

ABM for Management Decision Support [Spring 2013]

Lecture 1

Principles of Agent-Based Modelling and Simulation

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Content

- Part 1: Introduction to modelling and simulation
 - Modelling and Simulation
 - Simulation Paradigms
- Part 2: Agent-based modelling and simulation
 - Agent-Based Modelling
 - Agent-Based Simulation
 - Agent-Based Simulation in OR/MS

Part 1

Introduction to Modelling and Simulation



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Modelling and Simulation

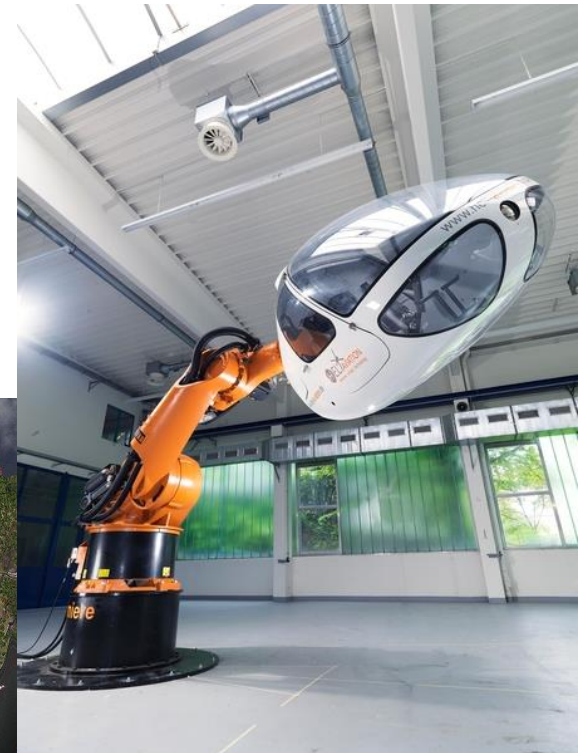
- Simulation examples

▼ London, Greater London PRINT

5 DAY FORECAST NEXT 24 HOURS

Day	Weather	Max. Day (°C)	Min. Night (°C)	Wind (mph)	Humidity Pressure Visibility
Thu	Heavy Rain	20	14	5	80% 1007mb Poor
Fri	Heavy Rain Shower	15	8	16	84% 1005mb Poor
Sat	Light Rain Shower	16	9	14	59% 1012mb Very good
Sun	Light Rain Shower	17	9	10	94% 1012mb Good
Mon	Light Rain Shower	17	11	10	93% 1014mb Good

Last updated at 09:30, Thursday 23 September EMBED



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Modelling and Simulation



- Model:
 - Some form of abstract representation of a real system intended to promote understanding of the system it represents.
 - A model is a static representation of the system
 - Models can have many forms (e.g. mathematical equations, diagrams, physical mock-ups)
- Why model?
 - Models give us a comprehensible representations of a systems
 - Something to think about
 - Something to communicate about

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Modelling and Simulation



- Simulation:
 - The process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behaviour of the system and /or evaluating various strategies for the operation of the system [Shannon 1975]
 - Uses a model to emulate the dynamic characteristics of a system
- Why simulate?
 - Predict the performance of a system under a specific set of inputs
 - Experimental approach to modelling (what-if analysis tool)

