

COMP4038 / G54SOD (Spring 2019)

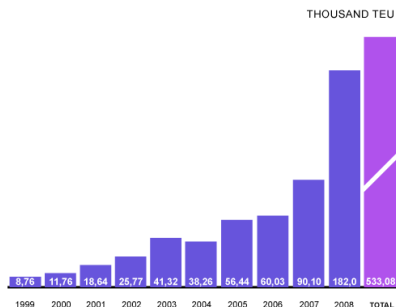
Lecture 01

Introduction (The Bigger Picture)

Peer-Olaf Siebers & Dario Landa-Silva

Container Terminal of Novorossiysk

Click on the main photo to see a video with the model in action



Applet Viewer: novorossiysk_container_terminal/Simulation\$Applet.class

Applet



▶ ◀ x32

AnyLogic

Container Terminal of Novorossiysk

Simulation duration (weeks)	-----	104
Trains arrivals per day (units)	-----	2
Preparatory period before train arrival (hrs)	-----	4
Parking service capacity (units)	-----	16
Entry gate lanes (units)	-----	3
Exit gates lanes (units)	-----	3
Trailers per crane (units)	-----	4
Maximum amount of trucks at terminal (units)	-----	60
Transport speed outside terminal (km/hr)	-----	20
Transport speed at terminal (km/hr)	-----	12
Portal cranes speed (km/hr)	-----	5
Portal cranes working rate (op/hr)	-----	22
Jib cranes working rate (op/hr)	-----	20
Gantry cranes working rate (op/hr)	-----	24

© 1992-2008 This AnyLogic™ model is developed by XJ Technologies www.xjtek.ru in cooperation with Marine Construction and Technology www.morproekt.ru

  **МОРСТРОЙТЕХНОЛОГИЯ**

Run the model

Run: 2 ◻ Idle Simulation: Stop time not set

478.7 sec

Applet started.



Applet Viewer: novorossiysk_container_terminal/Simulation\$Applet.class



Applet

Container Terminal of Novorossiysk Warmup period!

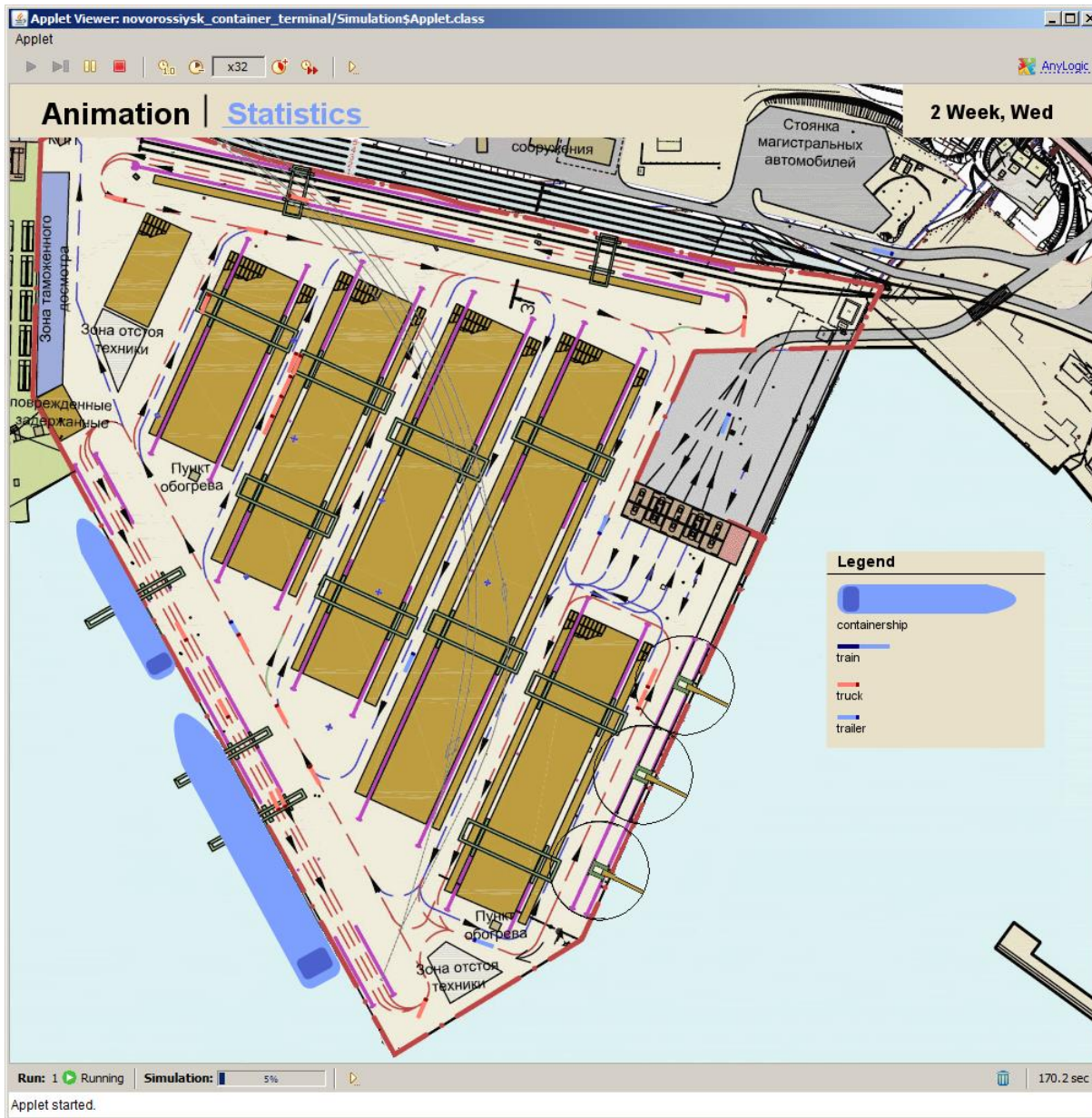
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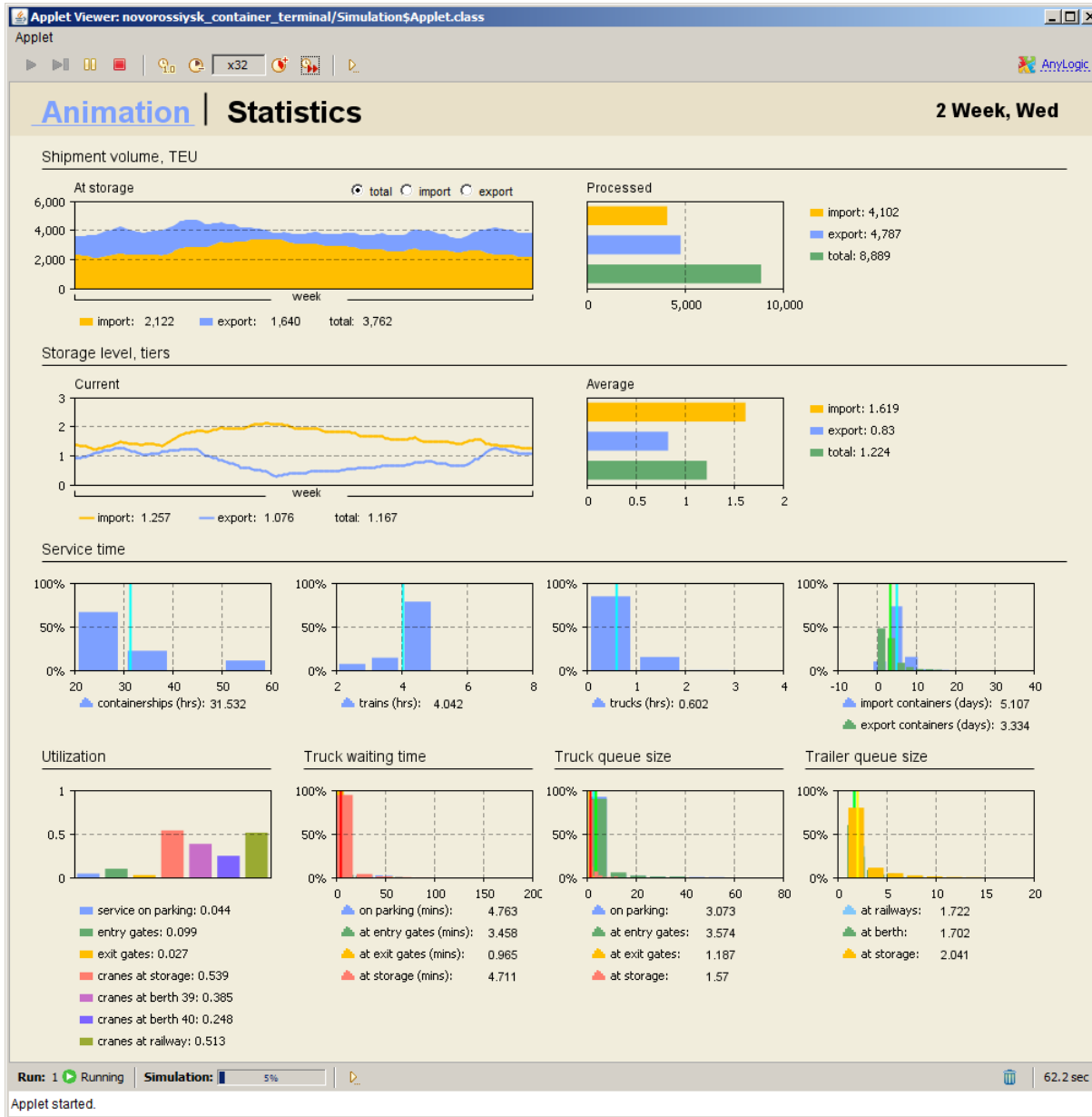
© 1992-2008 This AnyLogic™ model is developed by XJ Technologies www.xjtek.ru in cooperation with Marine Construction and Technology www.morproekt.ru

