Aachen Summer Simulation Seminar 2014

Lecture 01

Introduction to Modelling and Simulation

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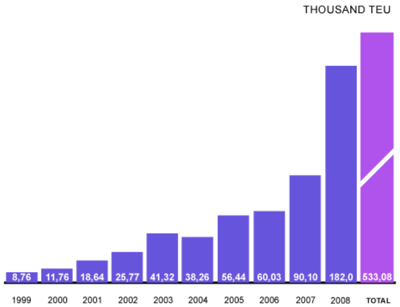


Personal Introduction

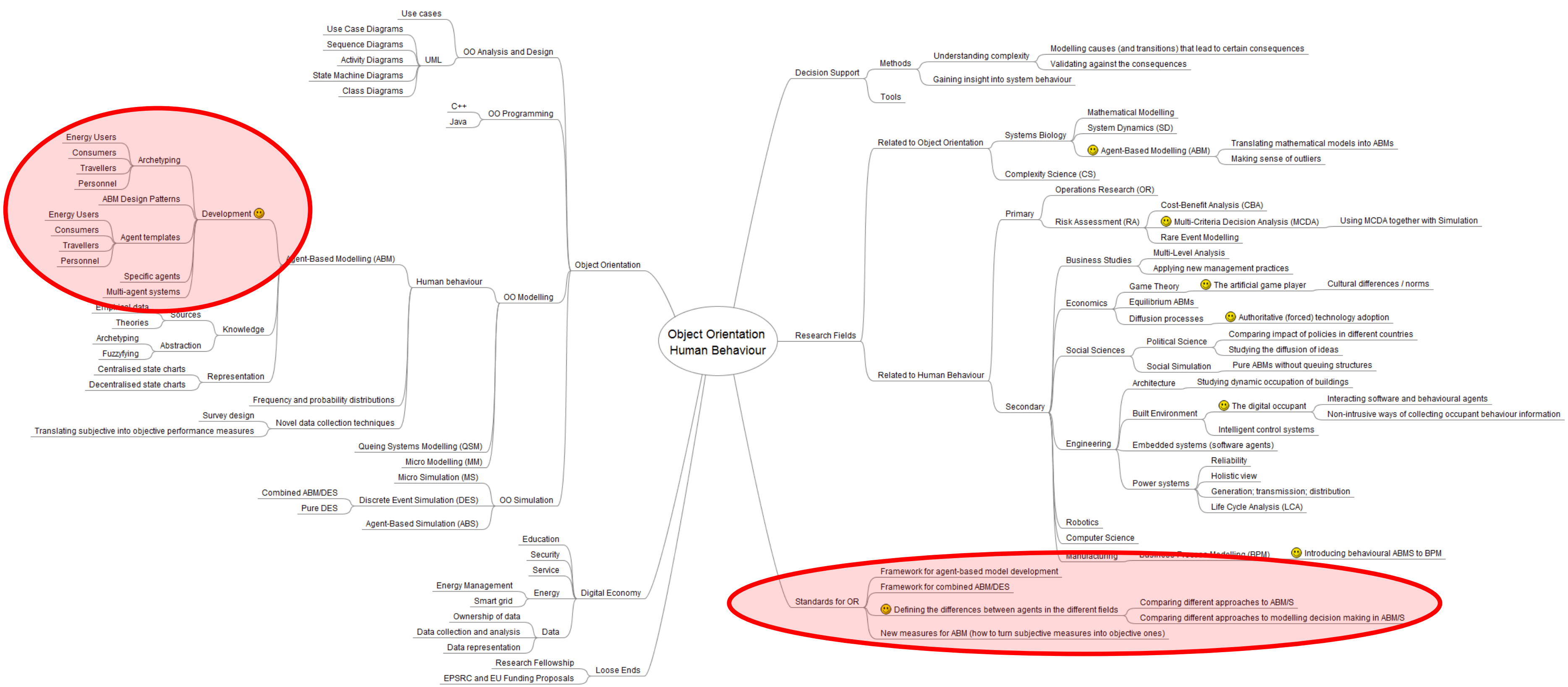
Personal Introduction

- Introduce yourself
  - The field you are working in
  - The specific topic you are interested in
  - The motivation for your participation
    - Why are you participating
    - What do you want to take away

Personal Introduction

- My research mission
  - Developing human behaviour models which can be used to better represent people and their behaviours in OR/MS models
  - Combining ideas from OR (DES) and Social Science (ABM/S)
    - More interested in developing frameworks and testing them
    - Less interested in solving/investigating specific cases
  - Using well established OOA/D principles and methods from Software Engineering for developing reusable components and the environment they live in.

