BISS 2013: Simulation for Decision Support

Lecture 19

Agent-Based Modelling and Simulation

Peer-Olaf Siebers (Nottingham University)
Stephan Onggo (Lancaster University)

pos@cs.nott.ac.uk

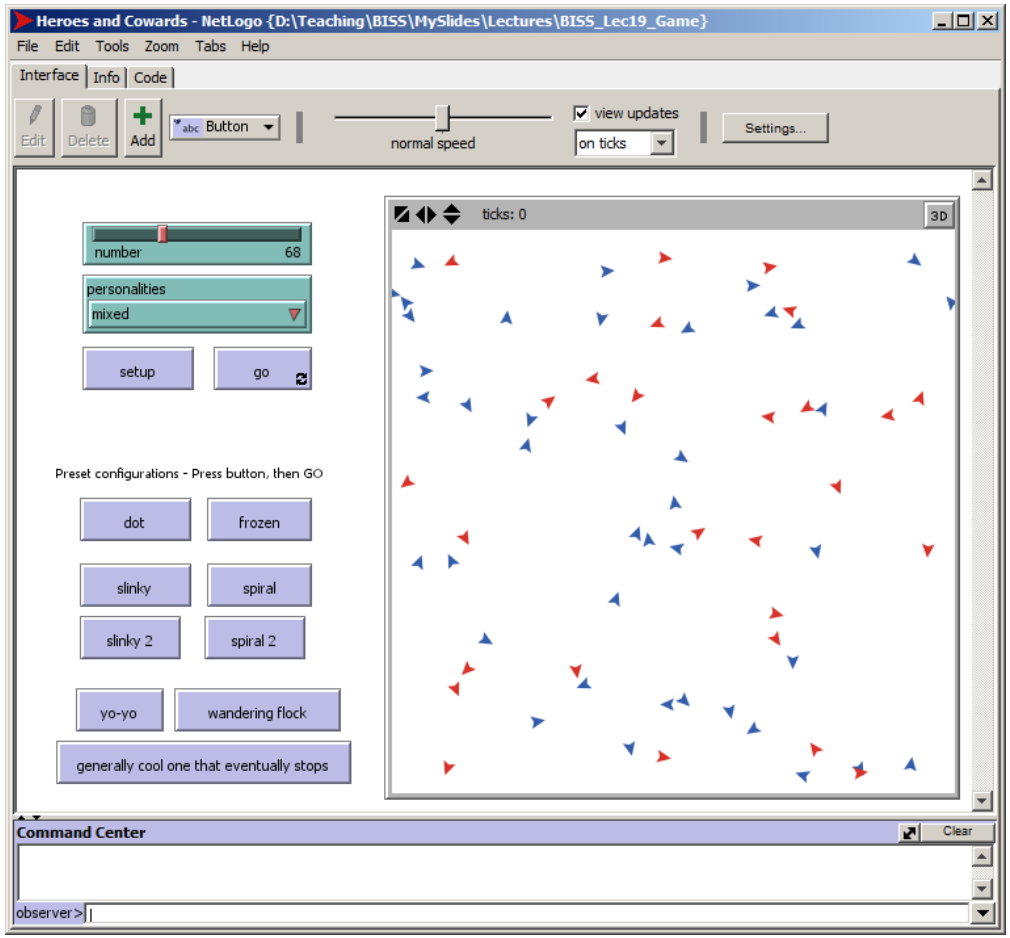
The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