Run: 3  Running Simulation:  1.2 sec

Applet started.





Content

- Module organisation
- The idea of "Would-Be-Worlds" [Casti 1998]
 - Relevant terminology
- A first look at:
 - Standard simulation modelling paradigms
 - The concept of simulation optimisation
 - Heuristic search and optimisation techniques

What is this module about?

- Module Catalogue
 - This module offers insight into the **applications of selected methods of decision support**. The foundations for applying these methods are derived from Operations Research Simulation, Social Simulation, Data Science, Automated Scheduling, and Decision Analysis.
 - Throughout the module, you will become more competent in **choosing and implementing the appropriate method** for the particular problem at hand.
 - This module requires some **object oriented (Java) programming skills**.

Module Convenors

- Peer-Olaf Siebers

- Simulation
- CompSci B35



- Dario Landa-Silva

- Optimisation
- CompSci C70



My Research Interests

- It's all about Agents and Agent-Based Modelling



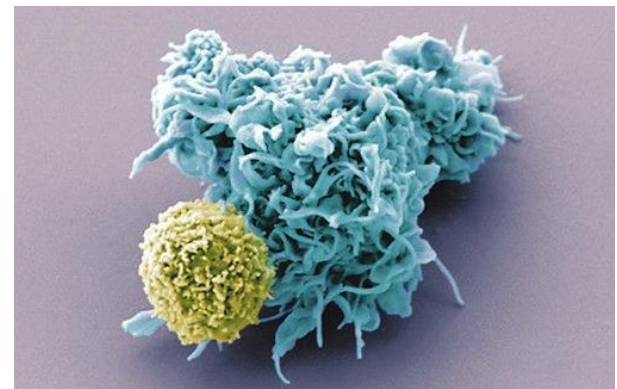
My Research Interests

- Technical Aspects
 - Engineering Agent-Based Social Simulations
 - Using Software Engineering methods and tools to define social agents and their interactions



My Research Interests

- Applications
 - My Mission: Applying OO-ABM to as many fields as possible
 - Business studies (Risk Assessment; CBA; MCDA)
 - Economics (Game Theory; Agent Based Computational Economics)
 - Social Sciences (Political Science; Social Simulation)
 - Engineering (Manufacturing; Urban Modelling; Energy; Transportation)
 - Computer Science (Robotics; Game Development)
 - Operations Research (Healthcare)
 - Systems Biology (Immunology)
 - Mental Health (EABSS framework)



Module Organisation

- Lectures
 - Mondays, 13:00-15:00
 - JC-BSSOUTH-A08
- Workshops
 - Thursdays, 10:00-11:00
 - JC-DEARING-A34
- Labs
 - Thursday, 16:00-18:00
 - JC-COMPSCI-C11



Module Organisation

- Credits: 20 = 200 hours of work

Activity	Description	Per Week	Hours
Lectures	-	3	33
Labs	-	2	22
Self Study	Revision	3	33
Self Study	Tutorials (3x2h)		6
Group Activity	Conceptual Modelling (supported by 2 labs)		6
Individual Coursework	Reflection + Modelling + Analysis + Report (supported by 2 labs)		80
Exam Preparation	-		20
		Total	200

Preliminary Topics

Introduction
Lecture 01: Introduction to simulation and optimisation (the bigger picture)
Workshop 01: Simulation study life cycle
Lab 01: Understanding the context
Lecture 02: Introduction to the software we are going to use
Workshop 02: Introduction to Java for non-Java programmers
Lab 02: AnyLogic Tutorials (1/2)
Developing Models and Algorithms
Lecture 03: Conceptual modelling + conceptual modelling exercise
Workshop 03: Data and information + representing unpredictable variability
Lab 03: AnyLogic Tutorial (2/2)
Lecture 04: Discrete event modelling and simulation
Workshop 04: Model verification and validation + introduction to focus groups
Lab 04: Group activity: Initial brainstorm
Lecture 05: Agent-based modelling and simulation
Workshop 05: Peer's research - Engineering agent-based social simulations
Lab 05: Group activity: Focus groups
Lecture 06: System dynamics modelling and simulation + hybrids
Workshop 06: Output analysis
Lab 06: Group activity: Presentations

