INF

FAKULTÄT FÜR
INFORMATIK

Introduction to Simulation

Introduction

Introductions

I am:

- Graham Horton

You are students of ...

- Bachelor: IngIF, CV, WIF, IF
- Master: DKE, DE
- ...?

This is:

- Introduction to Simulation

Goals of the Course

Show the need for Simulation and give some examples.

Give an introduction to three important areas of simulation:

- Continuous simulation (ODEs)
- Discrete–event stochastic simulation
- Agent based simulation

Learn to use the simulation software AnyLogic.

Solve some typical engineering problems using simulation.

Form the basis for further courses and thesis work.

General Information

Assumed previous knowledge:

- Basic Engineering mathematics
- Computer Programming

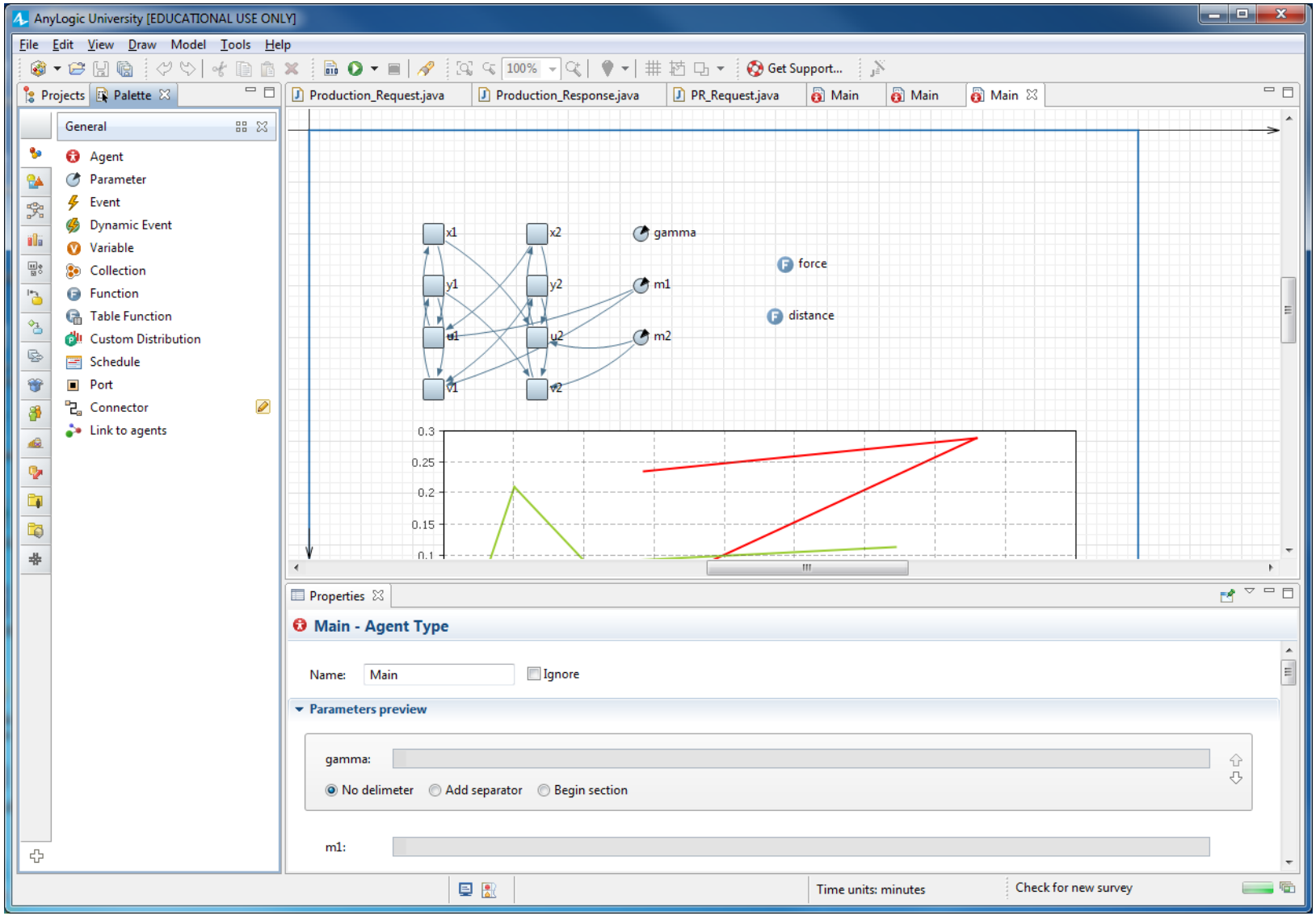
Formal lectures (*Vorlesungen*): Friday 11am

