INF

FAKULTÄT FÜR
INFORMATIK

Introduction to Simulation

Agent-Based Modelling and Simulation

Contents

Contents of the lecture

- Motivation
- Simple Examples
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- Application examples

Motivation

Why do we need agent based simulation?

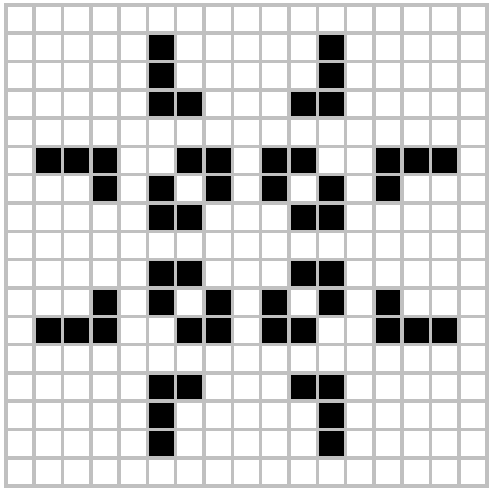
- Growing complexity in social-technical systems
- Distributed / agent based systems more frequent
- Interaction and self-organization → emergence
- Most natural populations are heterogeneous
- Individuals are adaptive and can learn
- …
- e.g. energy market, economy, societal dynamics

Traditional methods fail to capture that adequately

Simple Examples

Game of Life

- Cellular automaton
- Each cell can be either alive or dead
- Next generation state depends on Moore-neighborhood



Rules

1. A dead cell with 3 live neighbors comes alive
2. A living cell with less than 2 live neighbors dies
3. A living cell with 2 or 3 live neighbors stays alive
4. A living cell with more than 3 live neighbors dies

Simple Examples

Flocking behavior of birds

- Continuous space and movement
- Birds adapt their flight pattern to other birds in their vicinity
- Results in complex, seemingly coordinated flight patterns → flocks

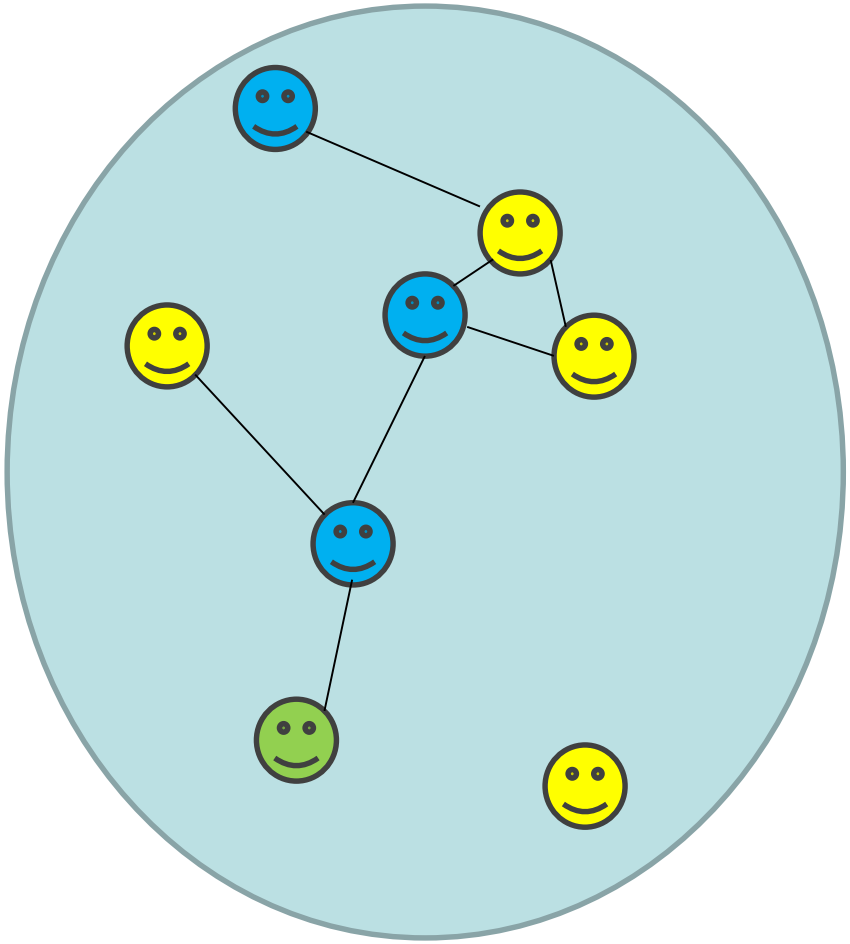
Rules

- Separation – avoid crowding neighbors (short range repulsion)
- Alignment – steer towards average heading of neighbors
- Cohesion – steer towards average position of neighbors (long range attraction)