Lancaster University
MANAGEMENT SCHOOL

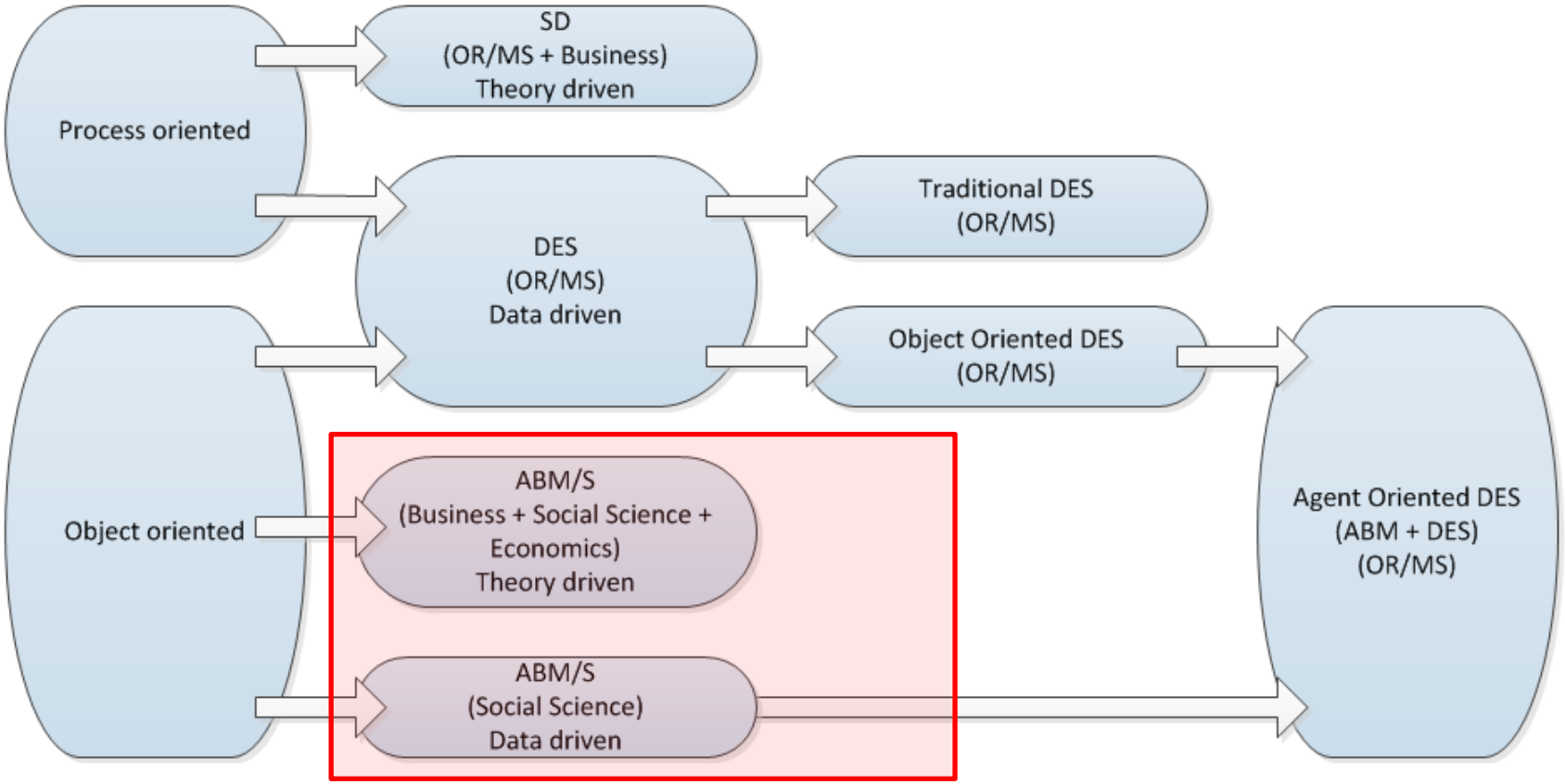
Motivation

- Introduce agent based modelling
- Introduce agent based simulation
- Clarify the difference between discrete event and agent based simulation