Practical classes (*Übungen*):

- English: Friday 9am (Claudia)
- German: Friday 1pm (Tim)
- Starting at 26.10.

All slides will be provided via the web (sim.ovgu.de).

AnyLogic


AnyLogic University [EDUCATIONAL USE ONLY]
File Edit View Draw Model Tools Help
Get Support...
Projects Palette
General
Agent
Parameter
Event
Dynamic Event
Variable
Collection
Function
Table Function
Custom Distribution
Schedule
Port
Connector
Link to agents
Production_Request.java
Production_Response.java
PR_Request.java
Main
Main
Main
x1
x2
y1
y2
u1
u2
v1
v2
gamma
m1
m2
force
distance
0.3
0.25
0.2
0.15
0.1
Properties
Main - Agent Type
Name: Main
Ignore
Parameters preview
gamma:
No delimeter
Add separator
Begin section
m1:
Time units: minutes
Check for new survey

AnyLogic and Assignments

We will use the simulation system AnyLogic.

- AnyLogic is available for Windows, Linux and MacOS.

The AnyLogic Personal Learning Edition is free and sufficient for this course.

- Install instructions: http://tinyurl.com/AnyLogicInstallation

We can provide keys for the University Researcher Edition for those interested.

- Contact us in the exercise

Most homework assignments will be simulation programming.

Examination and Homework

Exam and “Schein”:

- There will be a written exam at the end of the semester.
- You will get the “Schein” if you pass the exam.

Exam questions and old exam papers are on the ItS web site:

- www.sim.ovgu.de/Infos/Klausurenarchiv.html

Homework

- may be done in groups,
- need not be handed in,
- will not be discussed in class (unless requested).

Examination

For your exam preparations:

- At the end of each lecture there is a slide with exam questions.

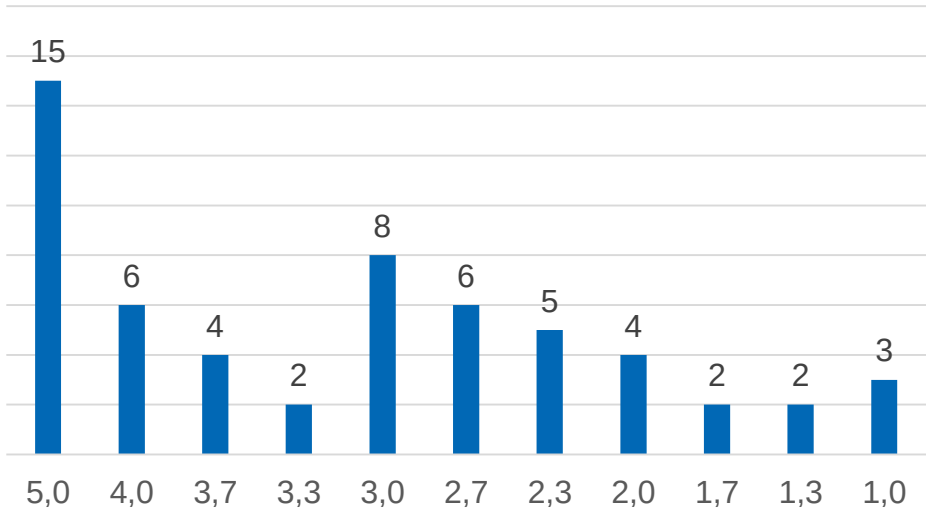
In addition:

- We will give you the exam paper!