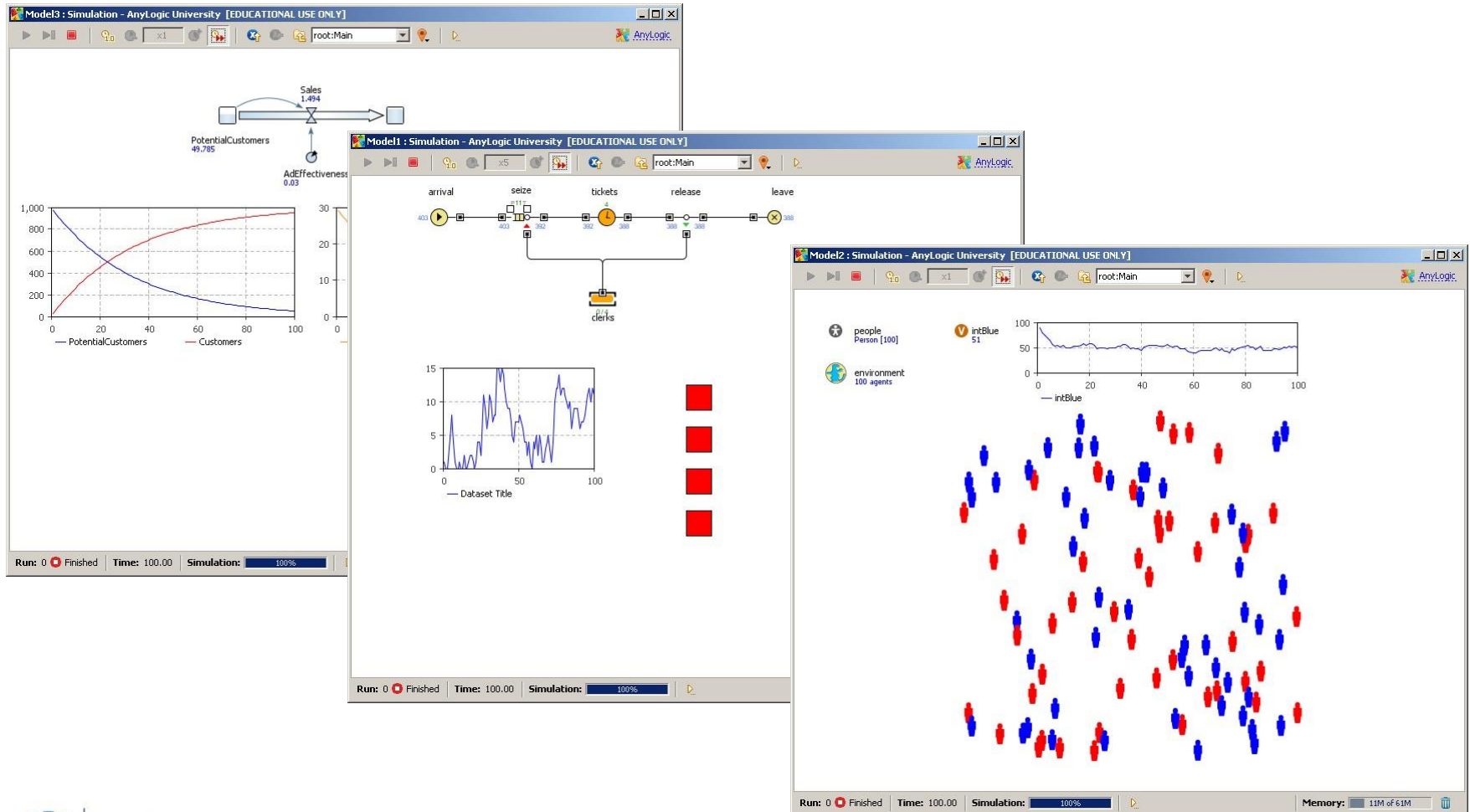
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Simulation Paradigms

- System Dynamics (continuous, deterministic)
 - **Aggregate view**; differential equations
 - Modelling methods: Causal loop diagrams; stock and flow diagrams
- Discrete Event (discrete, stochastic)
 - **Process oriented** (top down); one thread of control; passive objects
 - Modelling methods: Process flow diagrams; activity cycle diagrams
- Agent Based (discrete, stochastic)
 - **Individual centric** (bottom up); each agent has its own thread of control; active objects
 - Modelling methods: UML (class diagrams + state chart diagrams) + Equations
- Multi-Method (linked or integrated)

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Simulation Paradigms (Demos)