Theory

Elements of an agent based simulation model

- set of agents
- set of relationships
- environment



Agents in ABMS

Essential characteristics of an agent

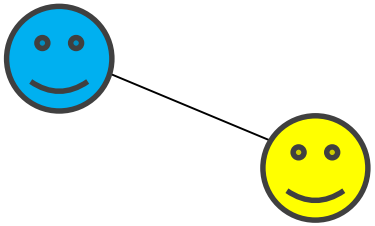
- self-contained
- autonomous
- has a state
- interacts with other agents and/or the environment

Possible additional characteristics

- adaptive
- goal-directed
- heterogeneous

Agent interactions

An agent



- is connected to other agents (neighbors)
- has only local information

- interacts with some agents at some point in time
  NOT with all agents at any time
- interacts with its local environment
  NOT with any part of the environment

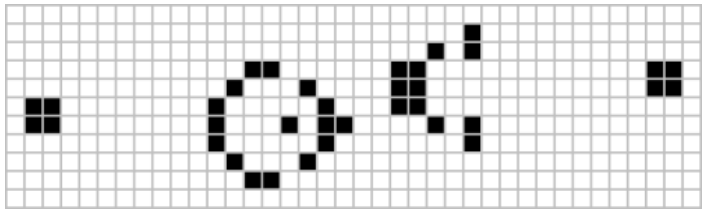
A topology describes who transfers information to whom

- Note: a model may contain multiple topologies

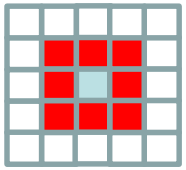
Topologies & Neighborhoods

Discrete – Cellular Automaton

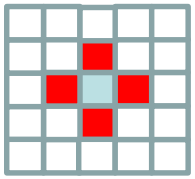
- At most one agent per cell
- GoL: cell=agent



- Moore Neighborhood

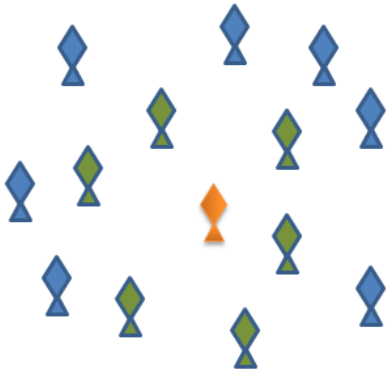


Euclidean Neighborhood



Continuous – Euclidean Space

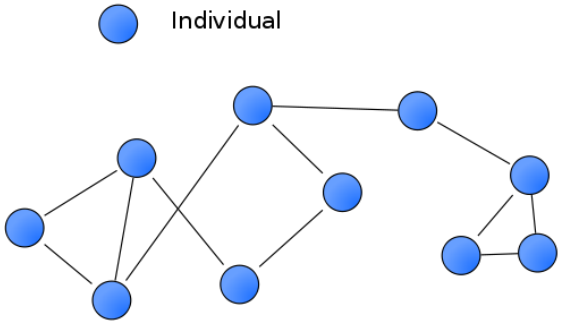
- Euclidean distance
- Continuous movement



Topologies & Neighborhoods

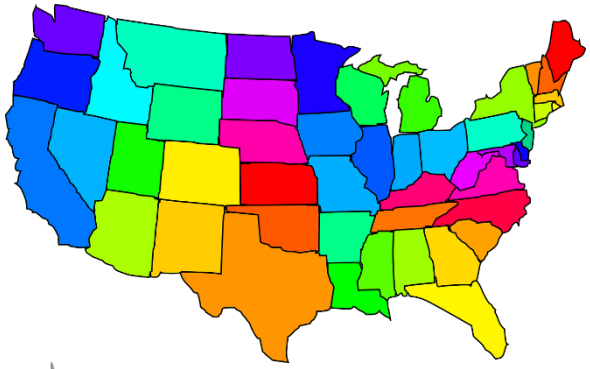
Network

- Static networks
- Dynamic networks evolve and can grow / shrink



GIS (Geographical Information System)