Experience shows …

- that this has little effect on the results(!)

Results in February 2017:



Difference for Bachelor and Master

Bachelor students get 5 and Master students 6 Credit Points for passing the course

Additional work for Master students:

- Extended Semester Assignment
- Requires deeper knowledge of Agent based simulation
- Additional exam questions regarding the semester assignment

Online exam registration

- Starts in January
- Different examination numbers:
  - Bachelor – 100372: Introduction to Simulation
  - Master – 120345: Introduction to Simulation (6CP)

Evaluation

There will be a student evaluation of ItS.

What criteria make a good course?

Examples:

- *The lecturer responds well to questions.*
- *The lecturer makes the material interesting.*
- *The slides are clear and helpful.*
- *The level of difficulty is appropriate.*
- *I have learned a lot from this course.*
- *I would recommend this course to other students.*

Literature

Almost all of the discrete simulation material can be found in

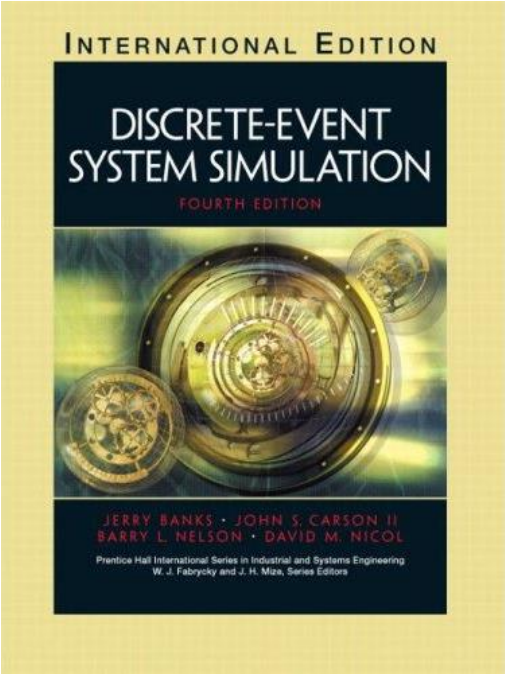
- Banks, Carson, Nelson: Discrete–Event System Simulation
- (Banks, Carson, Nelson, Nicol: Discrete–Event System Simulation)

Library reference numbers:

- *1997 a 4998:1* to *1997 a 4998:6*
- (The library has the older edition.)

References to chapters …

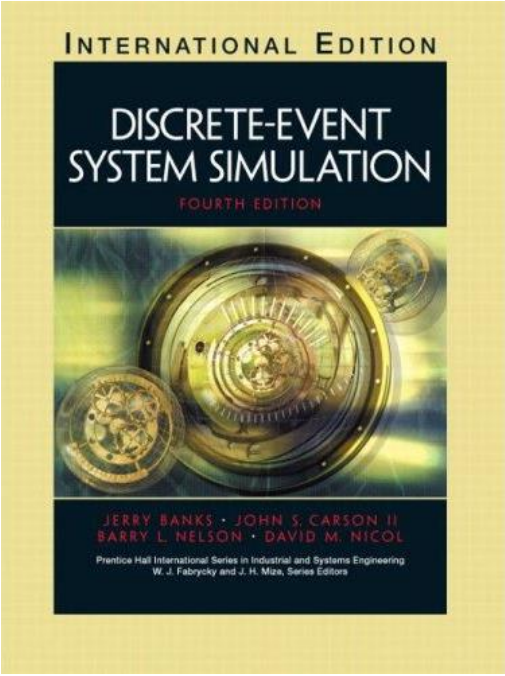
- will be given in each lecture.