Part 2

Agent-Based Modelling and Simulation

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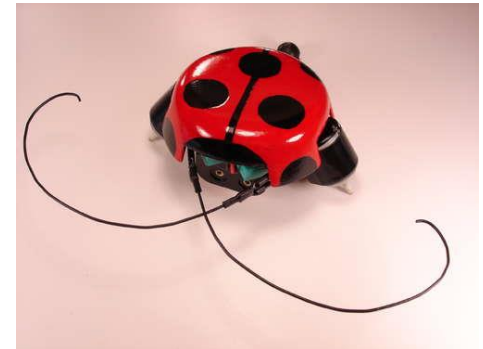
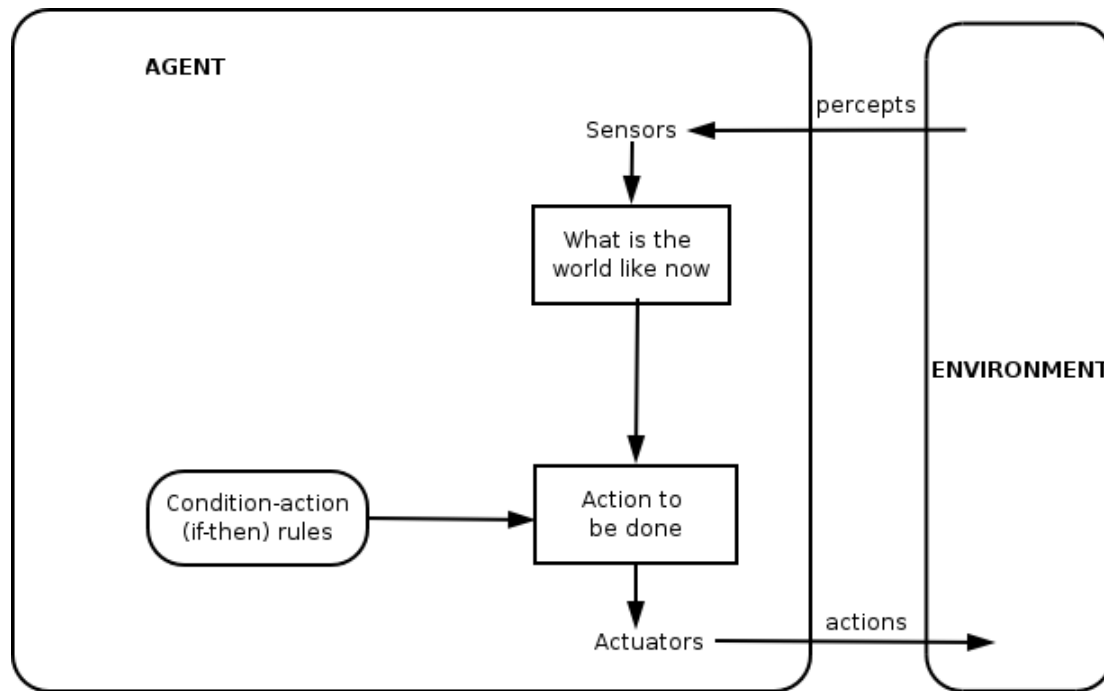
Agent-Based Modelling

- 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**.

