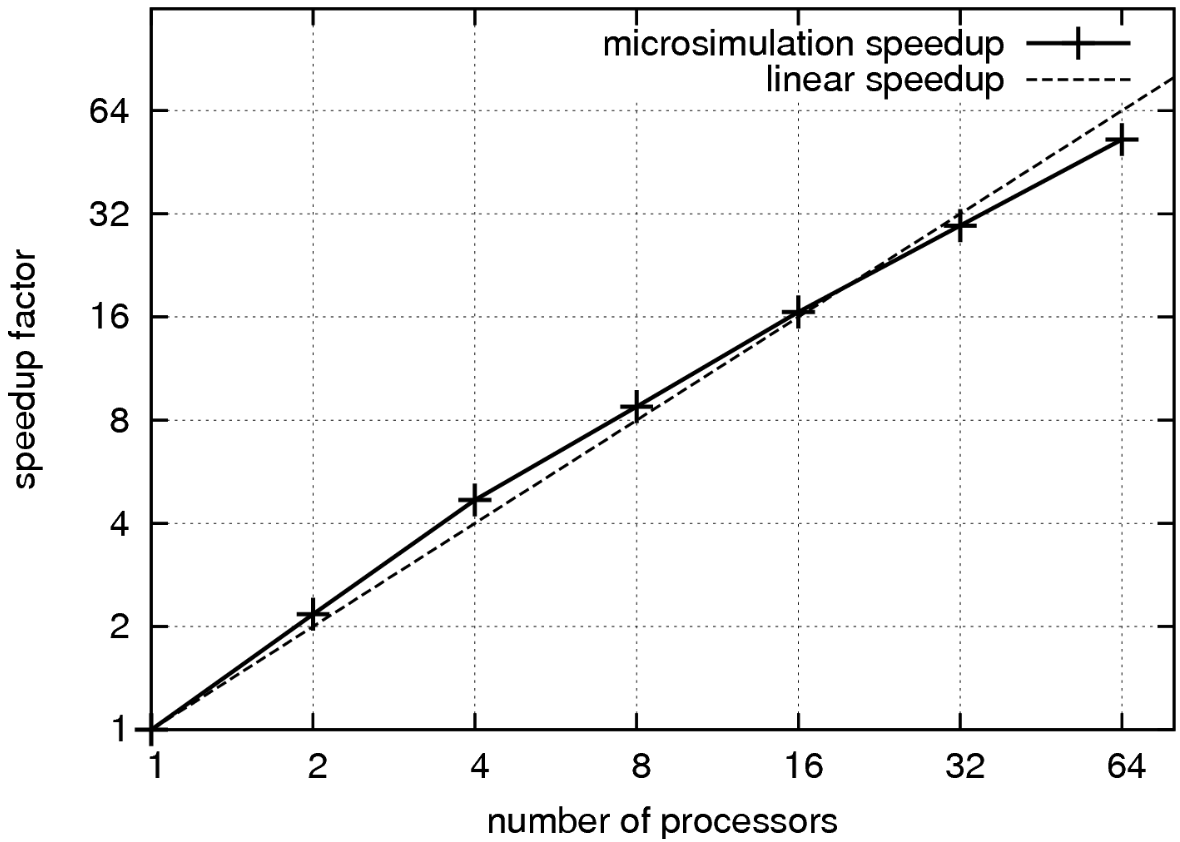
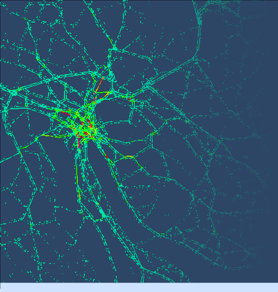
Parallelism

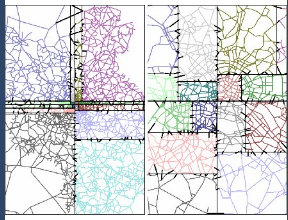
Previous traffic flow microsimulations work very well on multiple CPU.

Will this be true for an online system too?