- Realistic / real landscape
- Agents move from patch to patch



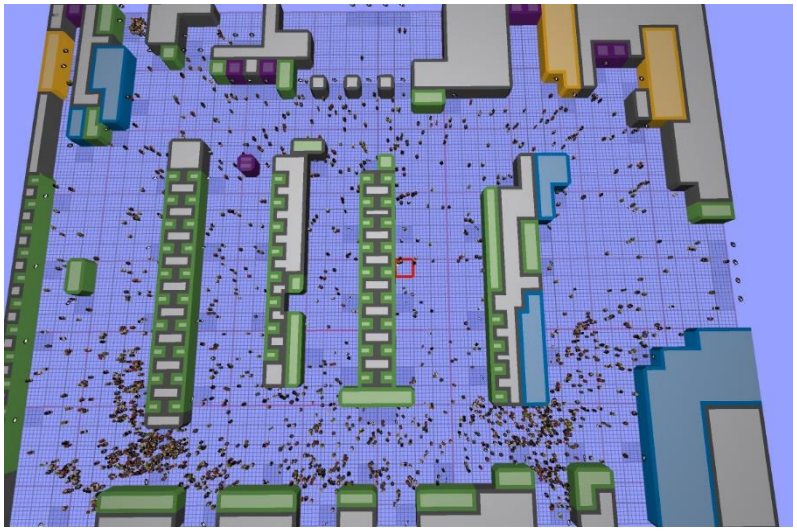
Soup / Random Access

- Actual location does not apply / matter
- Connections form randomly

Environment

May provide information on

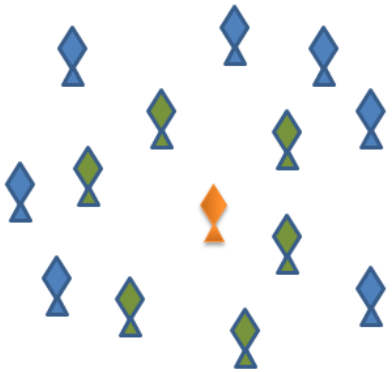
- agents location
- available resources
- model specifics: e.g. ground characteristic, network capacities



Applications

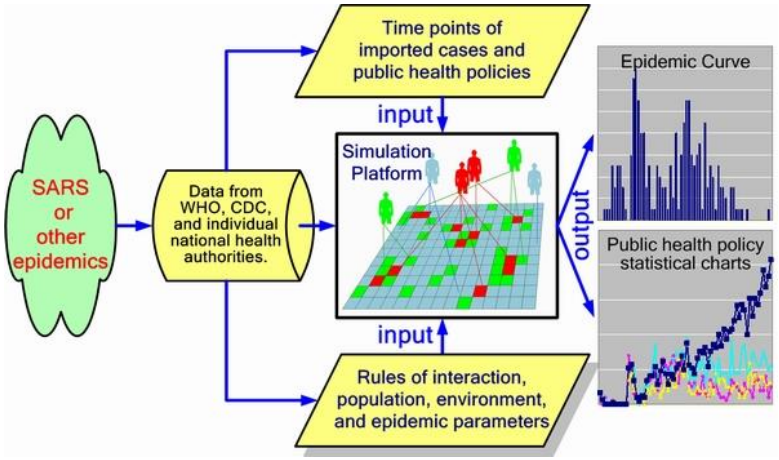
Small scale academic models

- Create and research emergence
- Set of idealized assumptions



Large-scale decision support systems

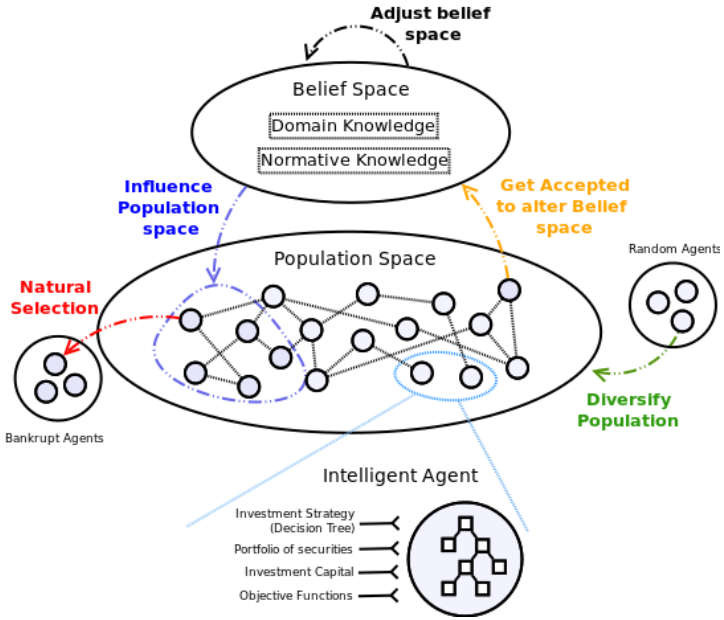
- Answer policy questions
- Include real data
- Are validated and credible