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Agent-Based Modelling

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

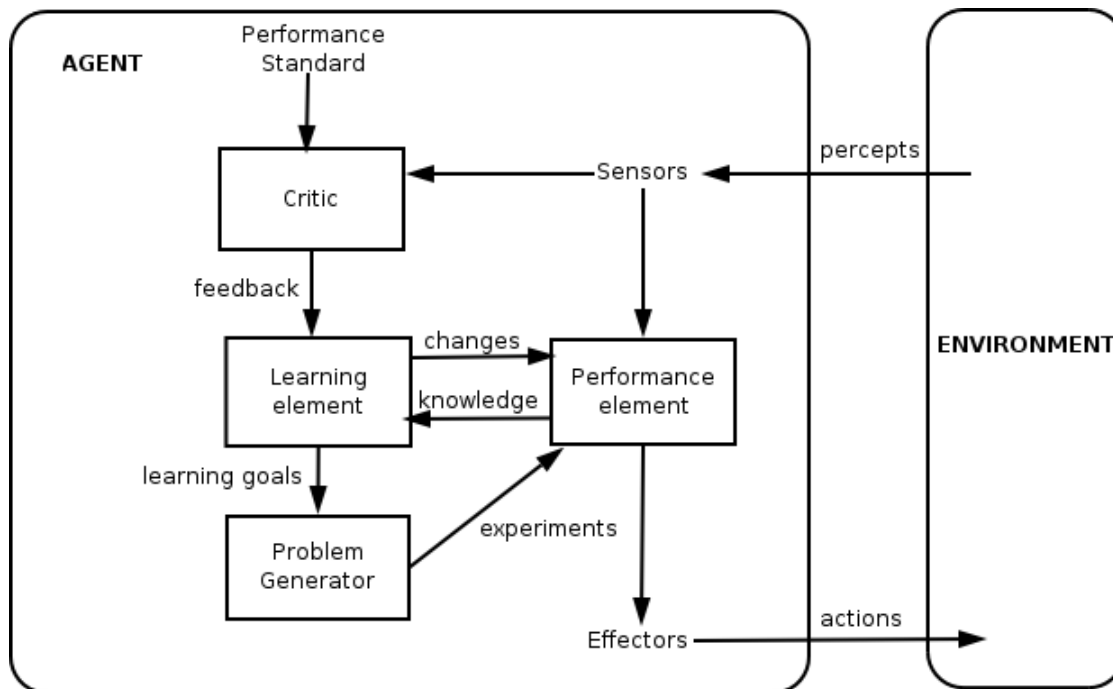


Russell and Norvig (2003)

4

Agent-Based Modelling

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



Russell and Norvig (2003)

4

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



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Agent-Based Modelling

- Agents can be ...
 - Individuals, households, organisations, companies, nations, ...
- Decentralisation
 - There is **no place where the global system behaviour is defined**
 - Individual agents interact with each other and their environment to produce complex collective behaviour patterns.
- 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
 - Example: Traffic Jam



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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
 - ...

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Agent-Based Simulation

- Based on our previous 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

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Agent-Based Simulation

- A word of caution:
 - 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

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Agent-Based Simulation

- The Sims: Interactive Organisational Agent-Based Simulation



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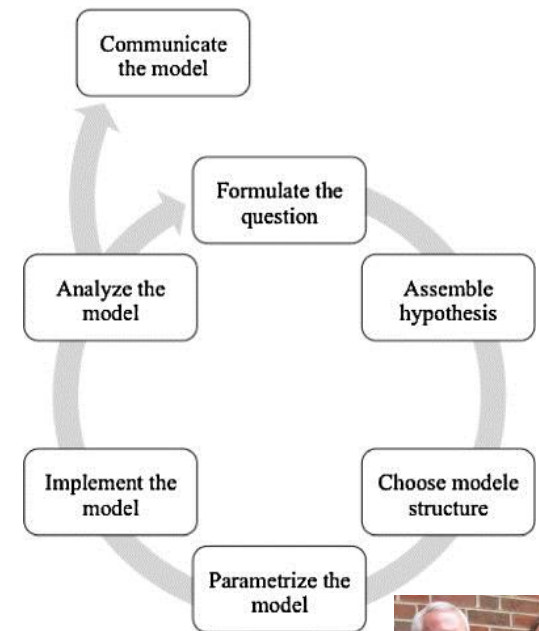
Agent-Based Simulation

- Some 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

- 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
- Alternative (e.g. Ecology)
- 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



Grimm and Railsback (2005)

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Agent-Based Simulation in OR/MS

- Operational Research / Management Science (OR/MS)
 - Combined DES/ABS models
 - Represent the process flow as a DES model
 - Add some active entities (ABS)