Personal Introduction



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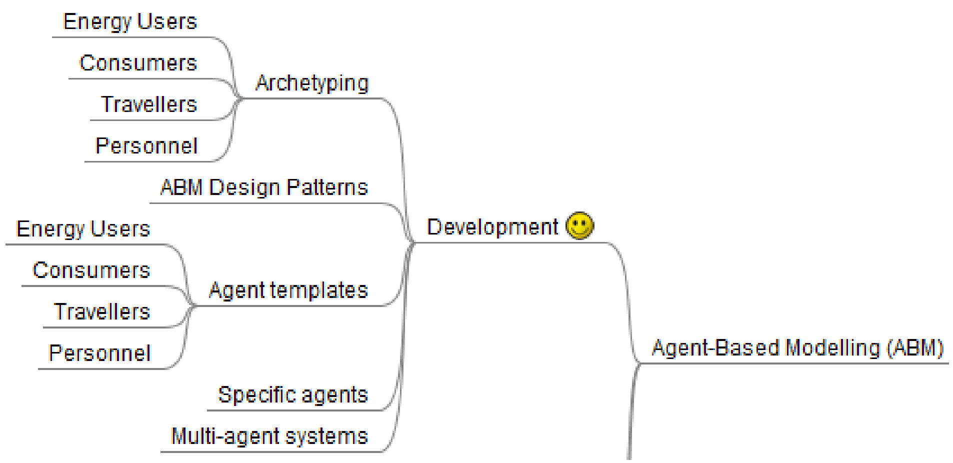
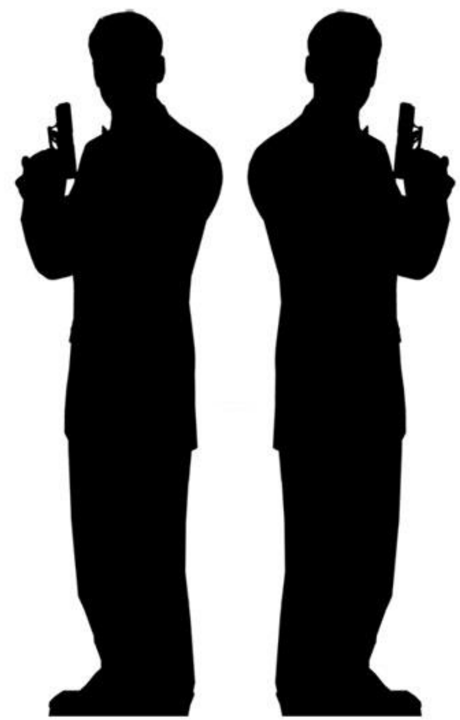
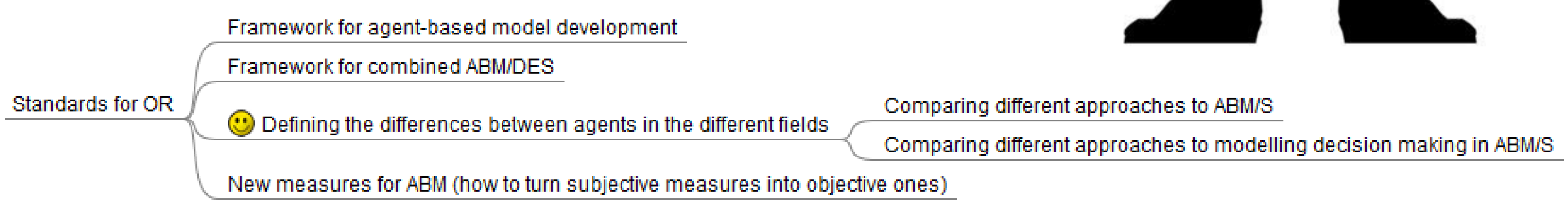
Personal Introduction

- Technical aspects







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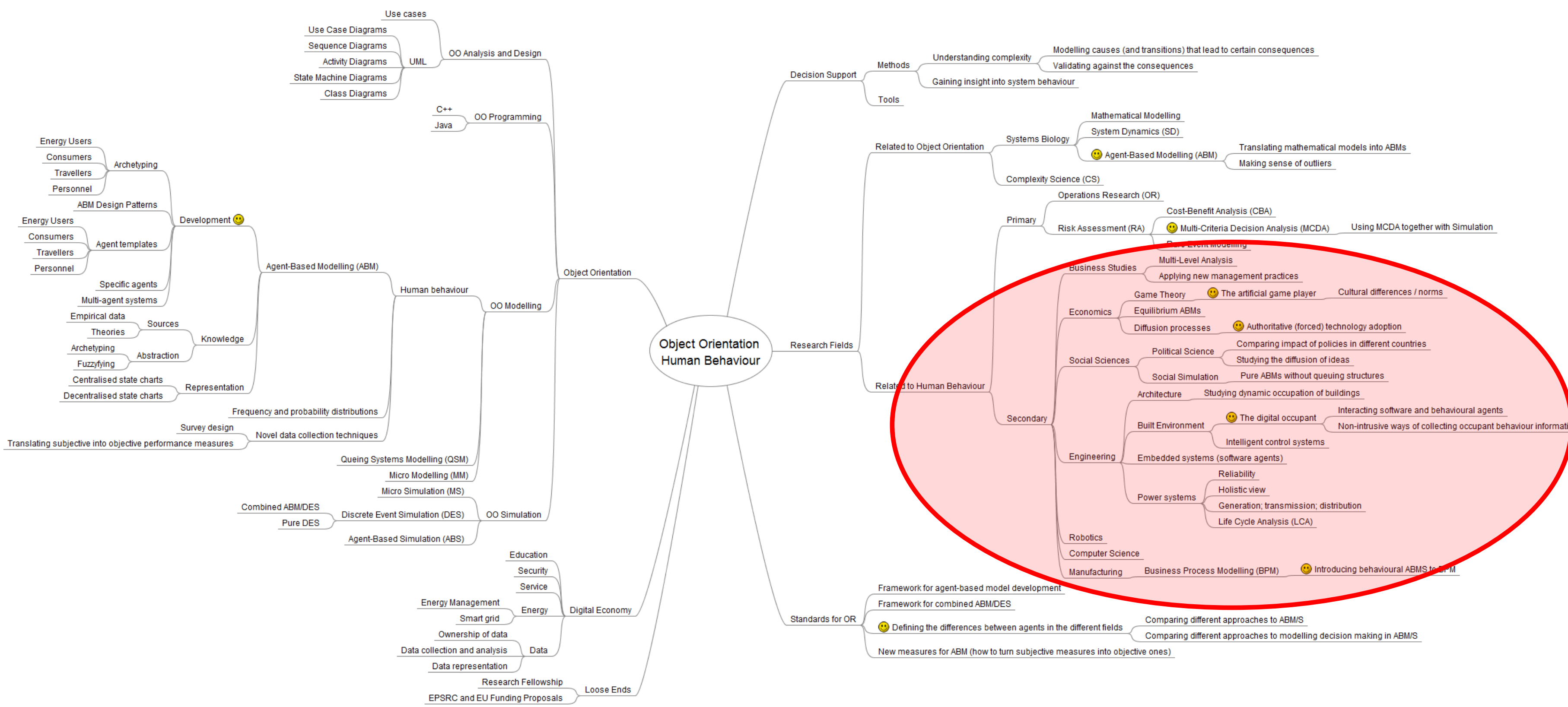
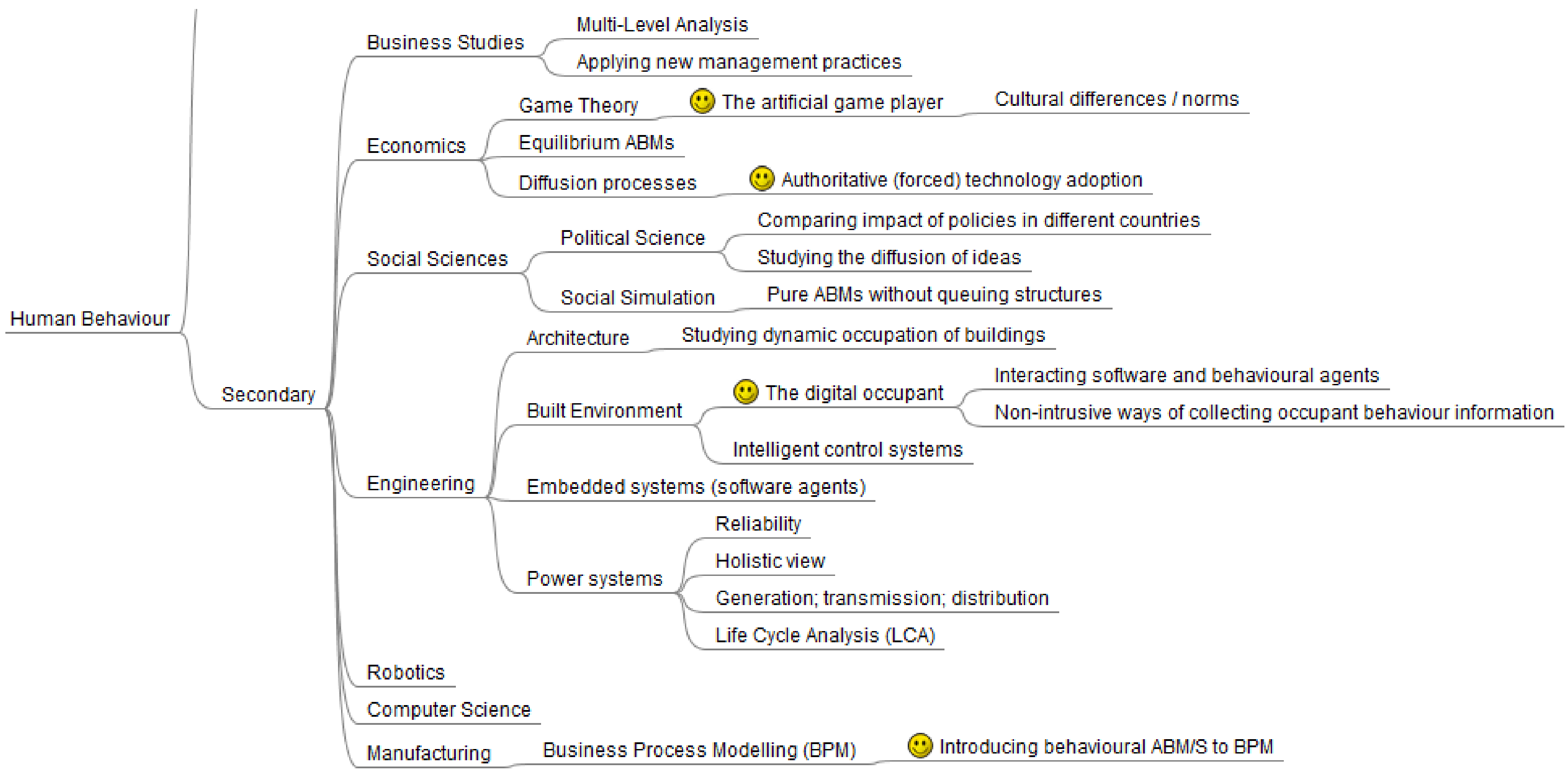