Background Reading

Relevant sections of the book today:

- 1.1
- 1.2
- 1.3
- 1.4
- 1.8
- 1.9



Brockhaus: "Simulation"

Simulation [lat. "imitate"]:

- the representation or replication as a model of certain aspects of a real or planned cybernetic system, in particular of its behaviour over time.

Simulation [lat. "nachahmen"]:

- *die modellhafte Darstellung oder Nachbildung bestimmter Aspekte eines vorhandenen oder zu entwickelnden kybernetischen Systems, insbesondere auch seines Zeitverhaltens.*

Brockhaus: "Modell"

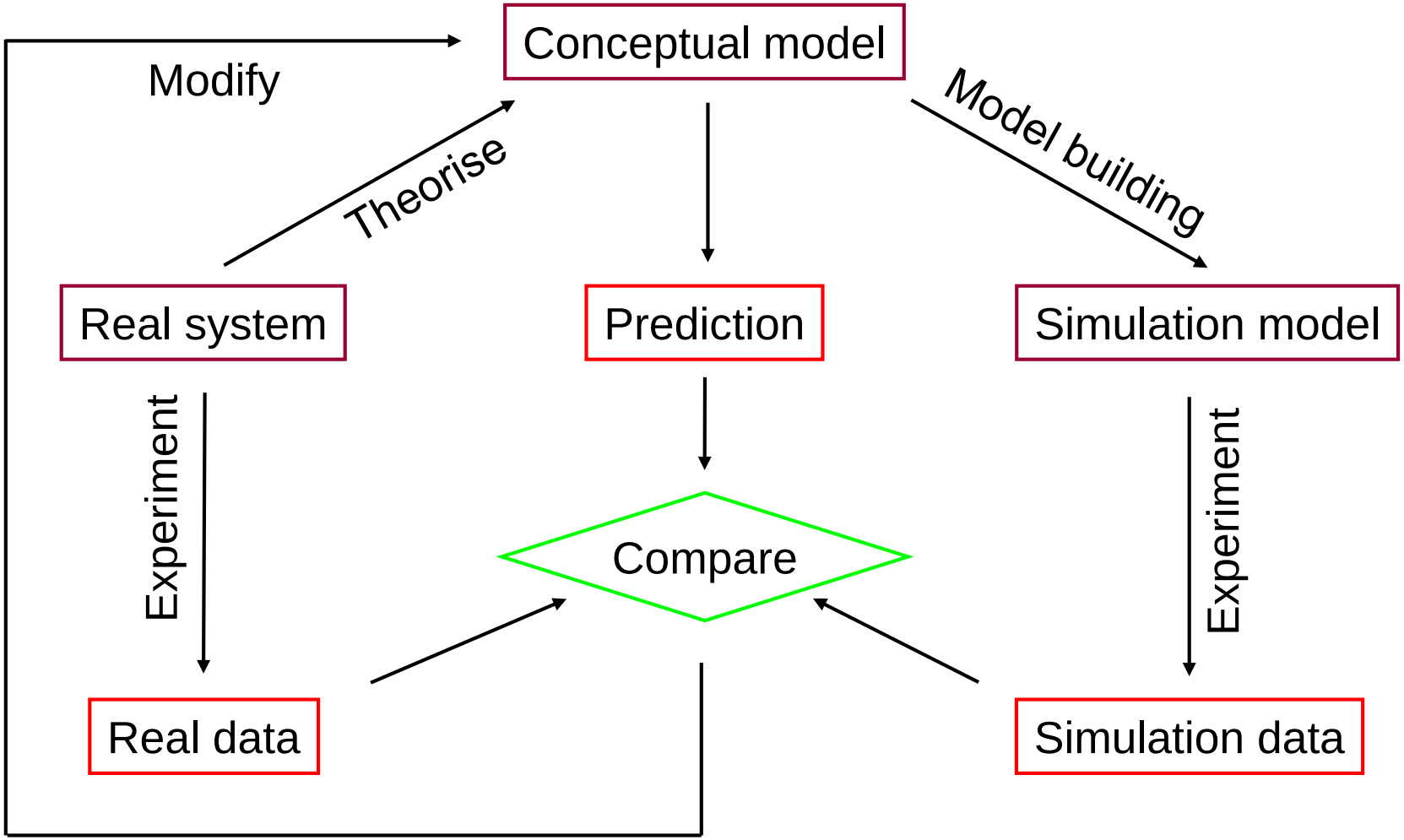
Model:

- a representation of nature which emphasises those properties that are considered to be important and ignores the aspects which are considered to be irrelevant.