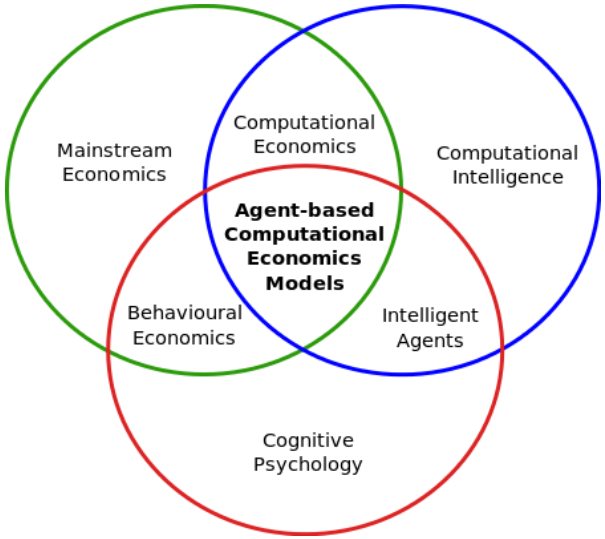


Applications

Agent Based Computational Economics

- Classical assumptions: rational & homogenous agents maximize utility, long run equilibrium → perfect markets
- ABMS makes more realistic assumptions possible



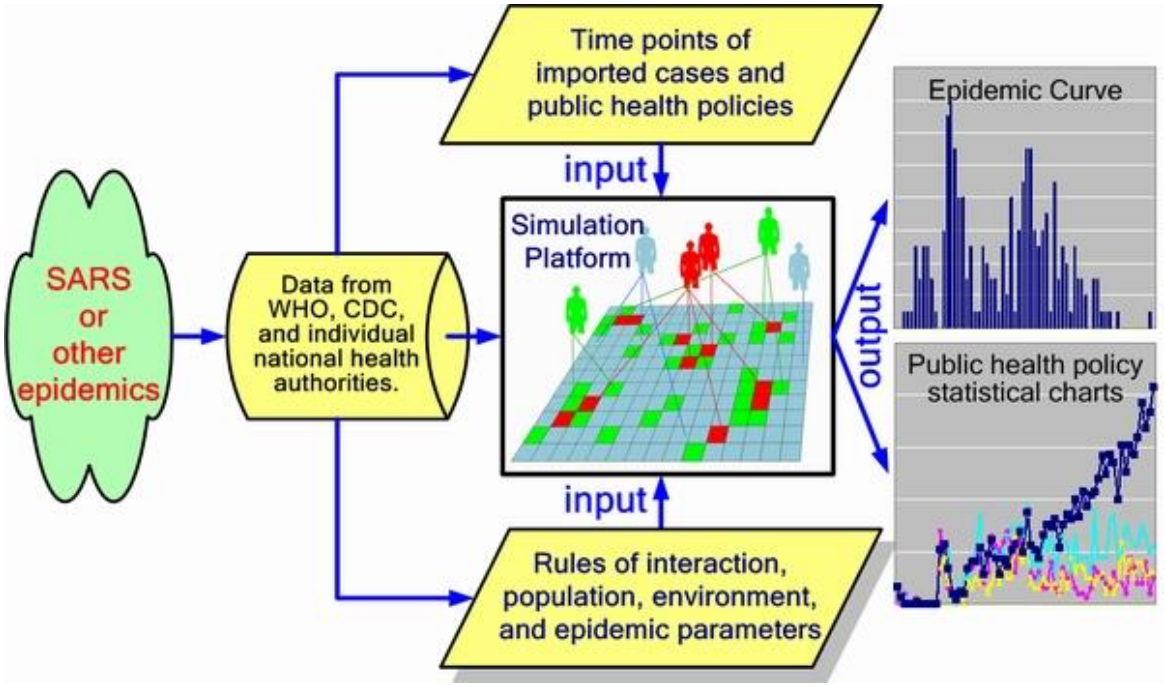


- Perfect Imperfection – Agent Based Models (ABM) – Stuart Gordon Reid (2013)