Heroes and Cowards Game



Reminder: Simulation Paradigms



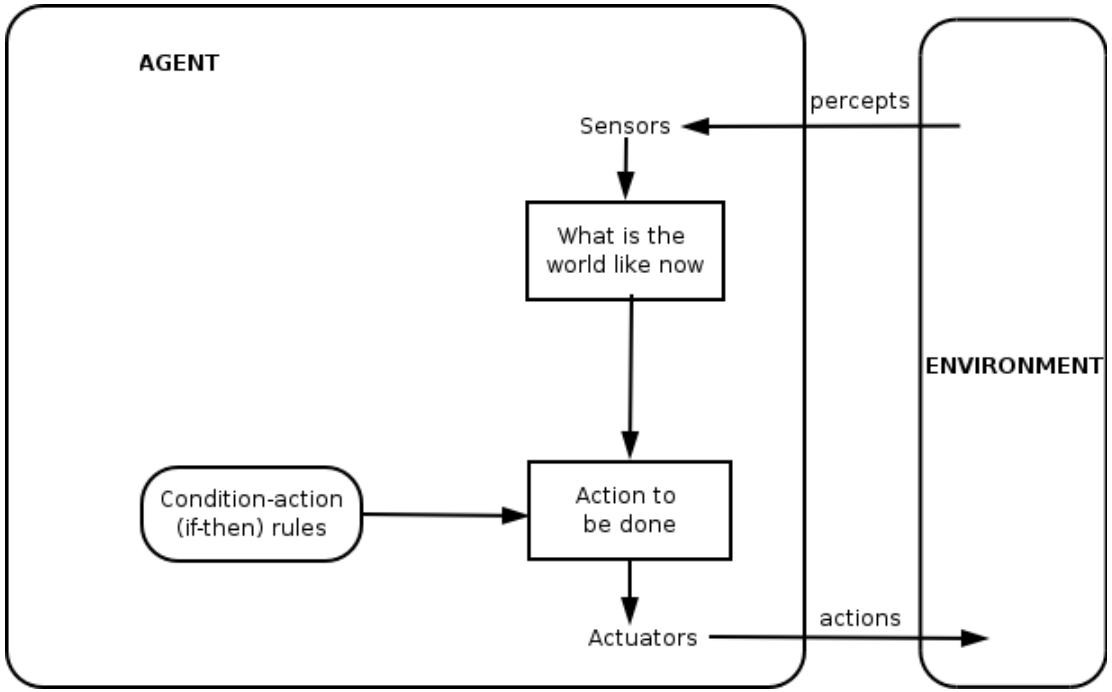
Data driven: Data for model formulation (in Social Sciences can be quantitative and qualitative); data for model validation
Theory driven: Theories for model formulation; data for model validation

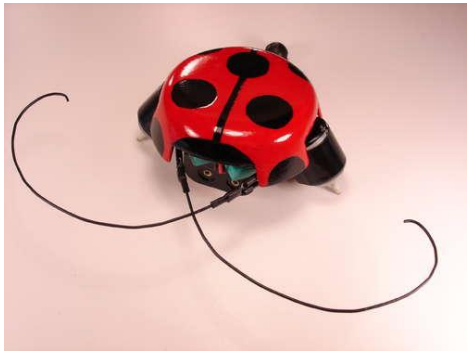
Agent-Based Modelling

- In Agent-Based Modelling (ABM), a system is modelled as a collection of **autonomous decision-making entities** called agents. Each agent individually assesses its situation and makes decisions on the basis of a **set of rules**.
- ABM is **a mindset more than a technology**. The ABM mindset consists of describing a system from the perspective of its constituent units. [Bonabeau 2002]
- ABM is **well suited to modelling** systems with heterogeneous, autonomous and proactive actors, such as **human-centred systems**.

Agent-Based Modelling

- Borrowing from Artificial Intelligence: From simple to complex
  - Simple reflex agent