Modell:

- *ein Abbild der Natur unter Hervorhebung für wesentlich erachteter Eigenschaften und Außerachtlassen als nebensächlich angesehener Aspekte.*

Three Methods of Science



Some Application Fields

Continuous simulation:

- All branches of (Natural) Science
- All branches of Engineering

Discrete simulation:

- Manufacturing and Automation
- Logistics and Transportation
- Reliability and Safety Engineering
- Operations Research

Users of Simulation

In Engineering and Management:

- Designing and optimising systems
- Because systems are very complex
- Because demands (accuracy, efficiency) are very high

In Science:

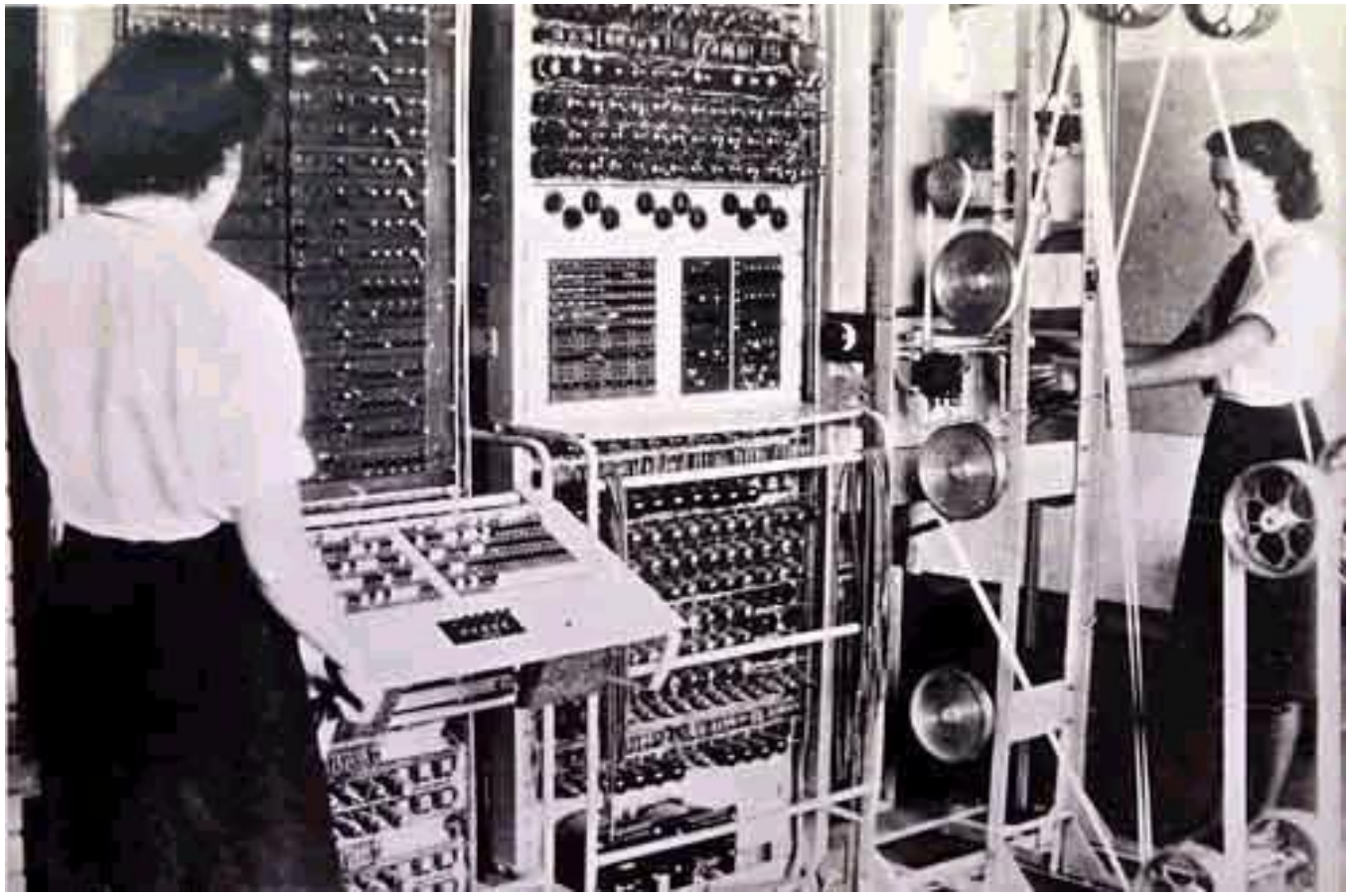
- To test theories (the "virtual laboratory")