Applications

Spread of Epidemics

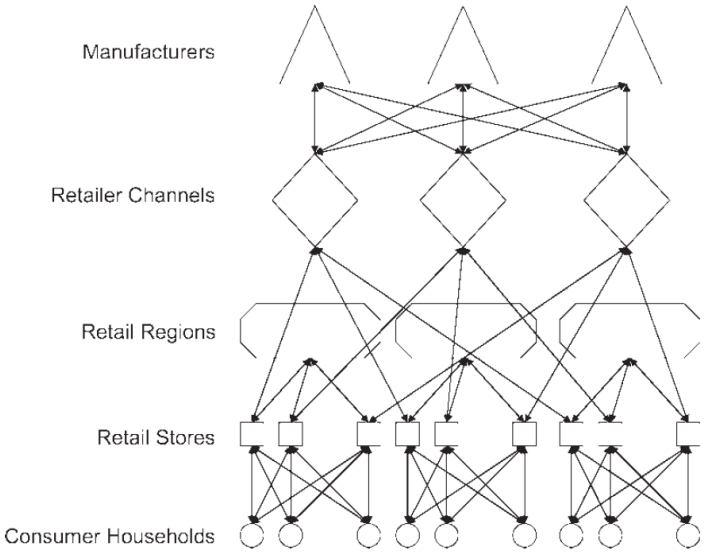
- **Simulating SARS: Small-World Epidemiological Modeling and Public Health Policy Assessments (Huang, Sun, Hsieh, Lin 2004)**



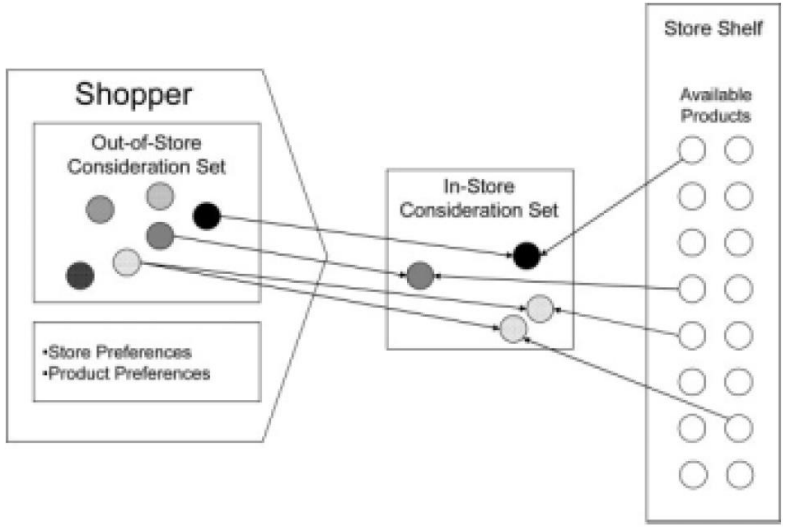
Applications

Consumer behavior

- **Multiscale Agent-Based Consumer Market Modeling (North et.al. 2009)**



Overview of the virtual market learning lab agents and agent relationships.