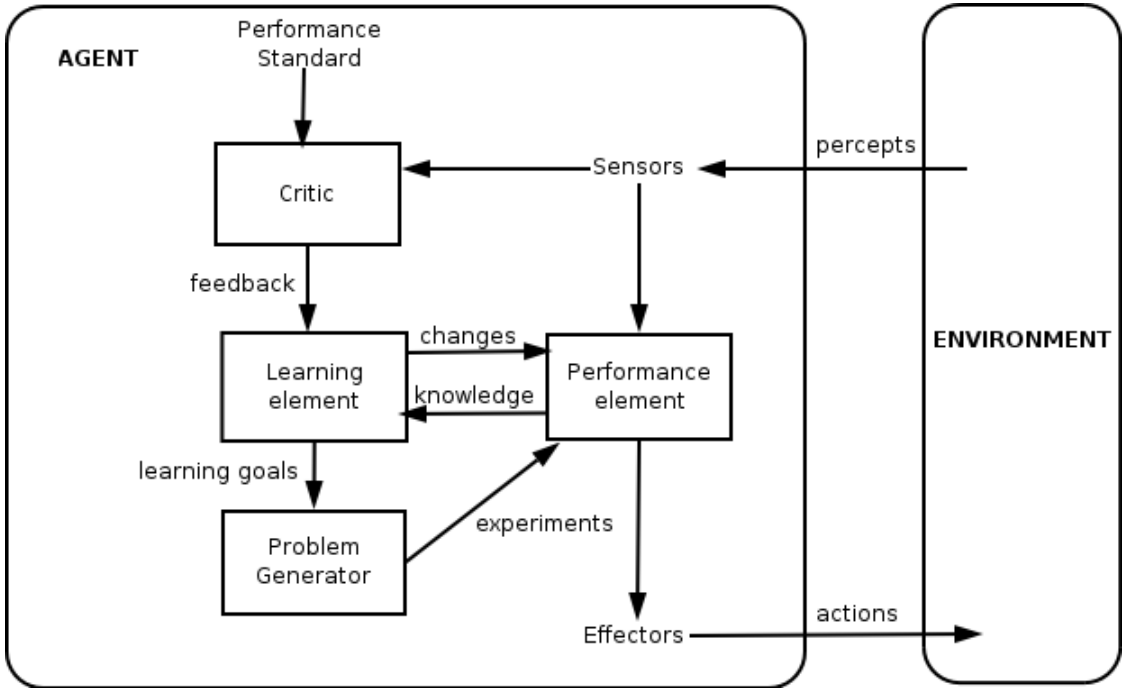




Russell and Norvig (2003)

Agent-Based Modelling

- Borrowing from Artificial Intelligence: From simple to complex
  - Learning agent



Russell and Norvig (2003)

Agent-Based Modelling

- What do we mean by "agent"?
  - Agents are **objects with attitude**!

- Properties:
  - Discrete entities
    - With their own goals and behaviours
    - With their own thread of control
  - Autonomous decisions
    - Capable to adapt
    - Capable to modify their behaviour
  - Proactive behaviour
    - Actions depending on motivations generated from their internal state

Agent-Based Modelling

- The agents can represent individuals, households, organisations, companies, nations, … depending on the application.

- ABMs are essentially **decentralised**; there is no place where global system behaviour (dynamics) would be defined.
- Instead, the individual agents **interact** with each other and their environment **to produce complex collective behaviour** patterns.

Agent-Based Modelling

- Benefits of ABM
  - ABM provides a natural description of a system
  - ABM captures emergent phenomena

- Emergence
  - Emergent phenomena result from the interactions of individual entities. **The whole is more than the sum of its parts** [Aristotle BC] because of the interactions between the parts.
  - An emergent phenomenon can have properties that are decoupled from the properties of the part (e.g. patterns appearing).
  - Example: Traffic Jam Dynamics

Agent-Based Modelling

- When to use ABM? [Siebers et al. 2010]
  - When the problem has a **natural representation as agents** - when the goal is modelling the behaviours of individuals in a diverse population
  - When agents have relationships with other agents, especially **dynamic relationships** - agent relationships form and dissipate, e.g., structured contact, social networks
  - When it is important that individual agents have **spatial or geo-spatial aspects** to their behaviours (e.g. agents move over a landscape)
  - When it is important that agents **learn or adapt**, or populations adapt
  - When agents engage in **strategic behaviour**, and anticipate other agents' reactions when making their decisions
  - ...

Agent-Based Modelling

- Agent model classification based on empirical embeddedness
  - **Case-based** (specific circumscribed empirical phenomena)
    - Example: Evolutionary studies of prehistoric societies
  - **Typification** (specific classes of empirical phenomena)
    - Example: Simulating issues related to land use management
  - **Theoretical abstractions** (pure theoretical models)
    - Example: Flocks of boids

- Agent decision making process (depends on model purpose)
  - Probabilistic: Representing decisions using distributions
  - Rule based: Modelling the decision making process