Preliminary Topics

Lecture 07: Constructive and Local Search Heuristics

Workshop 07: Combining Simulation and Optimization

Lab 07: Exploring Simulation Optimisation Examples

Lecture 08: Evolutionary Algorithms

Workshop 08: Evaluating Heuristic Algorithms

Lab 08: Experiments with Heuristics

Application

Lecture 09: Optimisation with ABM Simulation

Workshop 09: Optimisation Experiments in AnyLogic

Lab 09: Implementing Simulation Optimisation

Lecture 10: Experimentation + output analysis

Workshop 10: Guest speaker (from AnyLogic > DSE decision labs)

Lab 10: Coursework clinic

Decision Support in Practice

Lecture 11: Cost-Benefit and Multi-Criteria Decision Analysis

Workshop 11: Guest speakers (PhD students)

Lab 11: Coursework clinic

Preliminary Topics

Easter Break :)
Lecture 12: Reserve
Workshop 12: Reserve
Lab 12: Reserve

Module Organisation

- Resources
 - Module Website: Moodle
 - Slides (two versions) + reading list + announcements
- Assessment:
 - Coursework 1 (10%): Lab exercises
 - Coursework 2 (65%): Decision support case study
 - Exam (25%)

Module Organisation

- Software:
 - AnyLogic Free PLE 8



<http://www.anylogic.com/downloads>

Module Organisation

Resources

We will use [AnyLogic Free PLE 8](#) for this module. There is a [free introductory book](#) for version 7 available from the AnyLogic website. This is still useful for learning AnyLogic. There is also a [interesting blog](#) with the latest news about AnyLogic

Below you find a collection of books that I would recommend for self-study. Most of the module's teaching is based on Stewart Robinson's book. Borshchev's book (although a bit outdated) is useful if you want to learn more about the technical aspects, i.e. how to implement simulation models in AnyLogic. More up-to-date information is available in the [AnyLogic Help](#).

- **Simulation in General:**

- Borshchev (2013) *The Big Book of Simulation Modeling - Multimethod Modeling with AnyLogic 6* (with a focus on model implementation in AnyLogic 6 (please note that in the lab we use AnyLogic 8); also provides an introduction to the required Java)
- Kelton et al (2014) *Simio and Simulation: Modelling, Analysis, Applications - 3e* (with a focus on model implementation in Simio)

- **Discrete Event Simulation:**

- Robinson (2014) Simulation: The Practice of Model Development and Use - 2e

- **Agent-Based Simulation:**

- Gilbert and Troitzsch (2005) Simulation for the Social Scientist - 2e

- **System Dynamics Simulation:**

- Morecroft (2007) Strategic Modelling and Business Dynamics: A Feedback Systems Approach

- **Java Programming:**

- Sierra and Bates (2005) Head First Java (explains object oriented programming in Java from scratch)

- **Heuristic Optimisation:**

- Siarry (2016) Metaheuristics, Springer
- Rothlauf (2011) Design of Modern Heuristics - Principles and Applications
- Talbi (2009) Metaheuristics from Design to Implementation

Furthermore, the WSC Proceedings are also a valuable source of information, in particular the introductory tutorials are very useful. [\[url\]](#) (you can download all papers directly from this website for free). Another good resource for scientific papers is Google Scholar [\[url\]](#). You will also find more about my research in Google Scholar [\[url\]](#).



Simulation Examples

London, Greater London

5 DAY FORECAST

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

Mayor Rating: 94% (Green bar)

RCI: 109,040

Monthly Budget

Current Balance	\$94,953
Monthly Income	\$31,356
Monthly Expenses	\$30,025
Month End Cash	\$96,284

Wiki: Strange Goings-On At Advanced Research Center Have Wiki Residents On Edge
Mayor Rocks According to City Blocks



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 (relevant for us)

- **Operations system:**
 - Configuration of resources combined for the provision of goods and services (functions: manufacture, transport, supply, service).
- **Social system:**
 - 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.

Systems

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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 and Social Systems

- Such systems are subject to variability
 - Predictable variability
 - E.g. staff rota, planned maintenance of machines
 - Unpredictable variability
 - E.g. customer arrivals, machine breakdowns
- Such systems are interconnected
 - Components of a system affect one another
 - E.g. customers in a three stage service process

[Robinson 2014]

Nature of Operations and Social Systems

- Such systems are (highly) complex
 - Combinatorial complexity
 - Number of components and number of combinations of components
 - E.g. travelling salesman problem
 - Dynamic complexity
 - Mainly systems that are highly interconnected (feedback systems)
 - Where an action has a different effect in short/long run
 - Where an action has a different consequences in one part of the system compared to another part of the system
 - Where an action has non-obvious consequences

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

[Robinson 2014]

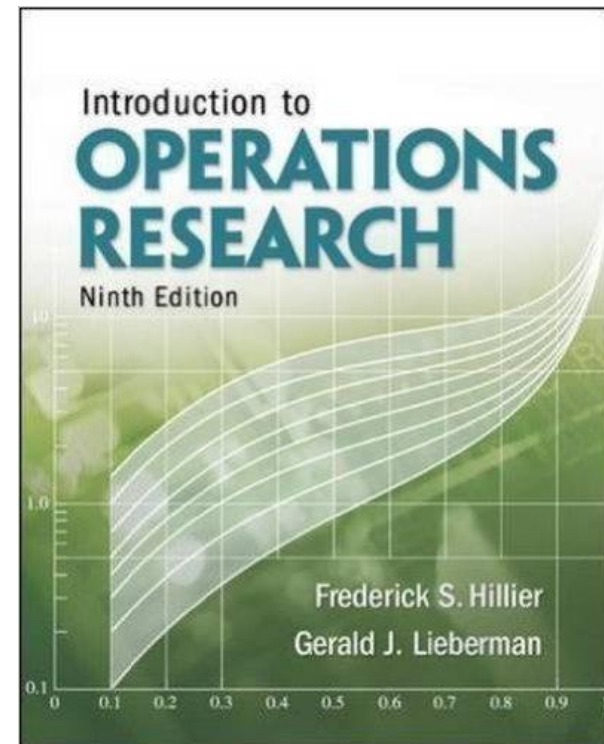


Why Simulate?

- 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
 - Real system might not exist

Why Simulate?

- Advantages: Simulation vs. other modelling approaches
 - Other modelling approaches
 - 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

Why Simulate?