Personal Introduction

- Applications



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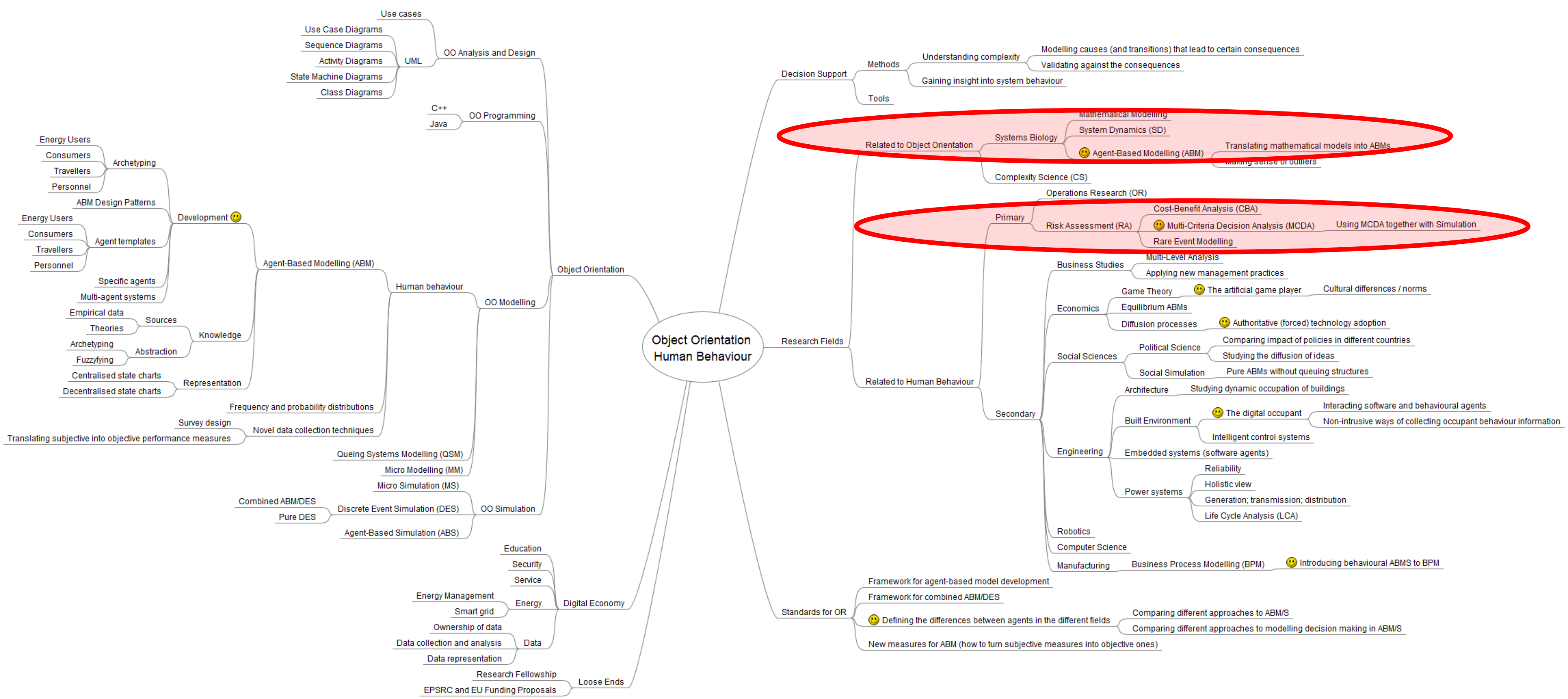