Agent-Based Simulation

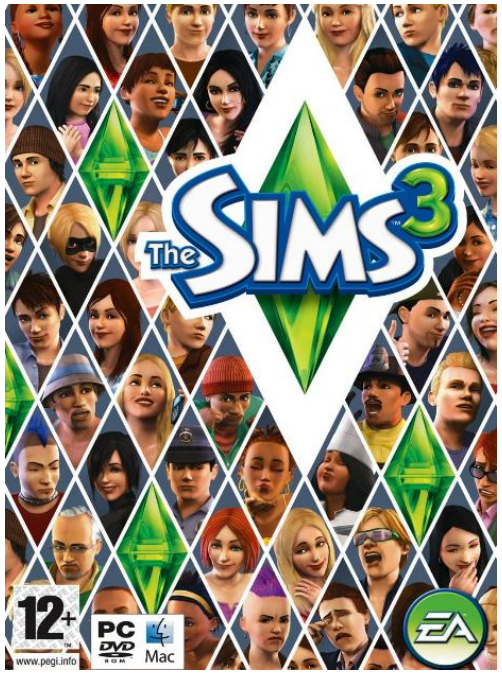
- Based on our definition of Simulation:
  - Agent-Based Simulation (ABS) is the process of designing an ABM of an (existing or fictive) real system and **conducting experiments** with this model for the purpose of **understanding the behaviour** of the system and/or **evaluating various strategies** to influence the behaviour of entities within the system [adapted from Shannon, 1975]
  - In ABMs a complex system is represented by a collection of agents that are programmed to follow some (often very simple) behaviour rules

Agent-Based Simulation

- A word of caution:
  - Many different developments have been going on under the slogan of Agent Based Simulation in very different disciplines, e.g. Robotics, Artificial Intelligence, Complexity Science, Economics, Social Science
  - Each discipline has its own understanding of what constitutes an agent and a multi agent system
- Two main paradigms:
  - Multi-agent decision systems
    - Usually embedded agents or a simulation of embedded agents
    - Focus is on decision making
  - Multi-agent simulation systems
    - The multi-agent system is used as a model to simulate some real-world domain and recreate some real world phenomena

