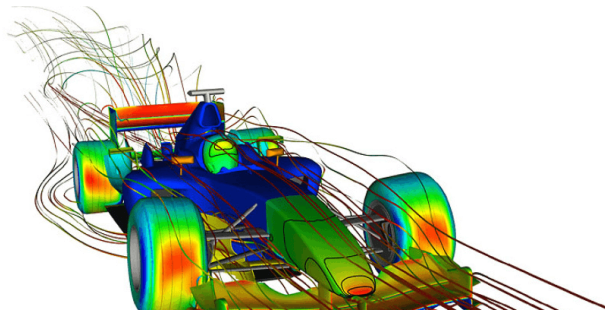# Simulation

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What is Simulation

What is *simulation*:
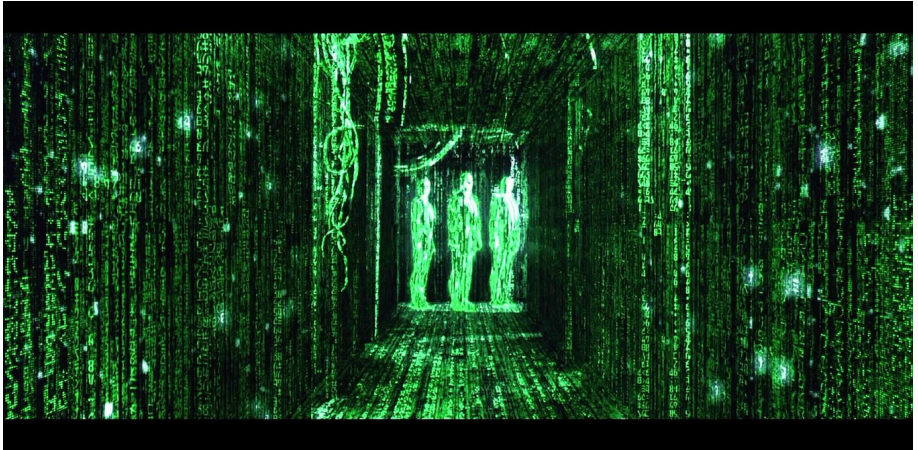
What is Simulation

What is *simulation*:

What is Simulation

What is *simulation*:

What is *simulation* (Oxford Dictionary):

> *The production of a computer* **model** *of something, especially for the purpose of study.*

"something" → often a *real world* process.

What is a *descriptive model*?

$$y = a \cdot x^2 + b \cdot x + c$$

Simulation

What is a *descriptive model*?

$$P[N(t) = n] = \frac{(\lambda \cdot t)^n}{n!} \cdot e^{-\lambda \cdot t}$$

What can we do with a *descriptive model*?

We can tell a computer on how to replicate the behavior of complex systems.

Why to do simulation:

- a valuable (i.e. cheap) tool for approximating real life behaviour
- can be used for testing scenarios
- the art of constructing the model itself may lead the modeller to greater understanding of the real system
- what-if analyses "in silico"
- visualization of results for complex methods (e.g. optimization strategies)
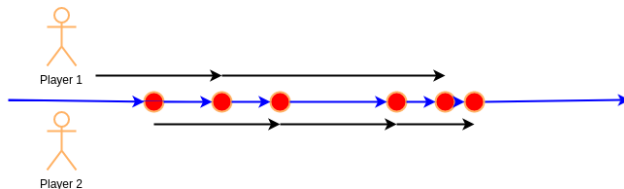
When simulation is not the best option:

- analytical problems with solutions in closed forms
- what-if analyses with too many options (better to use *prescriptive* models)
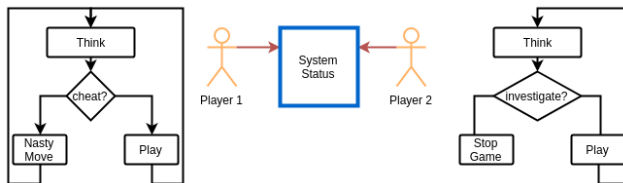
The types of simulation:

- discrete events
- agent-based
- system dynamics

Discrete Events:

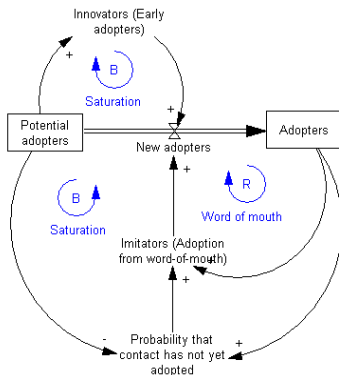Example: customers at a counter.

Agent Based:

A simple "pseudo agent" simulation: the Game of Life (Conway 1970).
(Fuzzy) description: it is given a region in which individuals live ...

1. any individual with less than two (live) neighbors dies (underpopulation)

2. any individual with more than three (live) neighbors dies (overcrowding)

3. any (live) individual with two or three neighbors remains alive

4. when exactly three individuals share an empty space, a new individual comes to life in such an empty space

How to *model* it? How to get *insights on what's going on*?

System Dynamics: stocks, flows, delays and feedback loops

A comparison [1]:

Feature	Discrete Events	Agent Based	System Dynamics
grain	fine	fine	coarse
oriented to ...	processes	individuals	system
individuals	heterogeneous	heterogeneous	homogeneous
driver	occurrence of events	interactions	feedback loops
type of models	event, activity, process	threads and environment	stock and flow
handling of time	discrete	discrete / cont.	continuous
minor what if an.	change process param.	change agent logic	chng system param.
major what if an.	change process struct.	change agent interact.	chng system struct.

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[1] Adapted from B. Behdani "Evaluation of paradigms for modeling supply chains as complex socio-technical systems", slideshare.

Using or building simulation software:

Using or building simulation software: **both!**

Syllabus
Theory:

- Elements of Probability
- Generating Random Numbers and Random Variables
- Statistical Analysis of Simulated Data and Validation
- Variance Reduction Techniques
- Markov Chain Monte Carlo
- Elements of Queuing Theory

Practice (anylogic):

- Discrete Event Simulation
- Agent Based Simulation

Organization

- Course Schedule:
  - Monday, 11:00 - 13:00
  - Thursday, 14:00 - 16:00
- Tutoring: Thursday, after the lecture
- Textbook: Sheldon M. Ross "Simulation", 5th edition, Elsevier pubs. (2012)
- Website: homes.di.unimi.it/ceselli/simulation
- Course Exam: TBD

Questions?

Example: the pharmacist shop.