- Advantages: Simulation vs. other modelling approaches
 - Transparency
 - More intuitive than a set of equations, an animated display of the system can be created, giving a non-expert greater understanding of, and confidence in, the model
 - Creating knowledge and understanding
 - Sometimes just building the model is enough
 - Visualisation, communication, interaction



Why Simulate?

- Disadvantages: Simulation vs. other modelling approaches
 - 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 etc.
- **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 in the state of the system occur continuously over time (driven by regular time advances).

Classification of Simulation

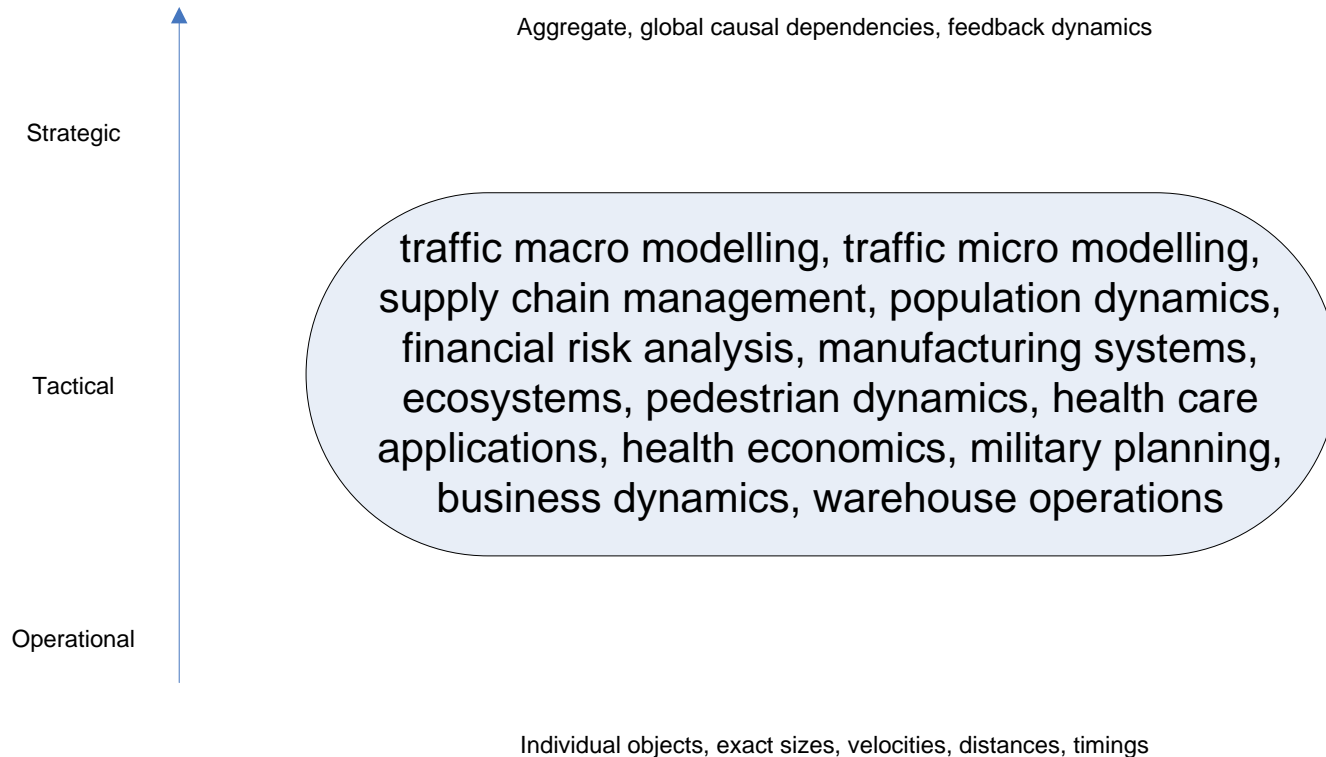
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Level of Abstraction

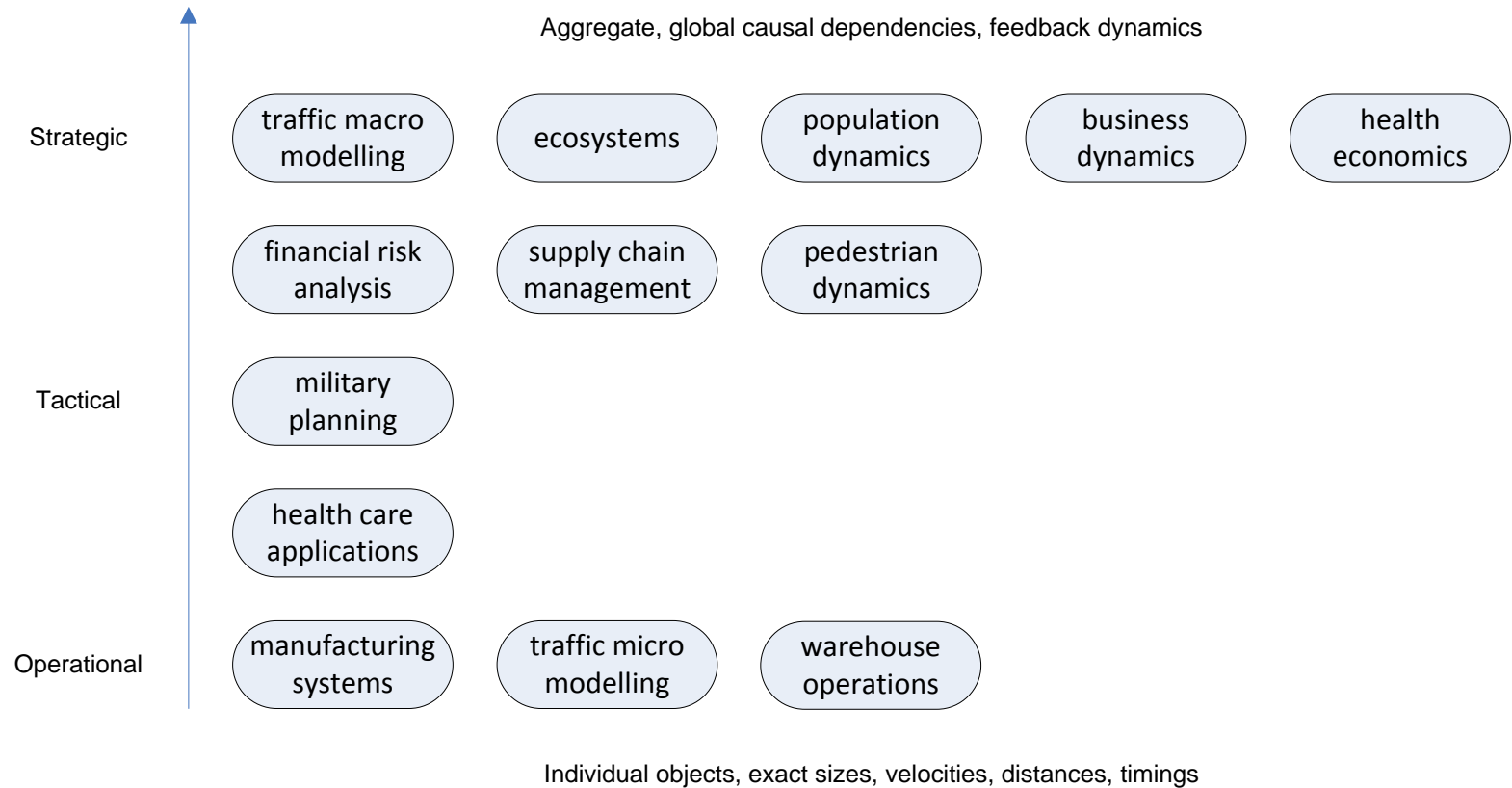
- Simulation can be applied at different stages:
 - Strategic
 - high abstraction, less detailed, macro level
 - Tactical
 - middle abstraction, medium details, meso level
 - Operational
 - low abstraction, more details, micro level