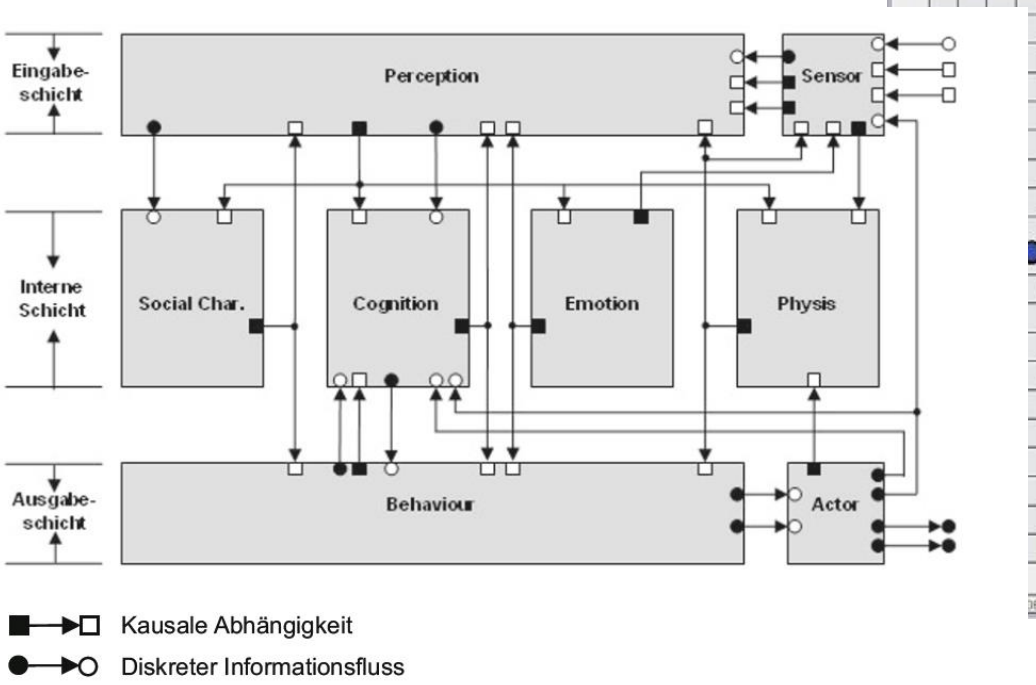


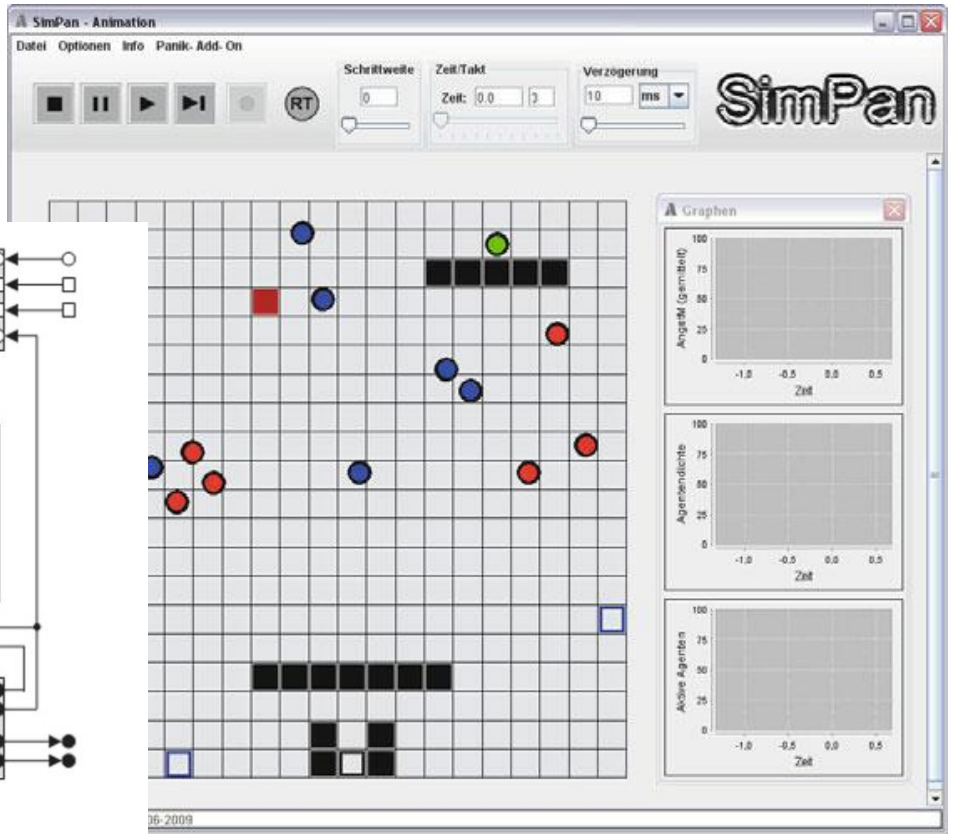
Virtual market learning lab shopper and store shelf.