In Society in general:

- Early warning systems (weather forecasting)
- Education and training (flight simulators)
- Computer games (SimCity)

History

Simulation is what the first computers were built to do



Supercomputing

Simulation is the reason there are supercomputers.

Example Application: Automobile Production

Automobile Production

Some properties of automobile production:

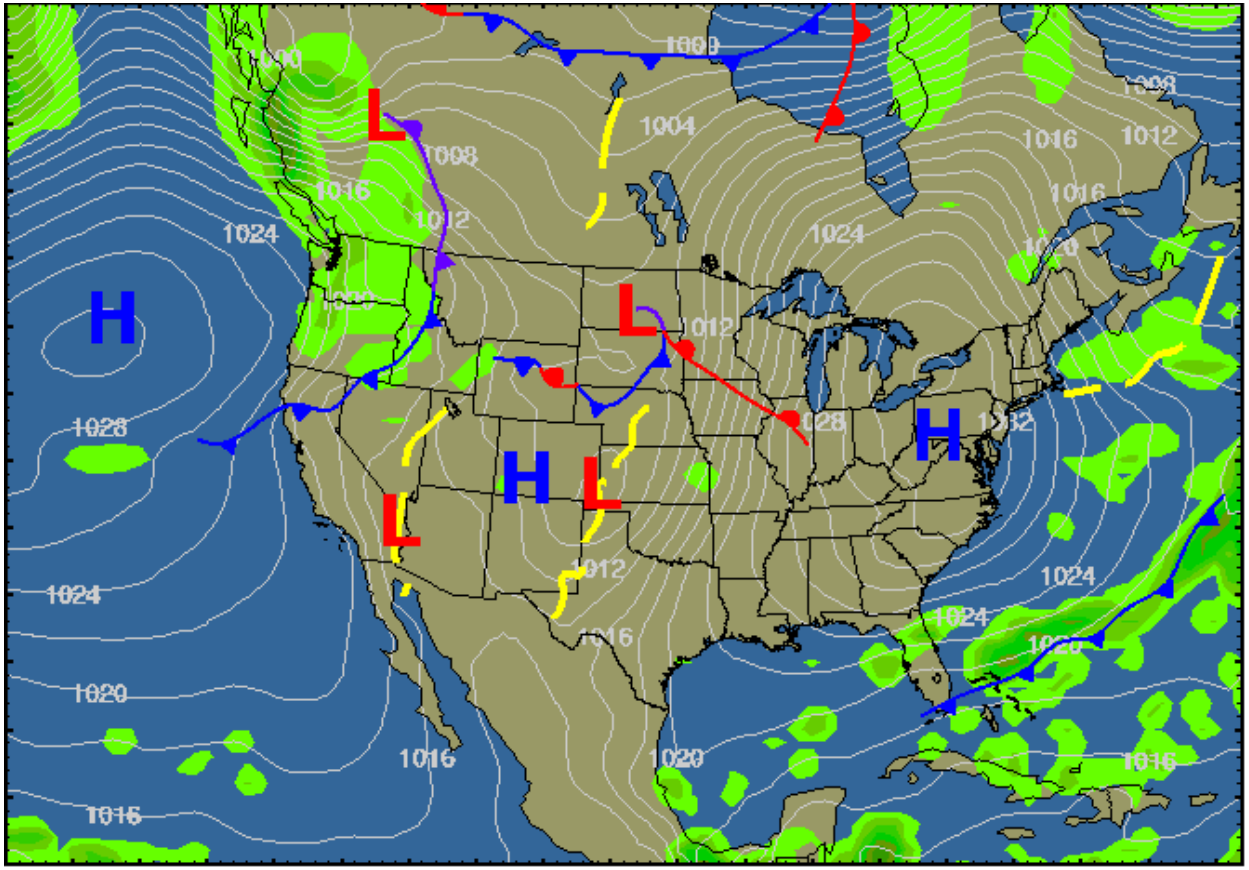
- It is very complicated.
- Efficiency must be very high.
- Lots of money is involved.
- There are many parameters.
- Modifications are very expensive.