Level of Abstraction



Level of Abstraction



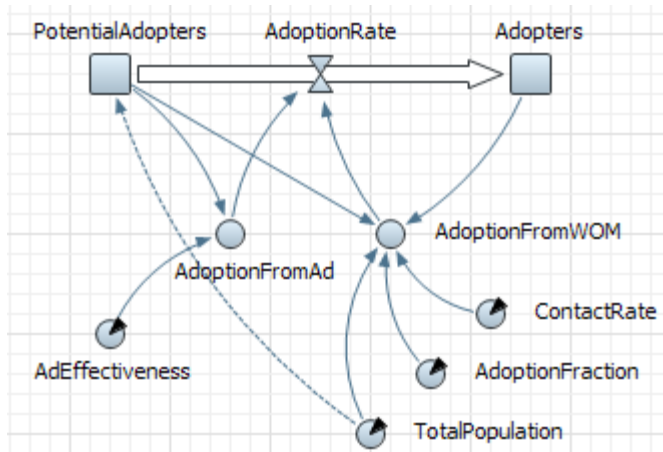
Simulation Modelling Paradigms

- System Dynamics Modelling (SDM) and Simulation (SDS)
 - Modelling: Causal Loop Diagrams + Stock and Flow Diagrams
 - Simulation: Deterministic continuous (differential equations)
- Discrete Event Modelling (DEM) and Simulation (DES)
 - Modelling: Activity Cycle Diagrams (deprecated) + Flow Charts
 - Simulation: Stochastic discrete (process oriented approach)
- Agent Based Modelling (ABM) and Simulation (ABS)
 - Modelling: Equations or UML
 - Simulation: Stochastic discrete (object oriented approach)
- Hybrid Modelling (HM) and Simulation (HS)

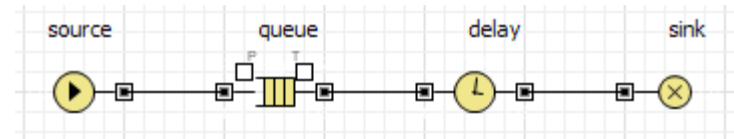
Paradigms

Click on a screenshot to see a video with the respective model in action

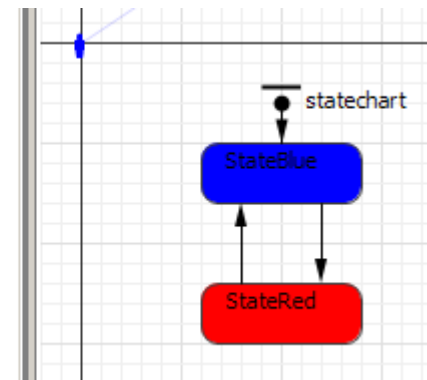
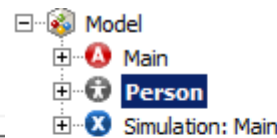
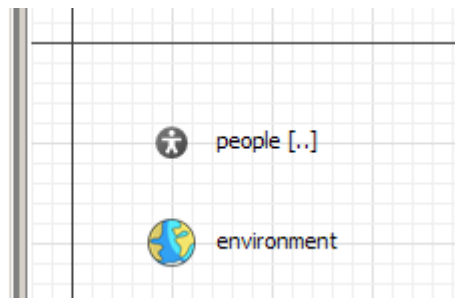
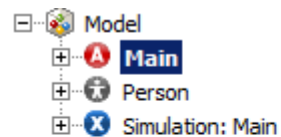
- SDM