Applications

Human behavior in panic situations

- **Die Simulation menschlichen Panikverhaltens, Ein Agentenbasierter Ansatz (Schneider 2011)**





Applications

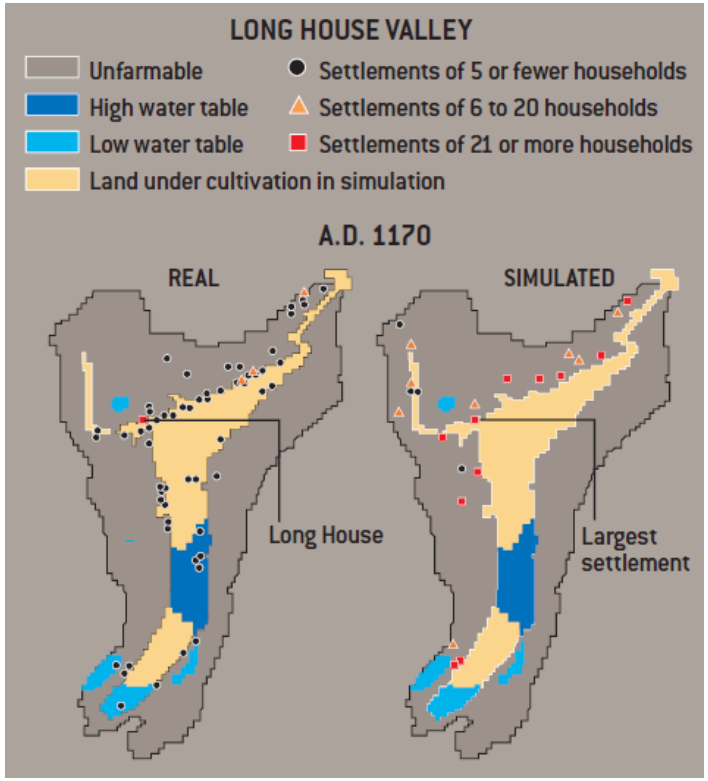
Crowd behavior

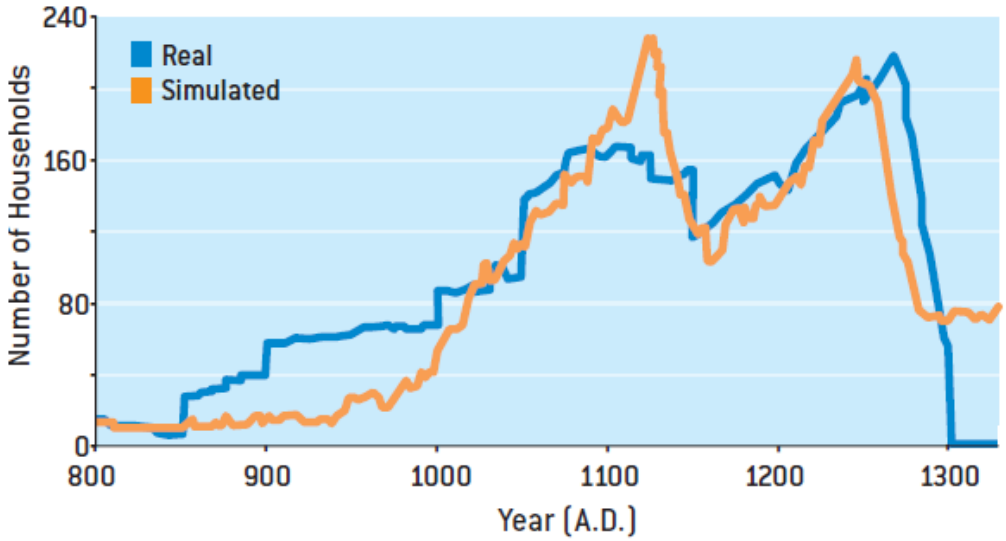
- Towards agent-based crowd simulation in airports using games technology (Szymanezyk, Dickinson, Duckett 2011)

Applications

Understanding ancient civilizations

- Simulating Ancient Societies: Computer modeling is helping unravel the archeological mysteries of the American Southwest (Kohler, Gumeran, Reynolds 2005)

