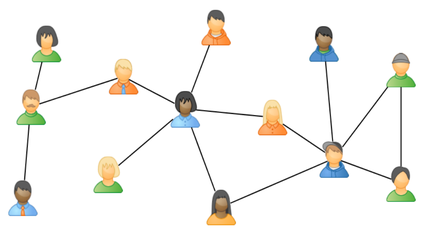
Universität Rostock

Traditio et Innovatio

SUPPORTING AGENT-BASED MODELING AND SIMULATION IN DEMOGRAPHY

Motivation

- Agent-based modeling has become an important tool in demographic research, allowing to develop and test **micro-level** (individual-level) theory to explain **macro-level** (population) phenomena using artificial societies.
- **Application examples**: Migration, Partnership formation, Healthcare, Epidemics, …
- **Linked Lives Models**: Tens of thousands of agents interacting in an intricate dynamic social network



State of the art:

repast python™

- Model and simulation closely intertwined
- No support for continuous time

Challenge 1: Modelling Language

- Requirements:
  - Agent-based approach
  - Dynamic social networks
  - Age-dependent behavior
  - Model decision processes

New domain-specific Modeling Language for Linked Lives ML3 [1]

- Focus on **agents** and their **social networks**
- Behavior modeled as competing **guarded commands**

using domain metaphors — tailored to domain problems

```
Person
// Guard: Who can it happen to?
| ego.sex = "f“, ego.isMarried()
// Rate: When will it happen?
@ if now < transitionYear
  then growingPopBirthRate[ego.age]
  else steadyPopBirthRate[ego.age]
// Effect: What will happen?
-> ?child := new Person( sex := ["m", "f"].random(),
                         sec := ego.sec )
   ?child.parents := [ego, ego.spouse]
```

arbitrary functions — OOP-like and imperative syntax

Stochastic race / competing risk: Events are scheduled according to the rule's rate using a time-dependent generalized exponential distribution, and the earliest one is executed

Results:

- ✓ Expressive and succinct [1][2]
- ✓ Decisions via stochastic race
- ✓ Inhomogeneous CTMC semantics

Challenge 2: Efficient Execution

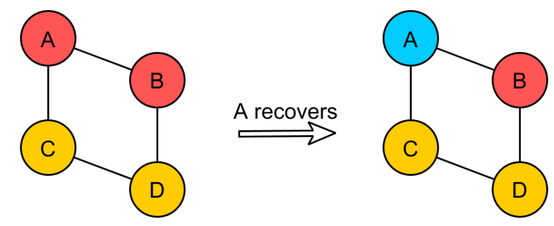
Requirements:

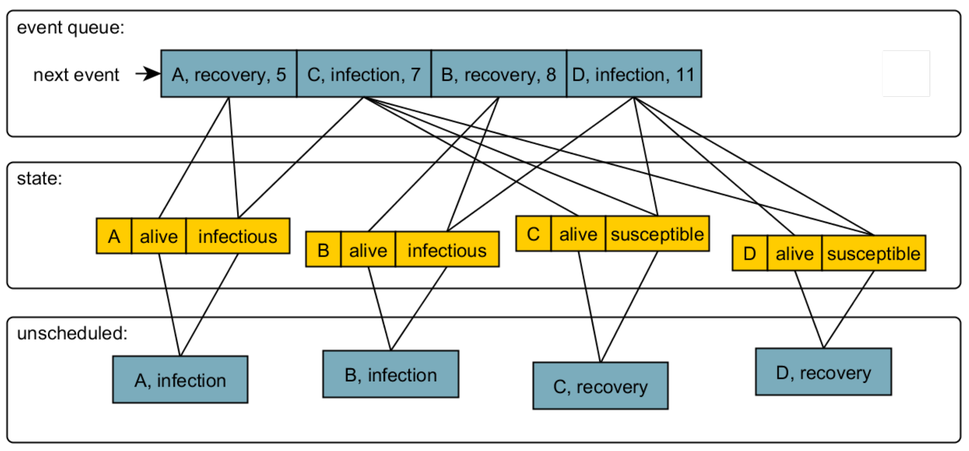
- Heterogeneous agents with complex interactions and effects
- Time-dependent transition rates