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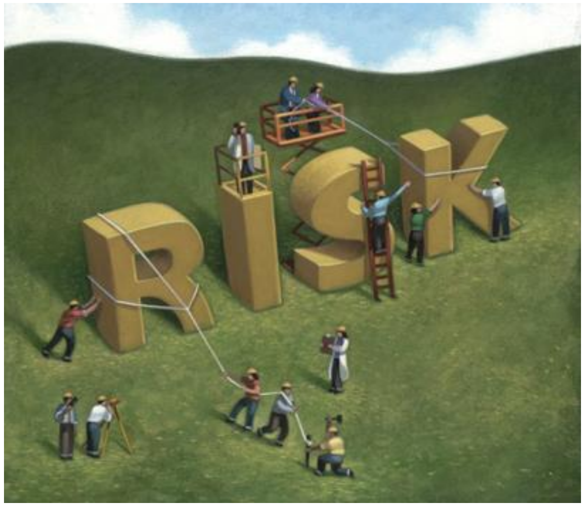
Personal Introduction

- Related topics

- Systems Biology
  - Mathematical Modelling
  - System Dynamics (SD)
  - 🙂 Agent-Based Modelling (ABM)
    - Translating mathematical models into ABMs
    - Making sense of outliers



- Risk Assessment (RA)
  - Cost-Benefit Analysis (CBA)
  - 🙂 Multi-Criteria Decision Analysis (MCDA)
    - Using MCDA together with Simulation
  - Rare Event Modelling

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Seminar Organisation

Seminar Mission Statement

- YOU will understand the main systems simulation methods relevant for decision support in Controlling so that you will be competent in choosing and implementing the right method for your particular problem.

- YOU will learn the general principles and techniques used in modelling and simulation and will gain some practical experience of how to develop and implement their own simulation models.

Seminar Organisation

- Day 1: Introduction to Modelling and Simulation
  1. Lec01: Introduction to Modelling an Simulation
  2. Lec02: Foundations of Simulation Modelling
  3. Lec03: Conceptual Modelling
  4. Practice01: AnyLogic Introduction (in pairs)
- Day 2: Application of Modelling and Simulation Methods
  5. Practice02: Java Basics + First Model (in pairs)
  6. Lec04: SDS Modelling
  7. GroupActivity01: Conceptual Modelling (in small groups)
  8. Lec05: DES Modelling
  9. Practice03: SDS or DES Tutorials (in pairs)

Seminar Organisation

- Day 3: Application of Modelling and Simulation Methods
  10. GroupActivity02: Focus Group (in small groups)
  11. Lec06: ABS Modelling + Hybrids
  12. Practice04: ABS Tutorial 1: Wind Turbine Maintenance (in pairs)
  13. Practice05: Exploring the AnyLogic Model Library (optional)
- Day 4: Knowledge Gathering
  14. Practice06: ABS Tutorial 2: Blob World (in pairs)
  15. Lec07: Input Modelling / Experimentation / Output Analysis
  16. GroupActivity03: Discussion of your own project ideas (whole group)
  17. Lec08: Model Verification and Validation

  Feedback

Seminar Organisation

- Recommended reading:
  - There is no course book that covers all topics!
    - Borshchev (2013) The Big Book of Simulation Modeling
    - Robinson (2004) Simulation: The Practice of Model Development and Use
    - WSC Proceedings: Introductory Tutorials (http://www.informs-sim.org/)

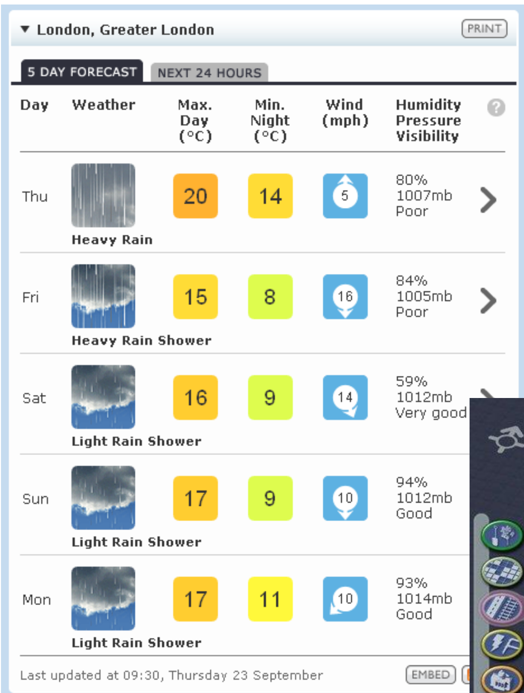
- Software and resources
  - Simulation IDE: AnyLogic (url)
  - Java programming:
    - Sierra and Bates (2009) Head First Java - 2e
    - The New Boston: Java for Beginners (url)

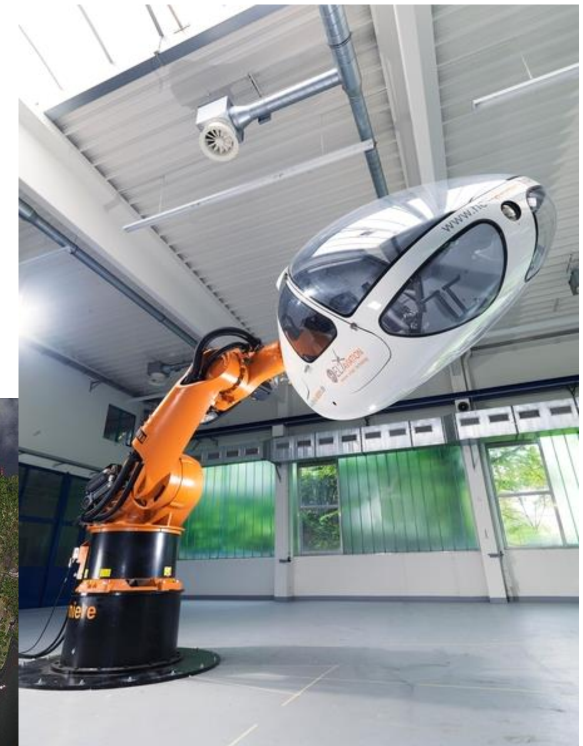
Introduction to Modelling and Simulation