Agent-Based Simulation

- The Sims: Interactive Organisational Agent-Based Simulation



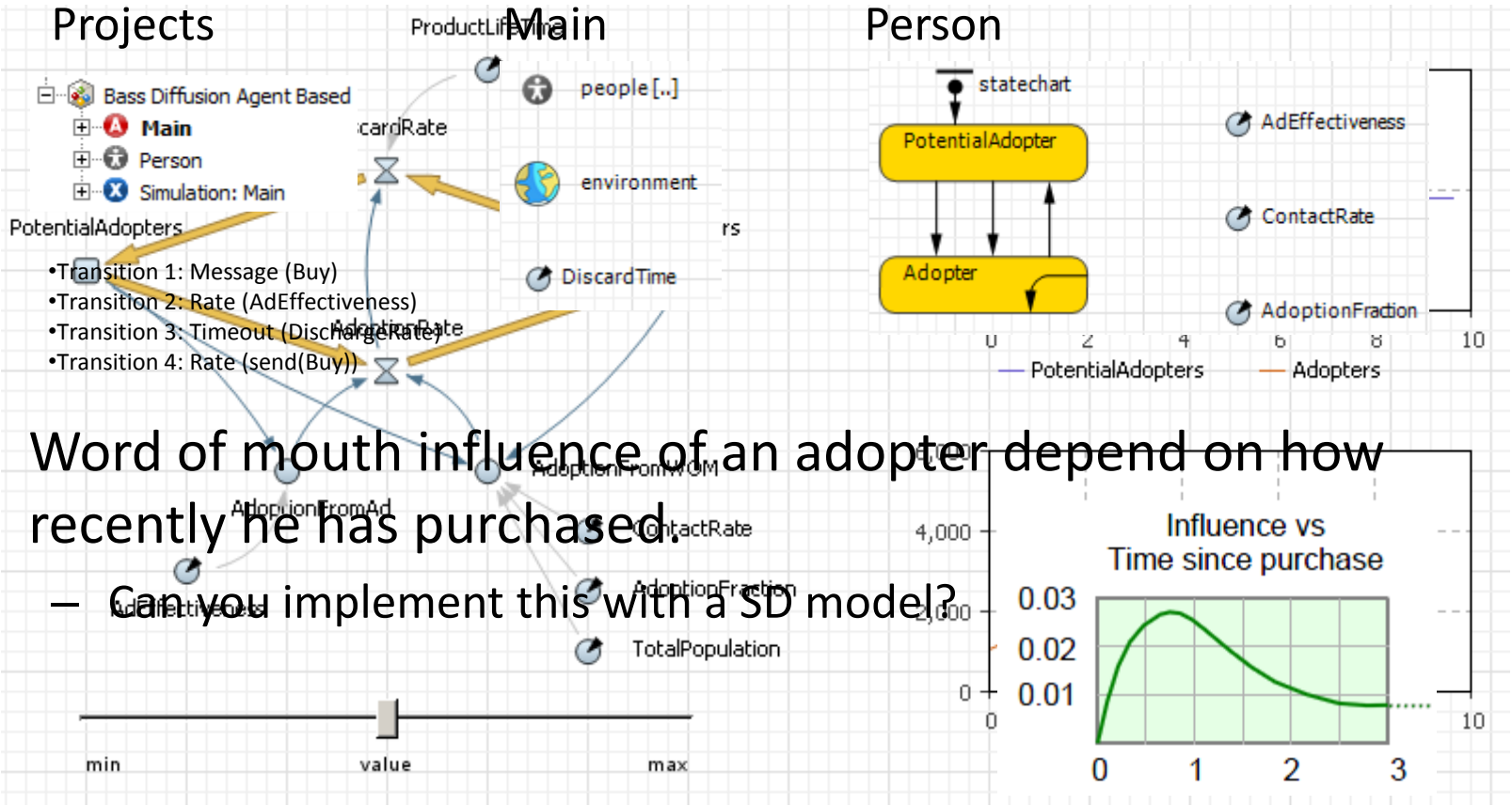
Agent-Based Simulation

- Some more examples:

Field	Application Examples
Social Science	Insect societies, group dynamics in fights, growth and decline of ancient societies, group learning, spread of epidemics, civil disobedience
Economics	Stock market, self organising markets, trade networks, consumer behaviour, deregulated electric power markets
Ecology	Population dynamics of salmon and trout, land use dynamics, flocking behaviour in fish and birds, rain forest growth
Political Sciences	Water rights in developing countries, party competition, origins and patterns of political violence, power sharing in multicultural states

Agent-Based Simulation

- ABM version of the Bass Diffusion + Discard model



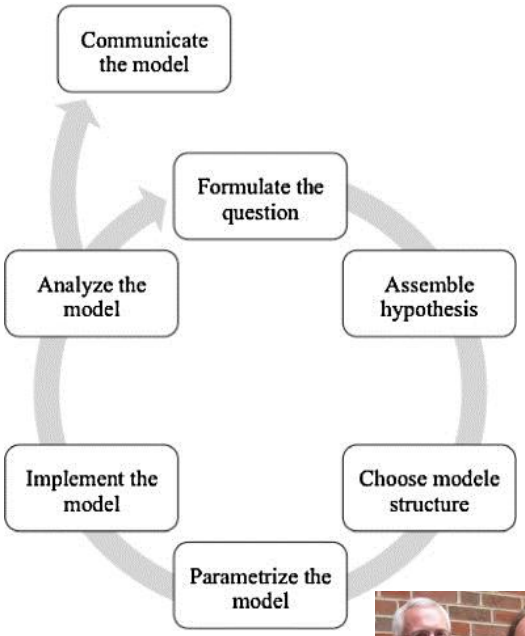
- Word of mouth influence of an adopter depend on how recently he has purchased.
  - Can you implement this with a SD model?

Agent-Based Simulation

- Building an ABS model (OR/MS)
  - Identify active entities (agents)
  - Define their states and behaviour
  - Put them in an environment
  - Establish connections
  - Test the model

- Validating an ABS model
  - System behaviour is an emergent property
  - Validation on a micro level
  - In mixed DES/ABS it is also possible to validate on macro level