Simulation is used to study...

- Efficiency
- Throughput
- Bottlenecks
- Optimisation
- ...

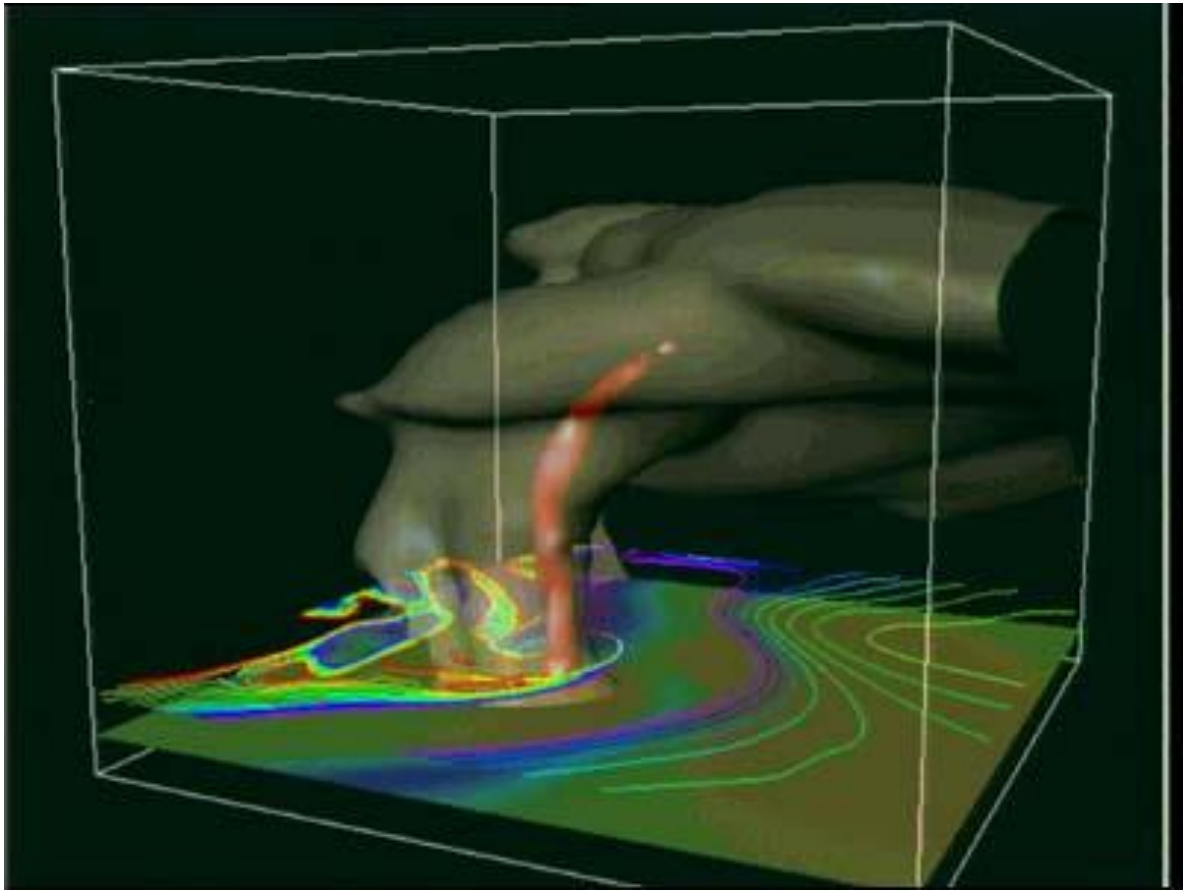
Weather Forecasting