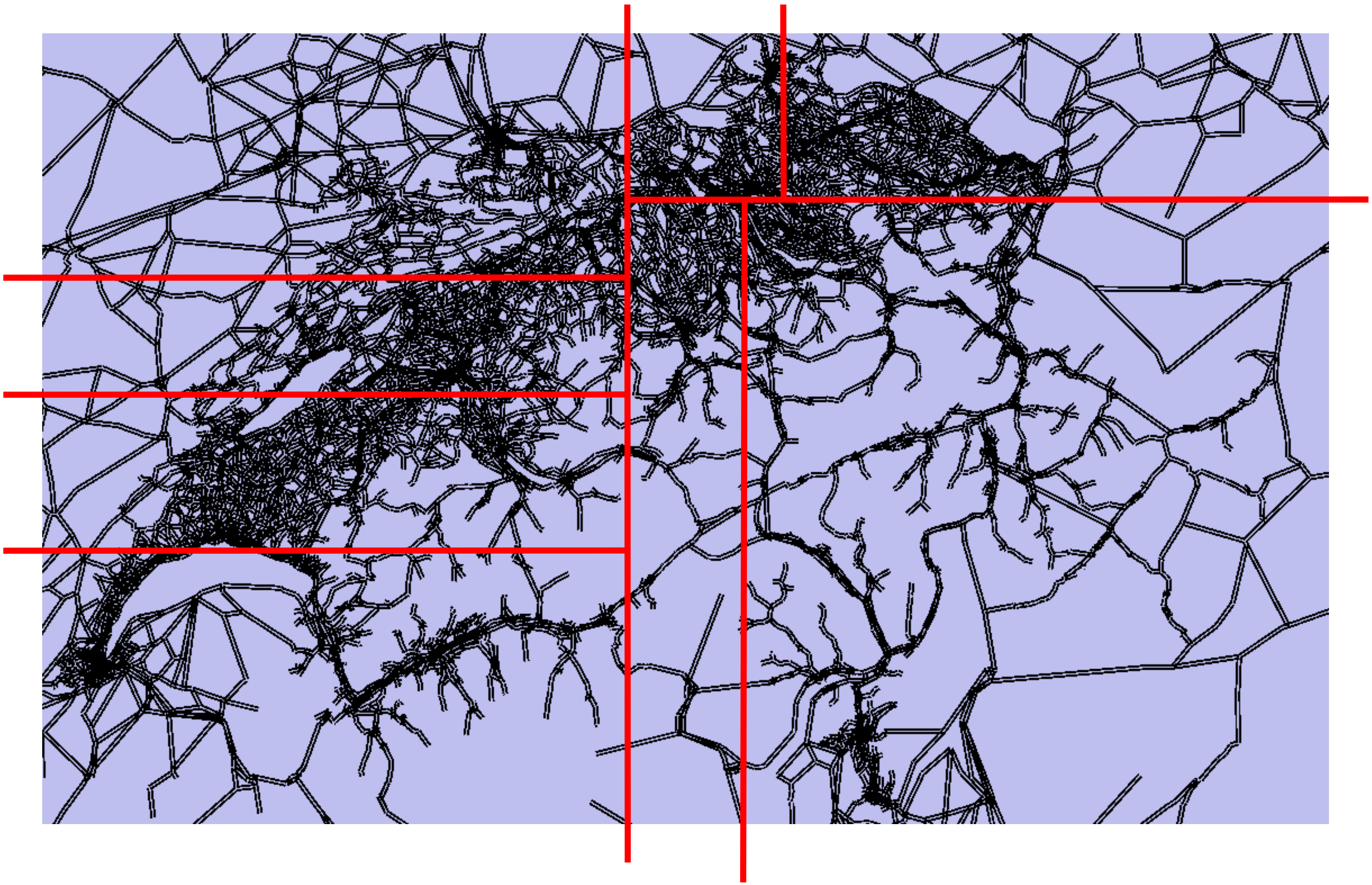


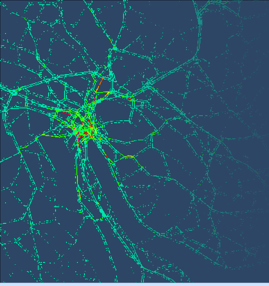
Challenge: Domain Decomposition



- Distribution of road network to different CPUs
- Road segments connecting different CPUS require communication
- Load balancing crucial for parallel performance
- So far decomposition reuses load information from previous iterations
- This information is missing in online system
  -> New algorithm for network distribution

Domain Decomposition





Conclusion

- Need based (re-)planning to cope with curse of dimensionality for long activity patterns
- Hierarchical routing tables to reduce memory consumption
- As we go (re-)planning to enable simulation of unexpected situations
- Parallelism necessary, yet challenging due to inherently dynamic environment