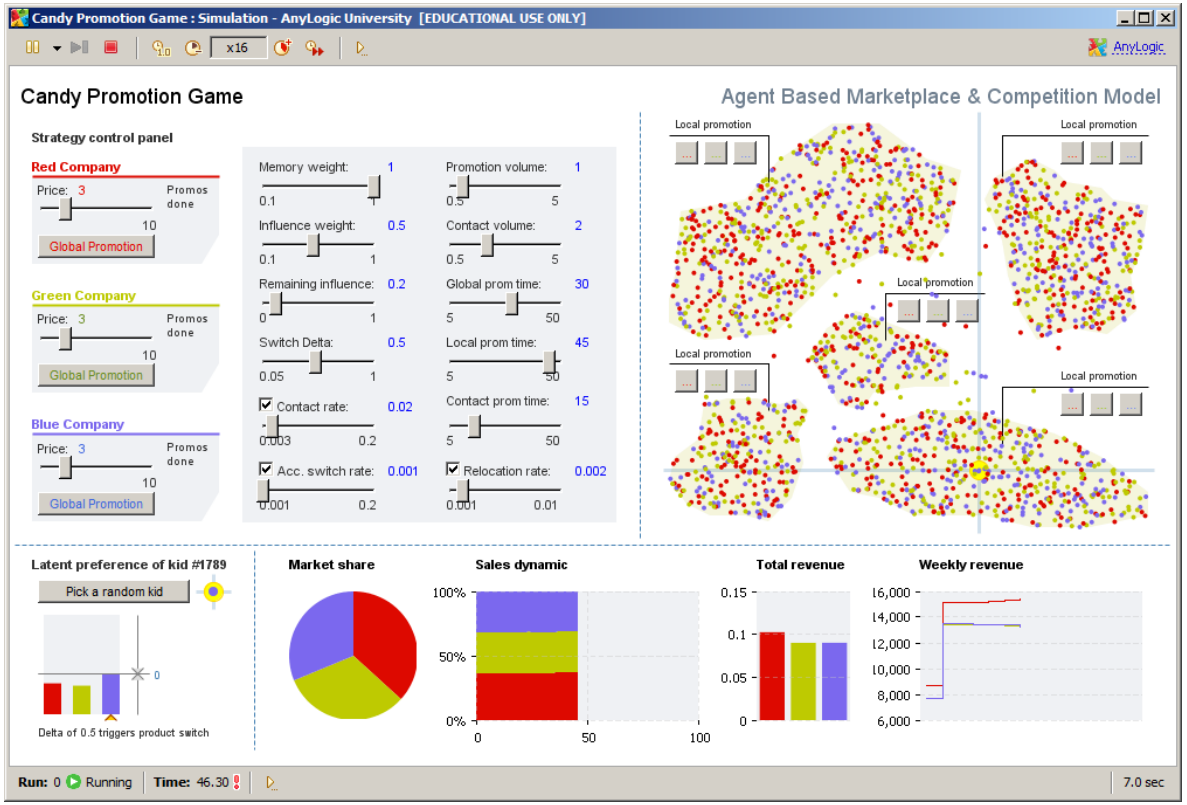
- Alternative (e.g. Ecology)



Grimm and Railsback (2005)

Agent-Based Simulation

- ABMs do not necessarily have to use state charts



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Agent-Based Simulation

- How does an agent based simulator work? [Macal 2013]
  - The **time-stepped simulation approach**: We have a time loop in which all the agents executed their behaviours at each integer time tick.
  - Each time an agent's behaviour is executed, it updates its own agent state, which possibly leads to updating the states of other agents and the environment (**synchronisation**).
  - An **event** in an ABS is the "time" at which an agent executes its behaviour and interacts with other agents and the environment. This may or may not correspond to time in the real world, only an ordered sequence of events is required to make the ABS work.
  - This is just one example algorithm: There are **many other ways** to advance time ...

Agent-Based Simulation

- How does an agent based simulator work? [Macal 2013]
  - Loop over time horizon
    - Loop over randomised list of agents. For each agent a in list:
      - Execute agent a behaviour
      - Update state of agent a (based on a's state, the states of agents that interact with a, and the state of the environment).
      - Update other agents states and the environment (if appropriate)
    - End loop over randomized list of agents
  - Increment t in time loop and repeat until end of simulation time horizon