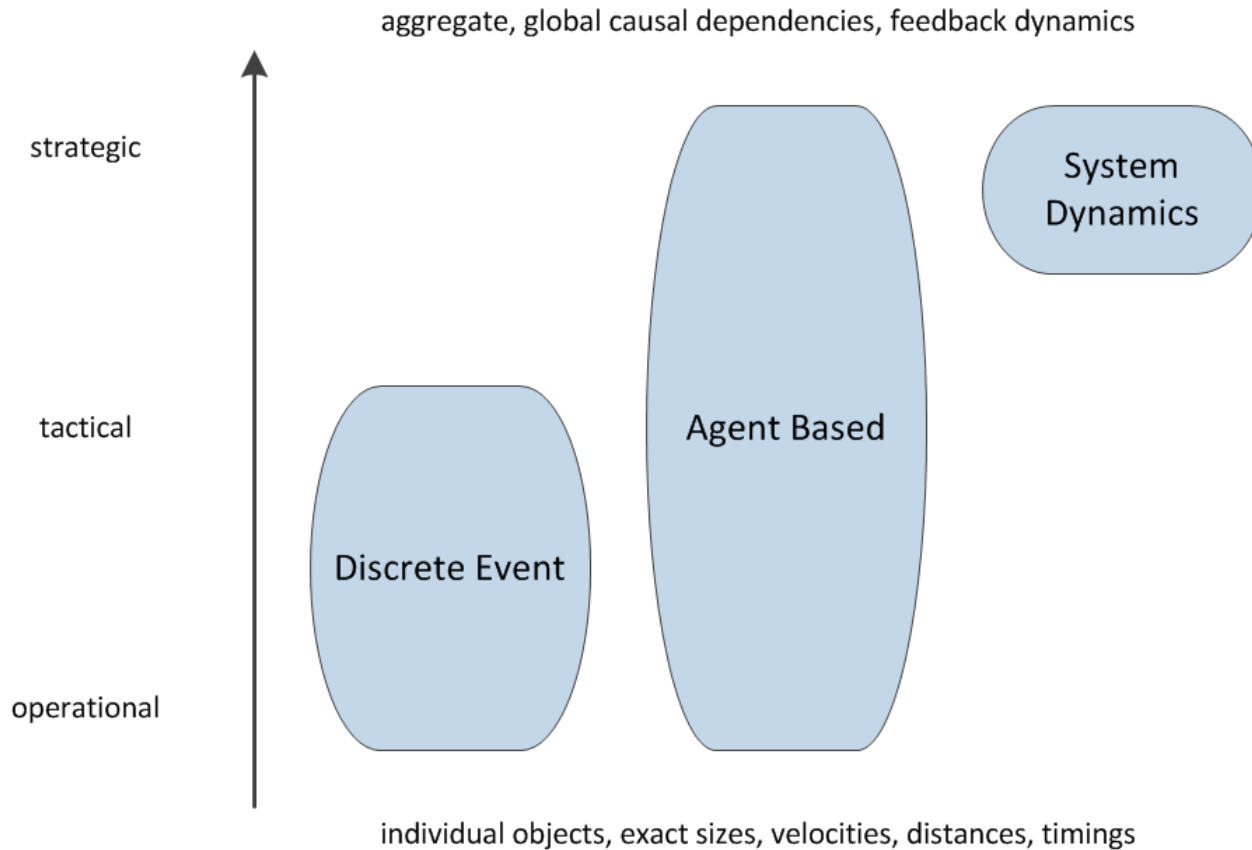
- DEM



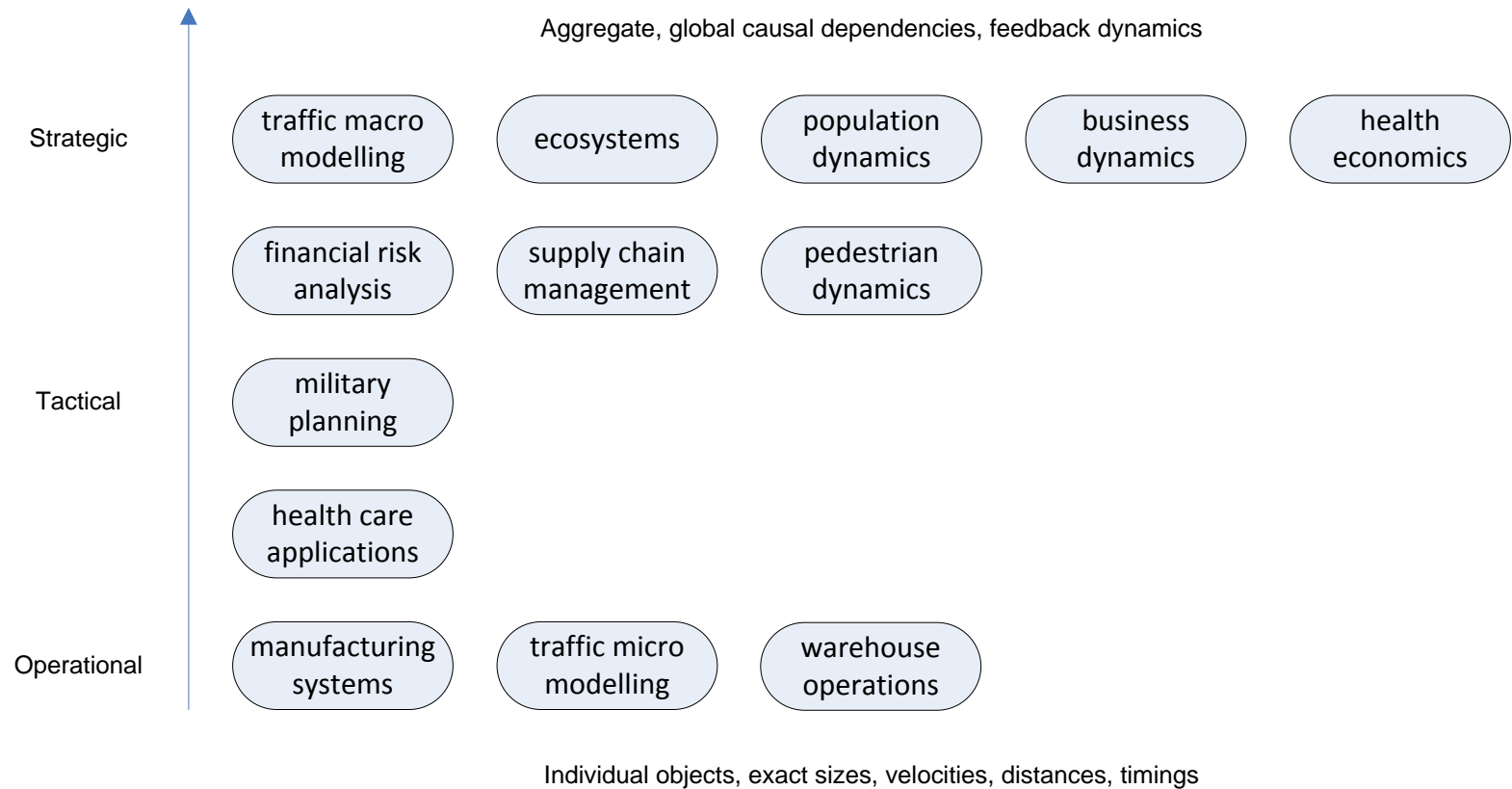
- ABM



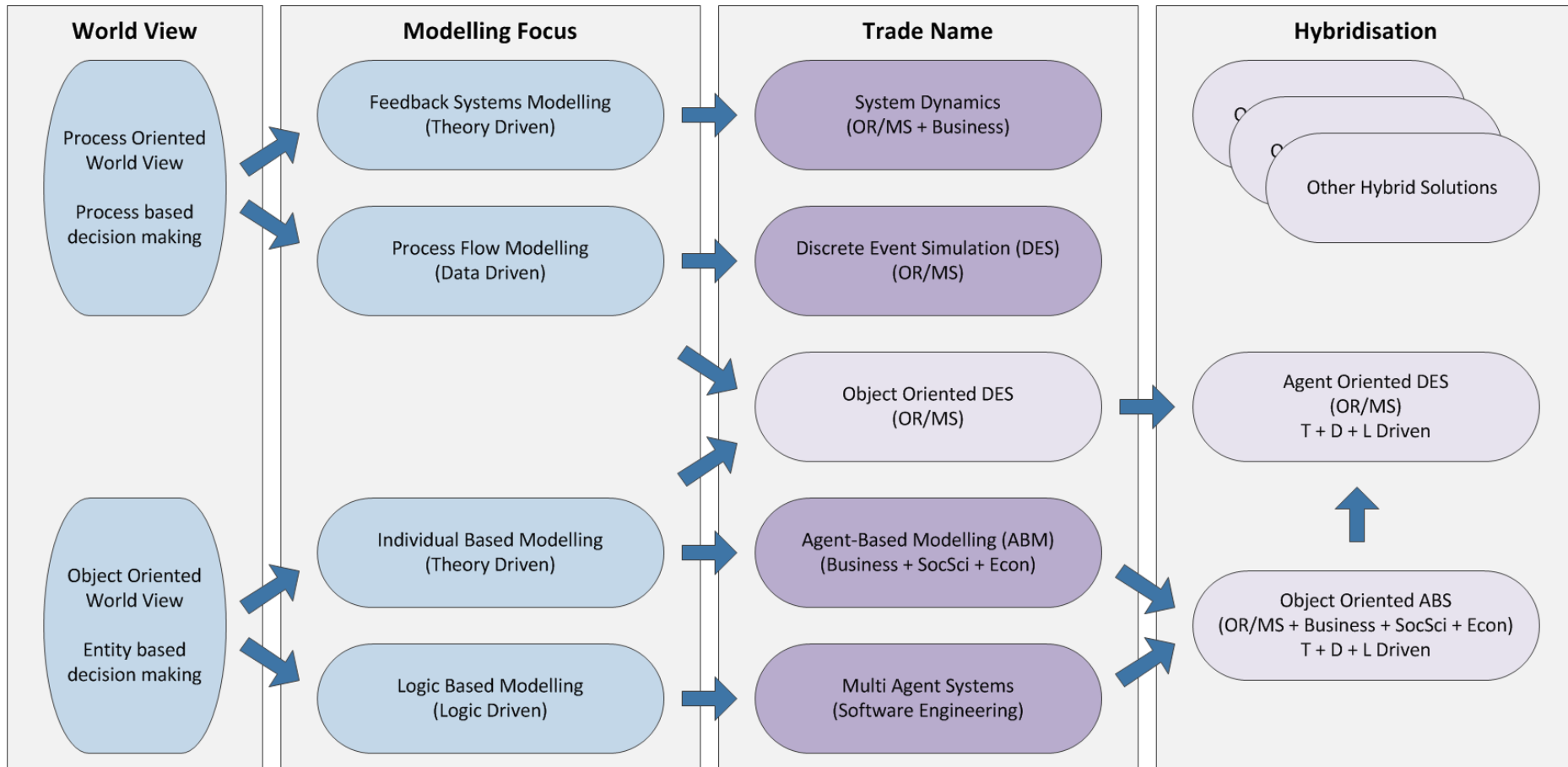
Paradigms



Level of Abstraction



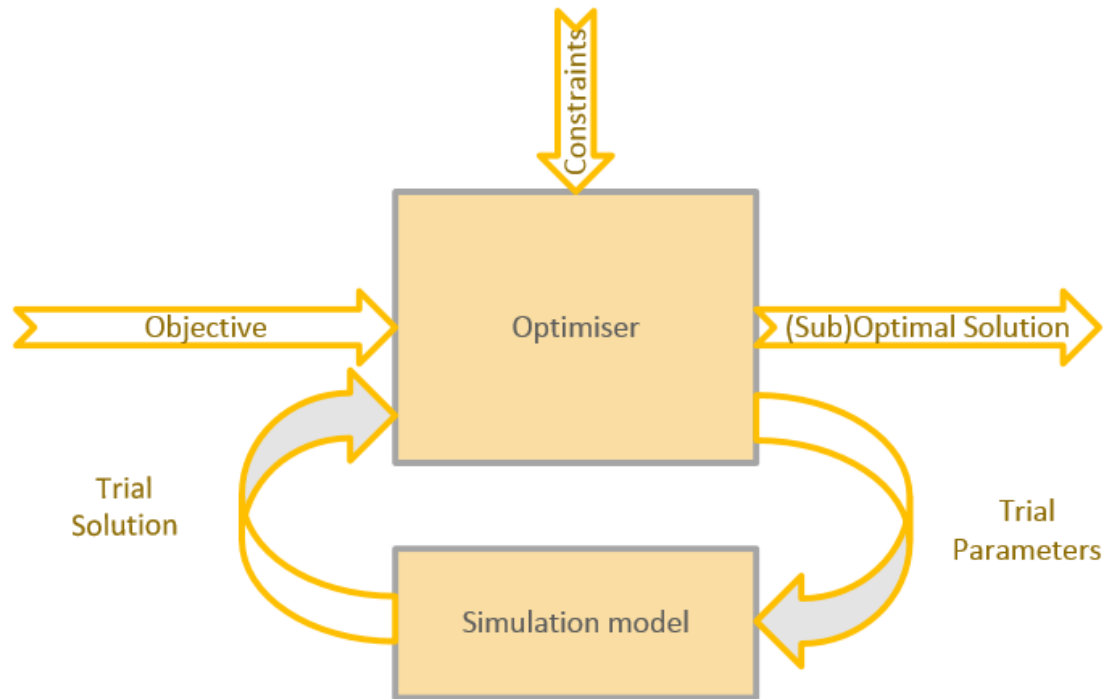
Simulation Modelling Framework



Theory Driven: Theories for model formulation; data for model validation
 Data Driven: Data for model formulation (can be quantitative and qualitative); data for model validation
 Logic Driven: Logic for model formulation; data for model validation

Simulation Optimisation

- How does it work?
 - The optimiser runs as a master application that controls the simulation model



Overview of the Optimisation Part

Achieve an understanding of modern [heuristic search](#) techniques with emphasis in tackling [search and optimisation problems](#).

[Heuristic Search and Optimisation](#) refers to a set of computational techniques that aim to find good quality solutions to very difficult problems in search, optimisation, design, etc. while consuming a reasonable amount of computational resources.

Heuristic methods are [AI inspired approaches](#) and are related both to [computer science](#) and [operations research](#).

Heuristic methods have been [successfully applied to many problems in different areas](#) including: engineering, management, finance, planning and scheduling, medicine, biology, automated navigation, image processing, robotics, art design, etc.

Describing Heuristics

A [heuristic search method](#) is a technique that seeks good quality (i.e. near optimal) solutions at a reasonable computation time but that is not able to guarantee either feasibility or optimality.

There is a [range of heuristic methods](#) including: simple constructive heuristics, local search, meta-heuristics, hyper-heuristics, hybrids, evolutionary methods, etc.