Motivation

- Introduce the idea of "Would Be Worlds" [Casti 1998]
- Introduce terminology used throughout the seminar
- Introduce the different simulation modelling paradigms

Simulation Examples





Simulation Examples

- My Simulation Projects
  - Simulating Retail Management Practices
    - Investigating the impact of human resource management practices on customer satisfaction
  - Modelling and Analysing Cargo Screening Processes
    - Optimising the process flow of the cargo screening process
    - Using simulation for cost-benefit analysis (risk assessment)
  - Future Energy Decision Making for Cities
    - Modelling Energy Consumption Patterns
    - Testing governmental intervention strategies

Simulation Examples

- My Simulation Projects
  - Sustaining Urban Habitats: An Interdisciplinary Approach
    - Explore ways of combining environmental and economic modelling with social and cultural ethnographic work to simulate urban sustainability
    - Studying two transition cities in Europe and two growth cities in China
  - Agent Based Modelling for Simulating Peacebuilding
    - Create an innovative framework that supports the development of object oriented agent based simulation models of peacebuilding activities
    - Test the validity of the framework through the case of peacebuilding efforts made by China

Systems

- System:
  - Collection of parts organised for some purpose (weather system: parts: sun, water, land, etc.; purpose: maintaining life)
  - Defining a system requires setting boundaries

- Different categories of systems:
  - Natural systems (weather system, galactic system)
  - Designed physical systems (house, car, production system)
  - Designed abstract systems (mathematics, literature)
  - Human activity systems (family, city, political system)

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Systems

- Operations systems:
  - Configuration of resources combined for the provision of goods and services (functions: manufacture, transport, supply, service).
- Social systems:
  - Entities or groups in definite relation to each other which create enduring patterns of behavior and relationship within social systems.
- Economic system:
  - Particular set of social institutions which deals with the production, distribution, and consumption of goods and services.

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Models

- 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
    - 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

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)

Nature of Operations Systems

- Operations systems are subject to variability
  - Predictable variability
    - E.g. staff rota, planned maintenance of machines
  - Unpredictable variability
    - E.g. customer arrivals, machine breakdowns

- Operations systems are interconnected
  - Components of a system affect one another
    - E.g. customers in a three stage service process

[Robinson 2004]

Nature of Operations Systems

- Operations systems are complex
  - Combinatorial complexity
    - Number of components and number of combinations of components
  - Dynamic complexity
    - Mainly systems that are highly interconnected; feedback systems; action has different effect in short/long run; action has different consequences in one part of the system compared to another; action has non-obvious consequences

- In simulation studies we are able to explicitly represent the variability, interconnectedness, and complexity of operations systems

[Robinson 2004]

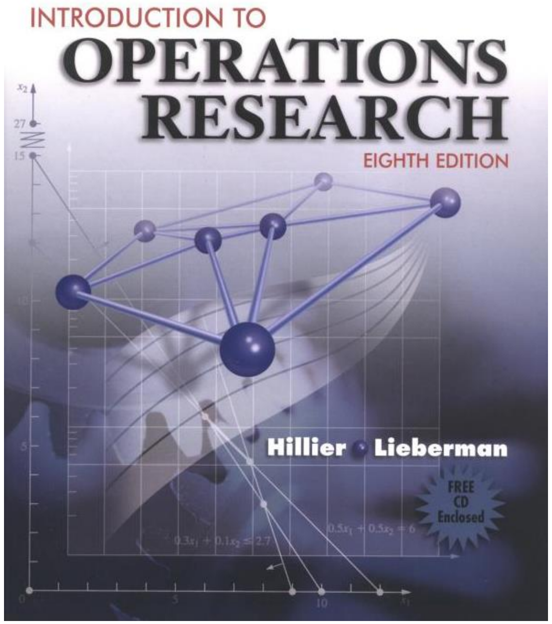
Why Simulate?

- It is possible with a simulation:
  - to predict system performance
  - to compare alternative system designs
  - to determine the effects of alternative policies on system performance

- Advantages: Simulation vs. Experimentation
  - Cost
  - Time (real time vs. virtual time)
  - Control of experimental conditions
  - If real system does not exist

Why Simulate?

- Advantages: Simulation vs. other modelling approaches
  - Analytical methods used in Operations Research (examples)
    - Linear Programming
    - Network Analysis
    - Dynamic Programming
    - Meta Heuristics
    - Game Theory
    - Markov Chains
    - Queuing Theory
    - Simulation



Why Simulate?

- Advantages: Simulation vs. other modelling approaches
  - Modelling variability: Some other approaches could be adapted to account for variability but it often increases their complexity
  - Restrictive assumptions: Most of the other approaches require assumptions, e.g. queuing theory assumes particular distributions for arrival and service times, for many processes these distributions are not appropriate
  - Transparency: More intuitive than a set of equations, an animated display of the system can be created, giving a non-expert grater understanding of, and confidence in, the model
  - Creating knowledge and understanding: Sometimes just building the model is enough
  - Visualisation, communication, interaction

Why Simulate?

- Disadvantages of simulation:
  - Expensive
  - Time consuming
  - Data hungry
  - Requires expertise: It is an art rather than a science
  - Overconfidence: When interpreting the results from a simulation, consideration must be given to the validity of the underlying model and the assumption and simplifications that have been made!

Classification of Simulation

- Static vs. Dynamic:
  - Static: No attempts to model a time sequence of changes.
  - Dynamic: Updating each entity at each occurring event.
- Deterministic vs. Stochastic:
  - Deterministic: Rule based.
  - Stochastic: Based on conditional probabilities.
- Discrete vs. Continuous:
  - Discrete: Changes in the state of the system occur instantaneously at random points in time as a result of the occurrence of discrete events.
  - Continuous: Changes of the state of the system occur continuously over time.