ABM-MDS Short Course

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Communication
layer



Let entities interact + communicate

Direct interactions
Network activities

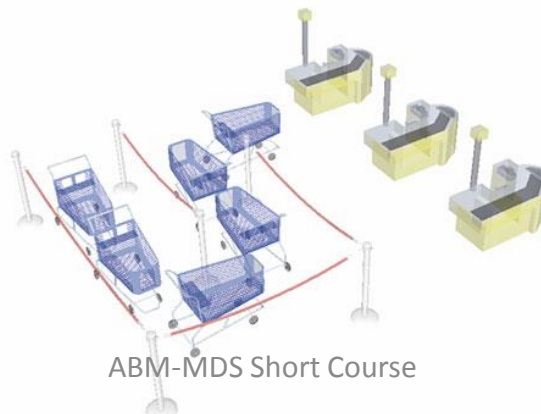
Agent layer



Active entities
Behavioural state
charts

Replace passive entities by active ones

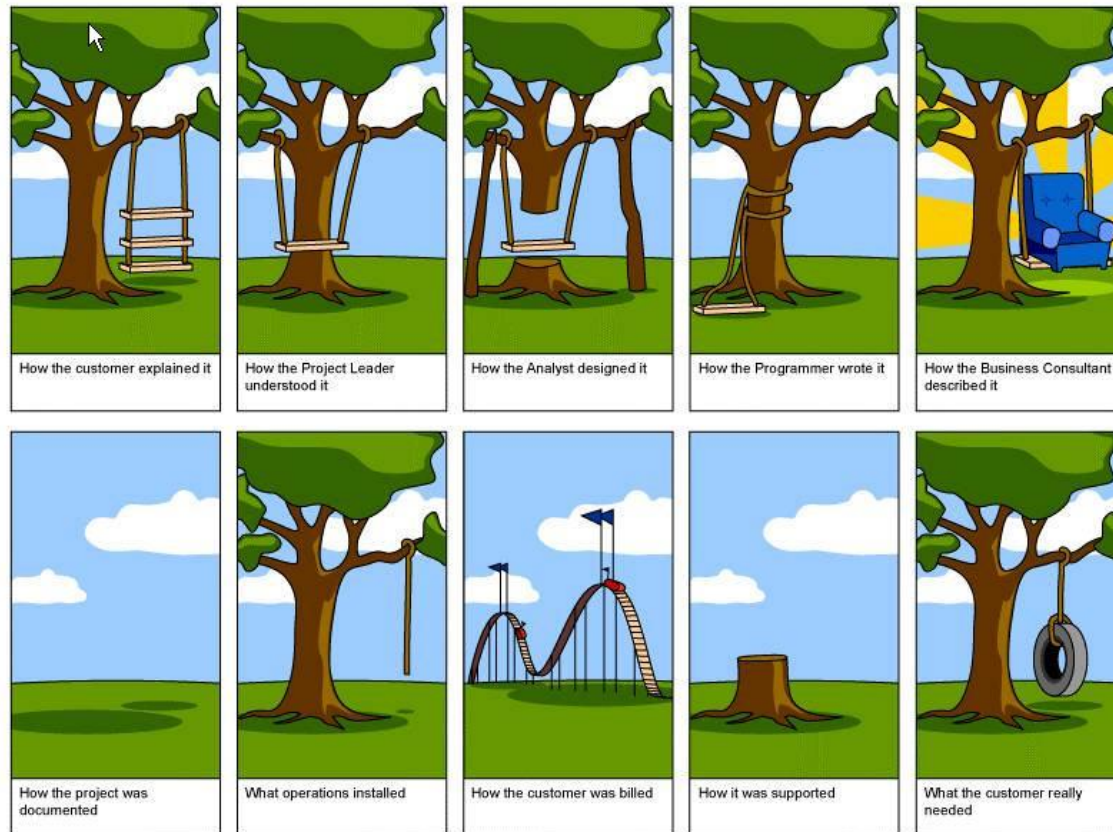
DES layer



Passive entities
Queues
Processes
Resources

Questions / Comments

- See you next week ...



Further Reading

- Siebers and Aickelin (2008)
- Macal and North (2007)
- Bonabeau (2002)

References

- Bonabeau (2002). Agent-based modeling: Methods and techniques for simulating human systems. In: Proceedings of the National Academy of Science of the USA. 99:7280-7287.
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