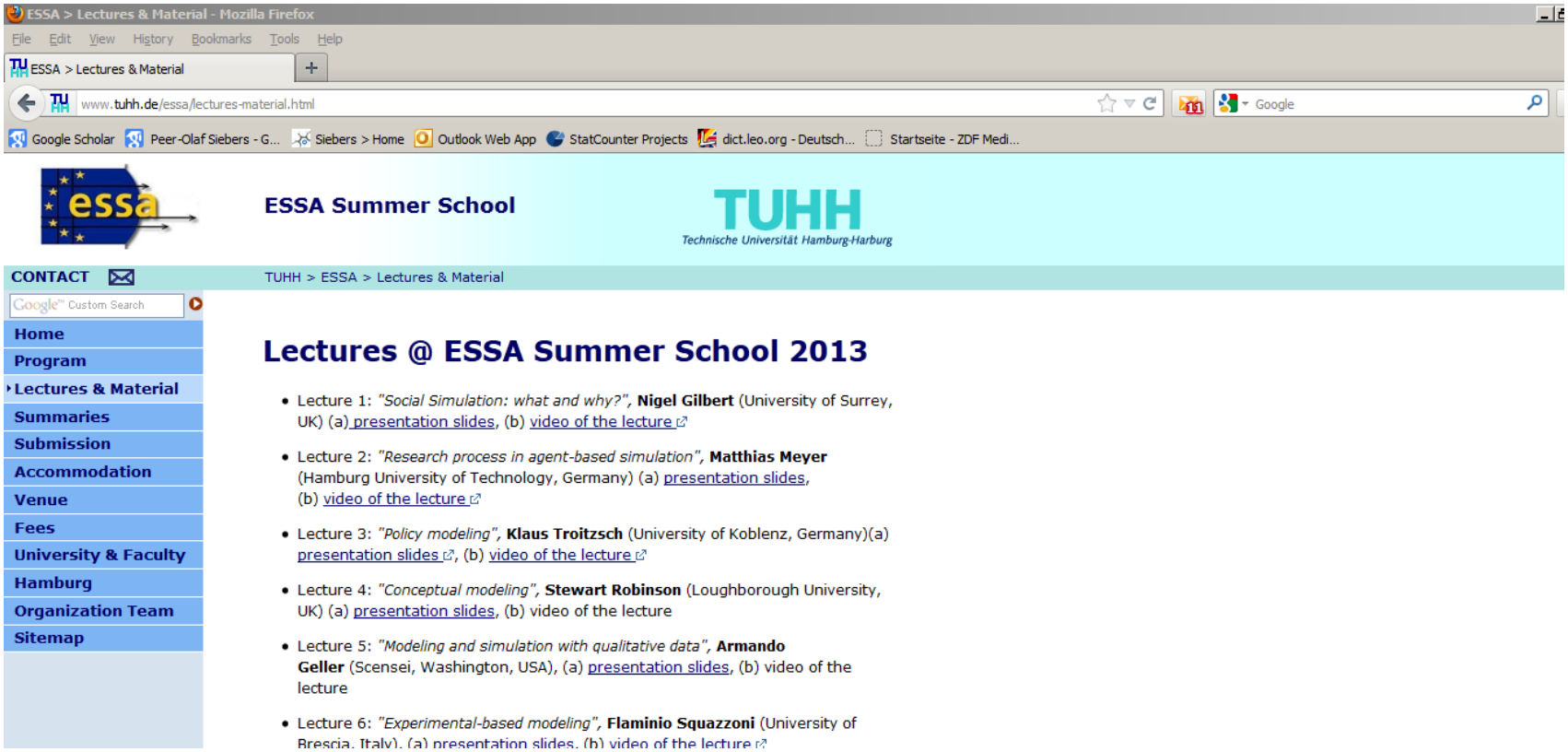
Agent-Based Simulation

- Software
  - Free:
    - Swarm, NetLogo, Repast, SeSAm, Mason, ...
  - Commercial
    - AgentSheets, AnyLogic, ...
- For a comprehensive list see
  - http://www.swarm.org/wiki/Tools_for_Agent-Based_Modelling

Agent-Based Simulation

DES models	ABS models
Process oriented; focus is on modelling the system in detail, not the entities	Individual based; focus is on modelling the entities and interactions between them
Top down modelling approach	Bottom up modelling approach
One thread of control (centralised)	Each agent has its own thread of control (decentralised)
Passive entities, i.e. something is done to the entities while they move trough the system; intelligence (e.g. decision making) is modelled as part in the system	Active entities, i.e. the entities themselves can take on the initiative to do something; intelligence is represented within each individual entity
Queues are a key element	No concept of queues
Flow of entities through a system; macro behaviour is modelled	No concept of flows; macro behaviour is not modelled, it emerges from the micro decisions of the individual agents
Input distributions are often based on collect/measured (objective) data	Input distributions are often based on theories or subjective data

More information about (Social) ABM/S



- ESSA Summer School: http://www.tuhh.de/essa/lectures-material.html

Summary

- What did you learn?

Questions / Comments