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Level of Abstraction

- Simulation can be applied at different stages:
  - Strategic
    - high abstraction, less detailed, macro level
  - Tactical
    - middle abstraction, medium details, meso level
  - Operational
    - low abstraction, more details, micro level

Level of Abstraction

Aggregate, global causal dependencies, feedback dynamics

Strategic

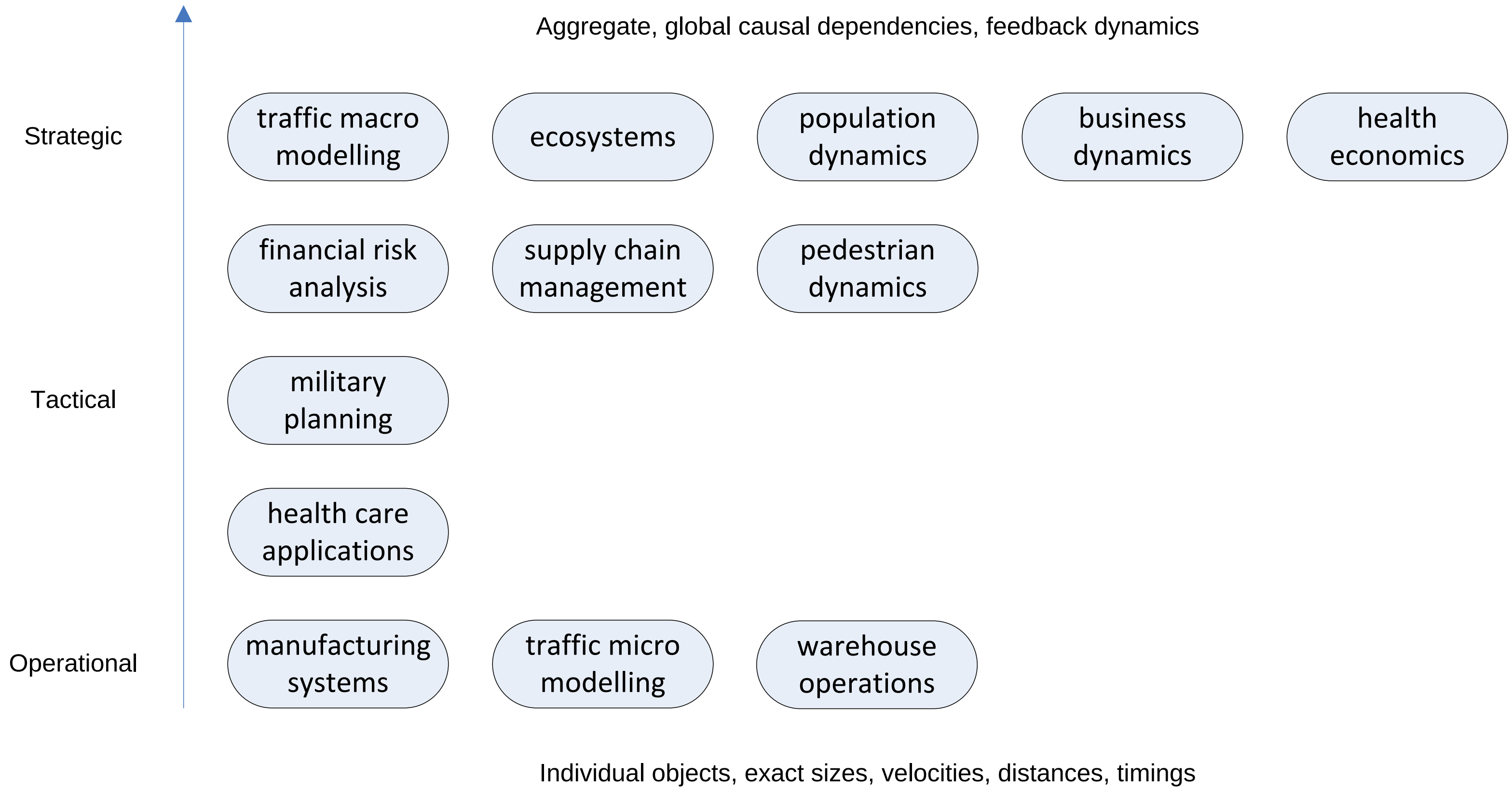
Tactical

Operational

traffic macro modelling, traffic micro modelling, supply chain management, population dynamics, financial risk analysis, manufacturing systems, ecosystems, pedestrian dynamics, health care applications, health economics, military planning, business dynamics, warehouse operations

Individual objects, exact sizes, velocities, distances, timings

Level of Abstraction



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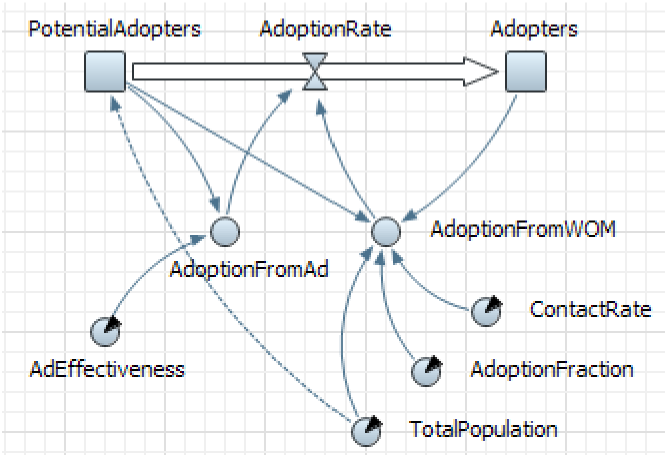
Paradigms

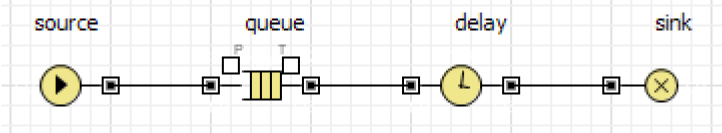
- System Dynamics Modelling (SDM) and Simulation (SDS)
  - Modelling: Stock and flow diagrams
  - Simulation: Deterministic continuous (differential equations)
- Discrete Event Modelling (DEM) and Simulation (DES)
  - Modelling: Flow charts
  - Simulation: Stochastic discrete (process oriented approach)
- Agent Based Modelling (ABM) and Simulation (ABS)
  - Modelling: Equations or state charts
  - Simulation: Stochastic discrete (object oriented approach)
- Mixed Method Modelling (MMM) and Simulation (MMS)