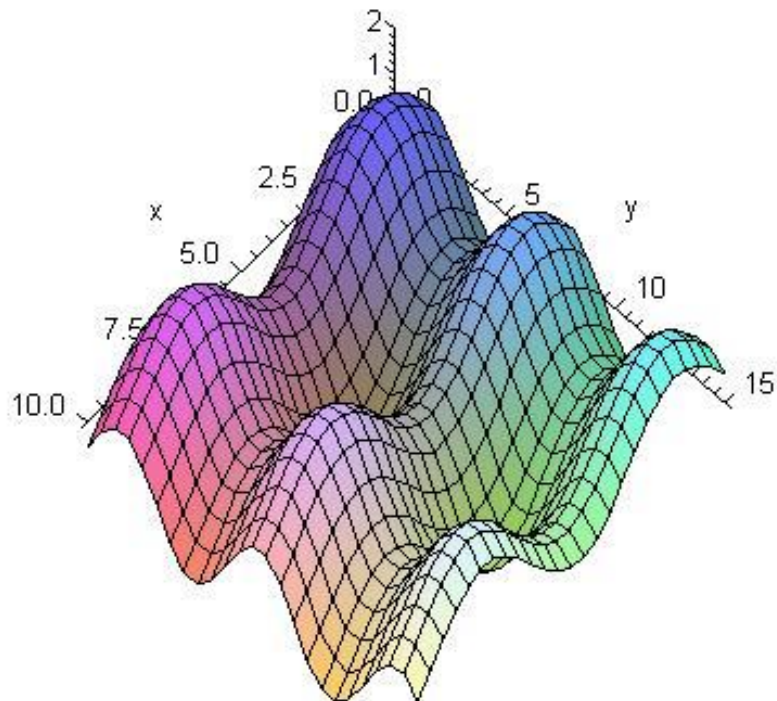
Societies and Publications

- Related conferences include: CEC, GECCO, HM, MIC, PPSN, SLS
- Related journals include: Applied soft computing, Evolutionary computation, Evolutionary intelligence, IEEE Trans. on EC, Intl. journal of meta-heuristics, Journal of heuristics, Memetic computing, Swarm intelligence and others.

Examples of (nonlinear) continuous search problems:

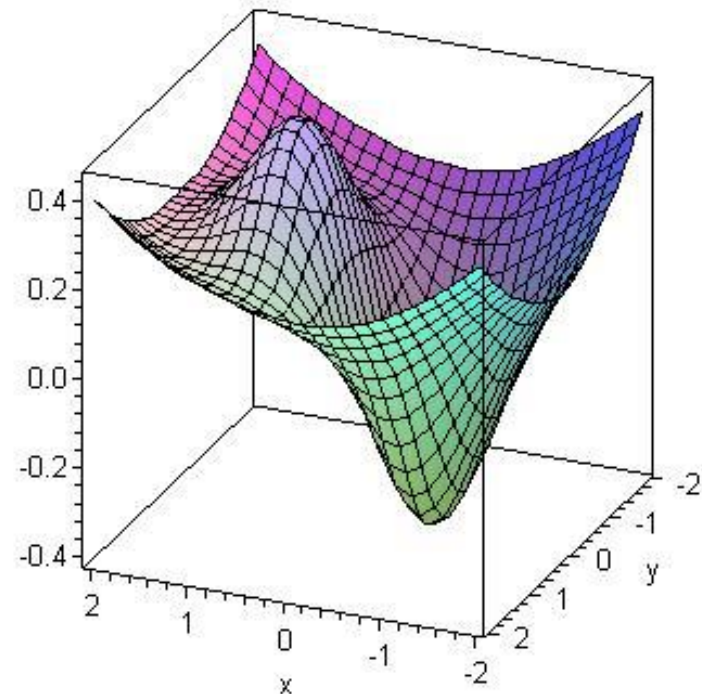
$$f(x, y) = x \cdot \exp\left(-\frac{(x^2+y^2) + \frac{x^2+y^2}{20}}{20}\right)$$

s.t. $0 < x < 10$ and $0 < y < 15$



$$f(x, y) = \text{Sin}(x) + \text{Sin}(y)$$

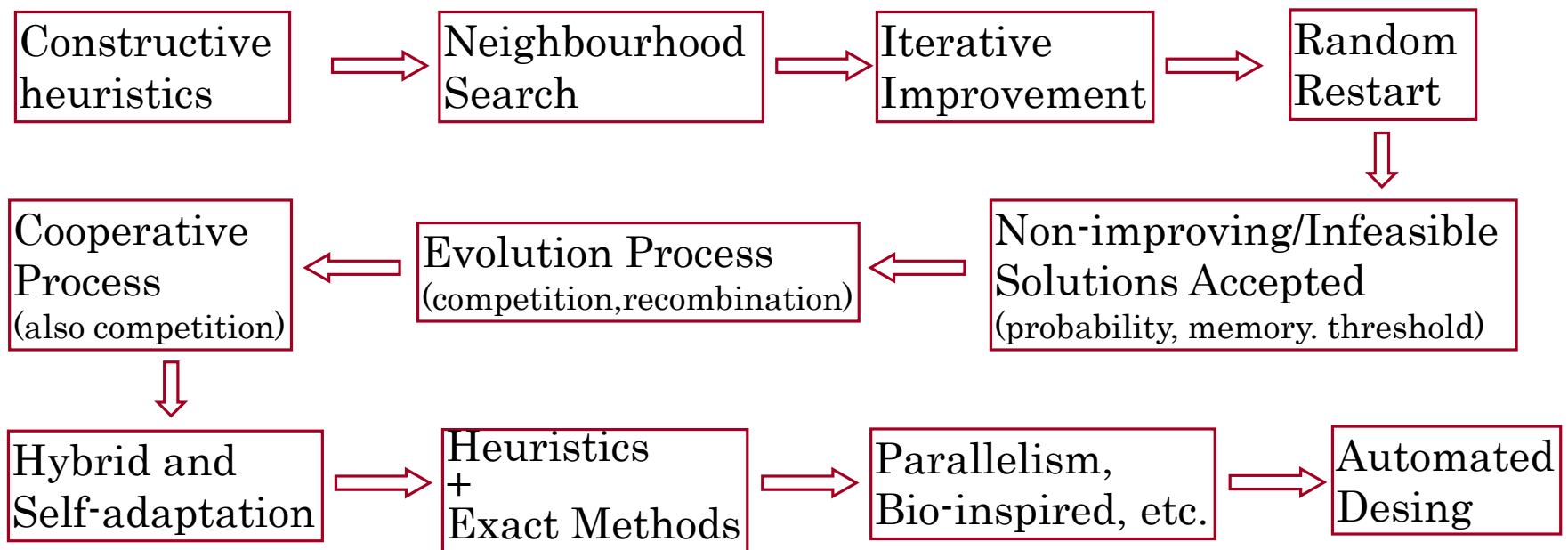
s.t. $-2 \leq x, y \leq 2$



Progress on Heuristic Search

A heuristic is a 'rule of thumb' based on domain knowledge from a particular application, that gives guidance in the solution of a problem (Oxford Dictionary of Computing).

A meta-heuristic is a iterative master process that guides and modifies the operations of subordinate heuristics to efficiently produce high-quality solutions (Voss et al. 1999).



And finally ...

- Questions and comments ...



References

- Casti (1998) *Would-Be Worlds: How Simulation is Changing the Frontiers of Science*
- Robinson (2014) *Simulation: The Practice of Model Development and Use*
- Shannon (1975) *Systems Simulation: The Art and Science*
- Voss et al (1999) *Meta-heuristics: Advances and Trends in Local Search Paradigms for Optimization*