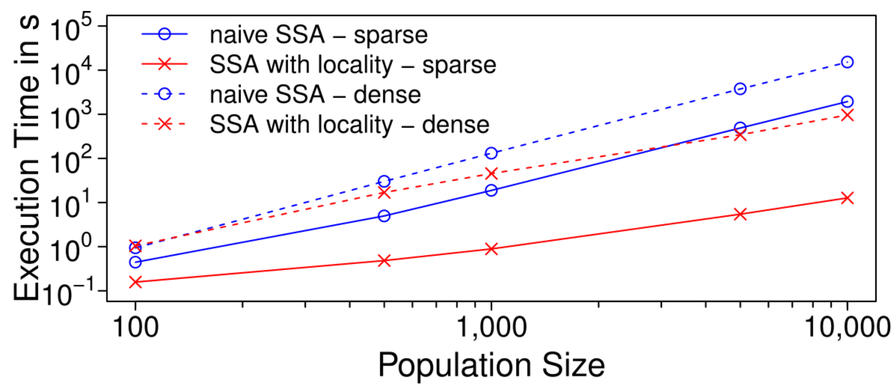
Exploitation of locality of events in the social network to reduce rescheduling and therefore runtime [3]

Example:

- Network-based SIR model
- Infection only spreads along the network's edges



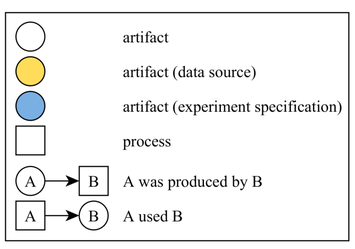




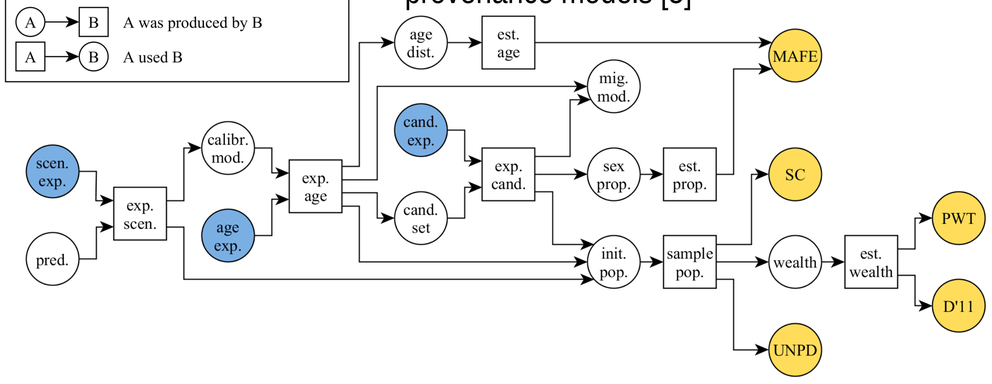
Challenge 3: Managing Simulation Studies

- Complex simulation experiments (e.g., calibration, validation, sensitivity analysis, uncertainty quantification) to be conducted **flexibly** and **replicably**
  → applying SESSL, a DSL for simulation experiment specification [4]

```
new Experiment
    with Observation with StatisticalModelChecking { ...
  val s = observe(agentCount(“Person"),“ego.status = ‘s’”)
  val i = observe(agentCount(“Person"),“ego.status = ‘i’”)
  prop = MITL(G(0, 10)((OutVar(s) > Constant(0))
    and (OutVar(i) > Constant(0))))
  test = SequentialProbabilityRatioTest(
    p = 0.8, alpha = 0.05, beta = 0.05, delta = 0.05)
... }
```



- Model and experiments must be documented **thoroughly** and **accessibly**
  → ODD+P: Complementing ODD with provenance models [5]



References

[1] T. Warnke et al. “ML3: A Language for Compact Modeling of Linked Lives in Computational Demography” In: Winter Simulation Conference, 2015. [2] T. Warnke et al. “Modeling and Simulation Decision Processes of Linked Lives - An Approach Based on Concurrent Processes and Stochastic Race” In: Population Studies, 2017. [3] O. Reinhardt, A. Uhrmacher. “An Efficient Simulation Algorithm for Continuous-Time Agent-Based Linked Lives Models” In: Annual Simulation Symposium, 2017. [4] O. Reinhardt et al. “Streamlining simulation experiments with agent-based models in demography” In: Journal of Artificial Societies and Social Simulation, 2018. [5] O. Reinhardt et al. “ODD+P: Complementing the ODD Protocol With Provenance Information” In: Winter Simulation Conference, 2018.

Software: git.informatik.uni-rostock.de/mosi/ml3

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