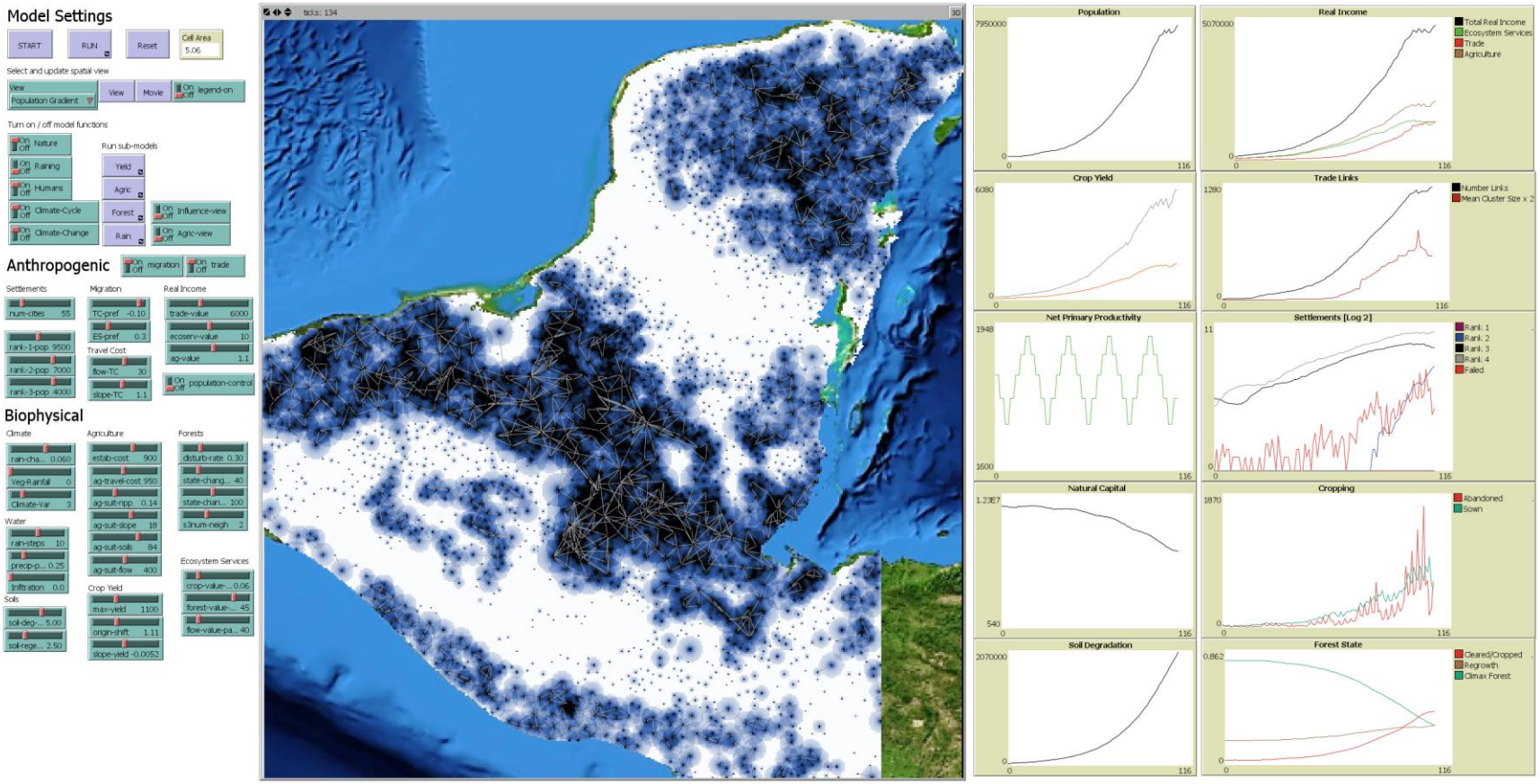




Applications

Understanding ancient civilizations

- **MayaSim: An agent-based model of the ancient Maya social-ecological system (Heckbert 2013)**



Applications

Further examples

- Supply chains
- Adaptive immune system
- Threat of bio-warfare
- Military engagements
- …

Advantages

Advantages of ABMS (over DES and SD)

- Can utilize insights from cognitive and social sciences to model agent behavior
- Can give insights into emergent phenomena
  in DES these have to be modeled explicitly
- Can model heterogeneous populations
  in SD these are homogenous
- Can model learning and adaption

Disadvantages

But there are pitfalls

- No common modeling approach
- No agreed upon rules for what an agent is and what not
- Not easy / possible to validate – due to system complexity

Other Agent based Stuff

Optimization

- Ant optimization
- Particle swarm optimization methods

Swarm intelligence

- Fleets of robots for exploration tasks

Computer Games

- Games like SimCity, Sims etc.

…

Some Agent based Simulation Tools

NetLogo (used for this lectures examples)

- Freeware
- Specific for agent based systems
- Developed at CCL (The Center for Connected Learning and Computer-Based Modeling) Northwestern University, IL

Others

- AnyLogic 8.x
- Repast – Recursive Porous Agent Simulation Toolkit
- …

Learning Goals

Questions to test your knowledge:

- What are the elements of an agent based simulation?
- What are possible topologies?
- What elements are essential for an agent?