Paradigms

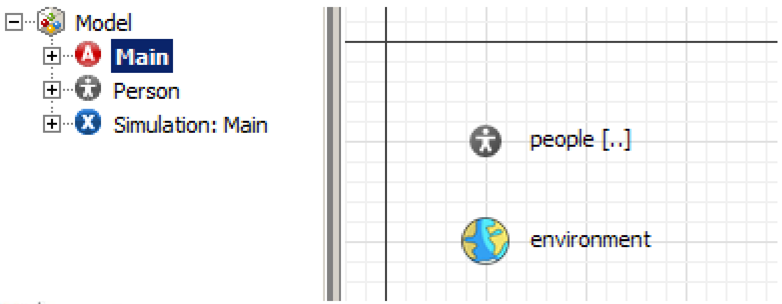
- SDM

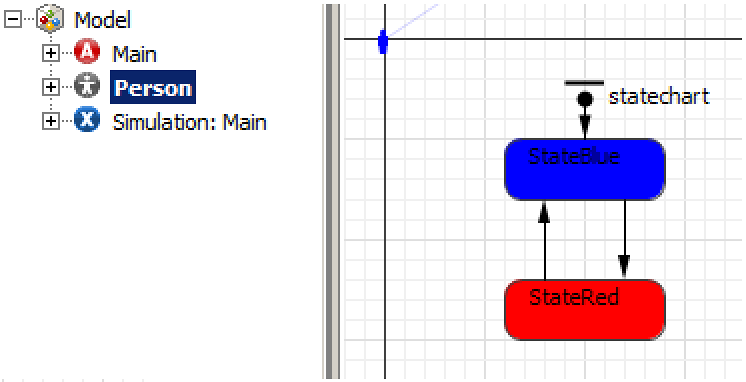


- DEM



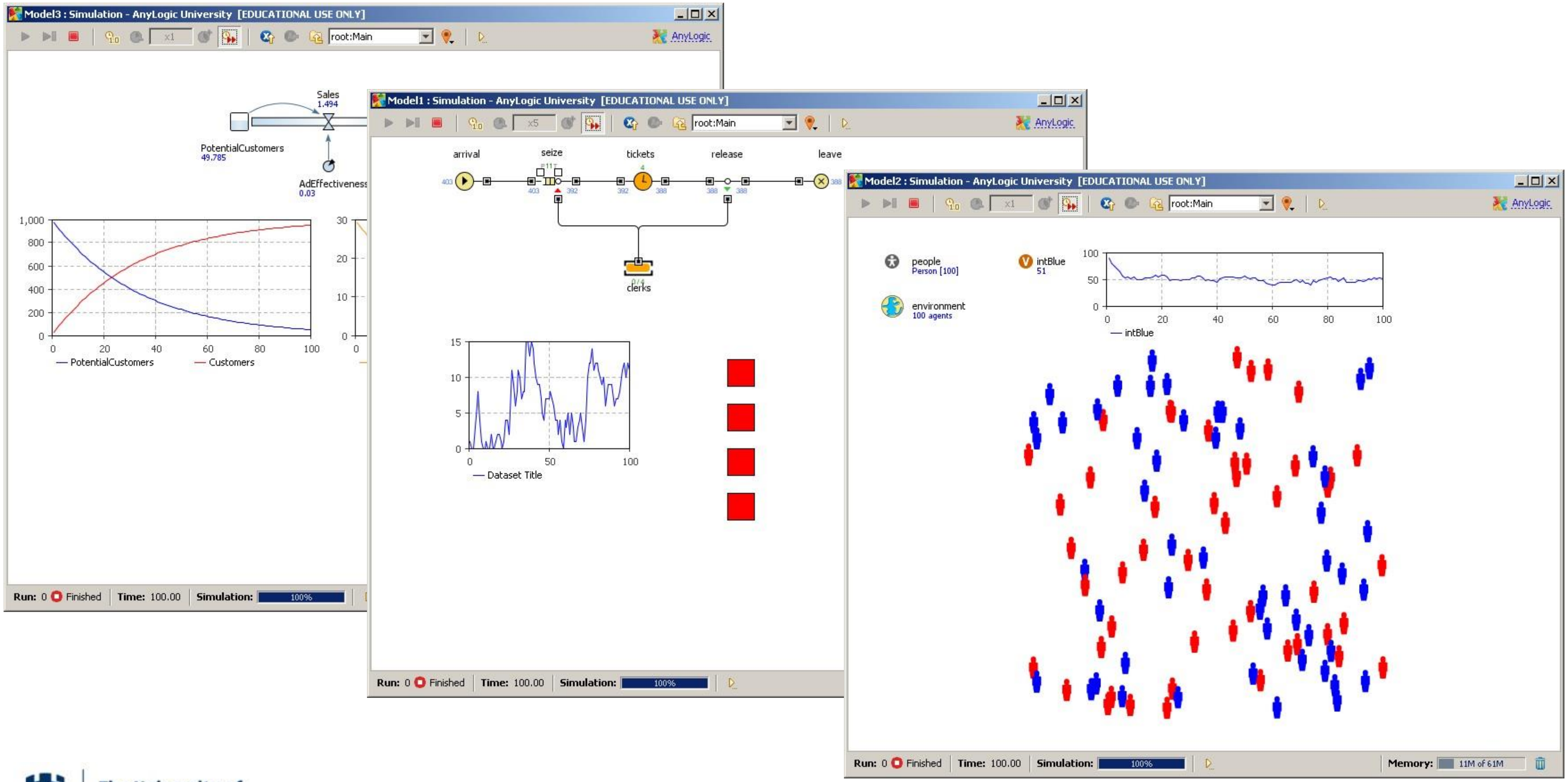
- ABM



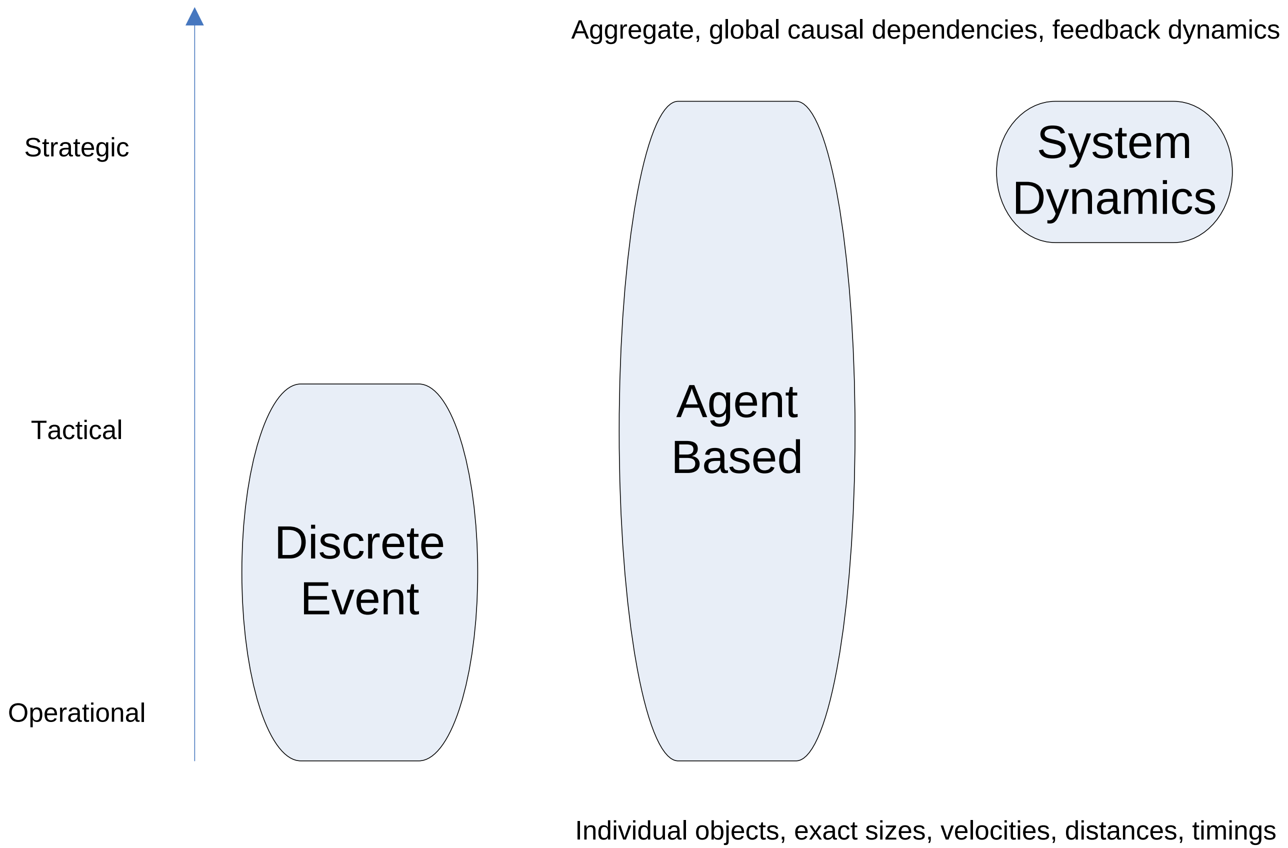


Paradigms

- Simple examples

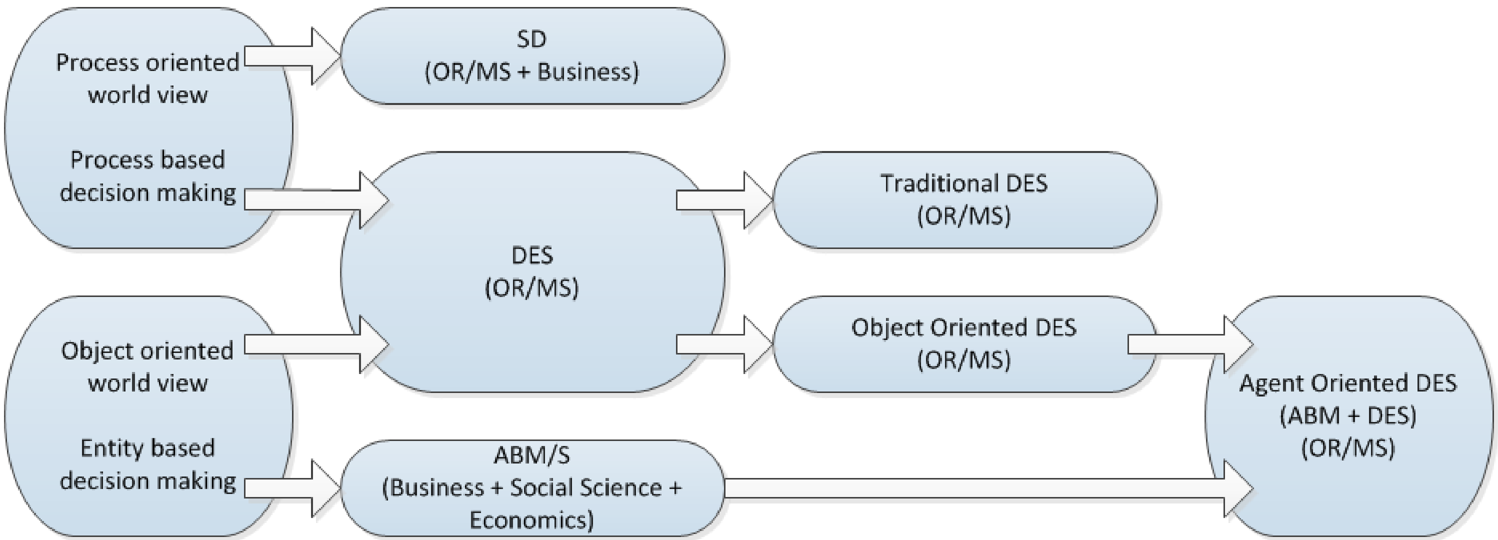


Paradigms


Aggregate, global causal dependencies, feedback dynamics
Strategic
Tactical
Operational
Discrete Event
Agent Based
System Dynamics
Individual objects, exact sizes, velocities, distances, timings

Paradigms

- Alternative view:



Summary

- What did you learn?

Questions / Comments

References

- Casti (1998). Would-Be Worlds: How Simulation is Changing the Frontiers of Science
- Robinson (2004). Simulation: The Practice of Model Development and Use
- Shannon (1975). Systems Simulation: The Art and Science.