Weather forecasts are computed by simulation.



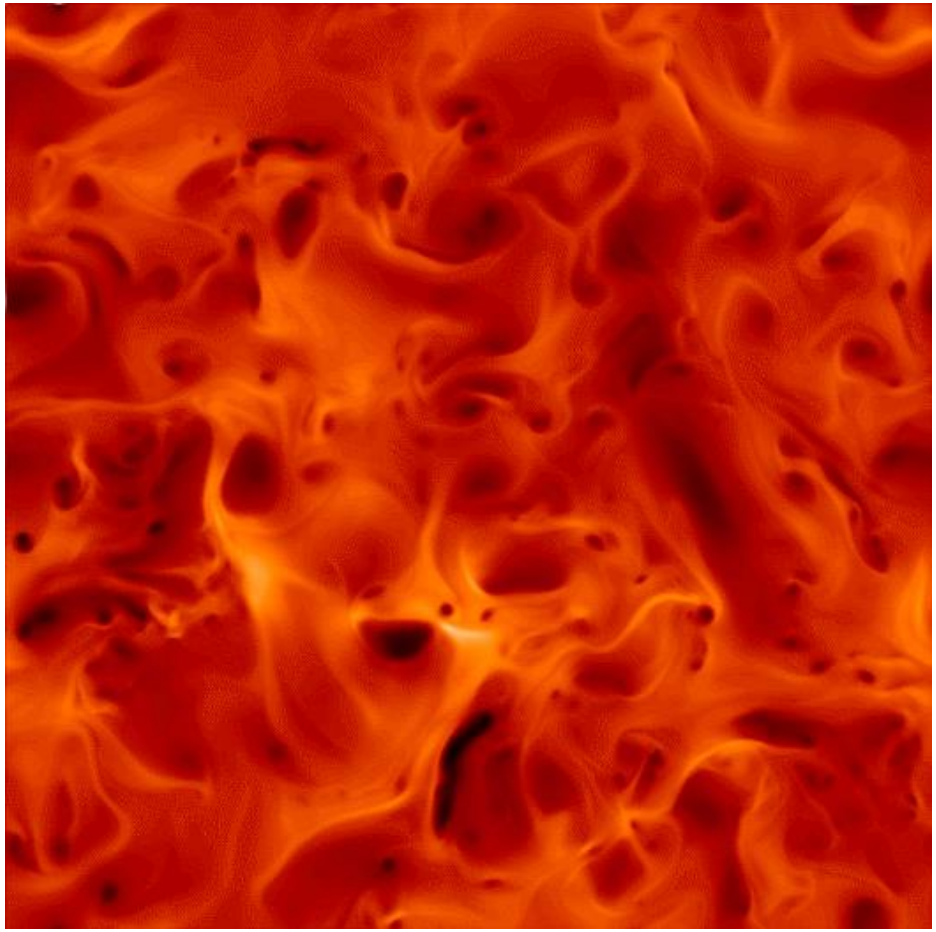
Tornados

Simulation is used to predict natural disasters.



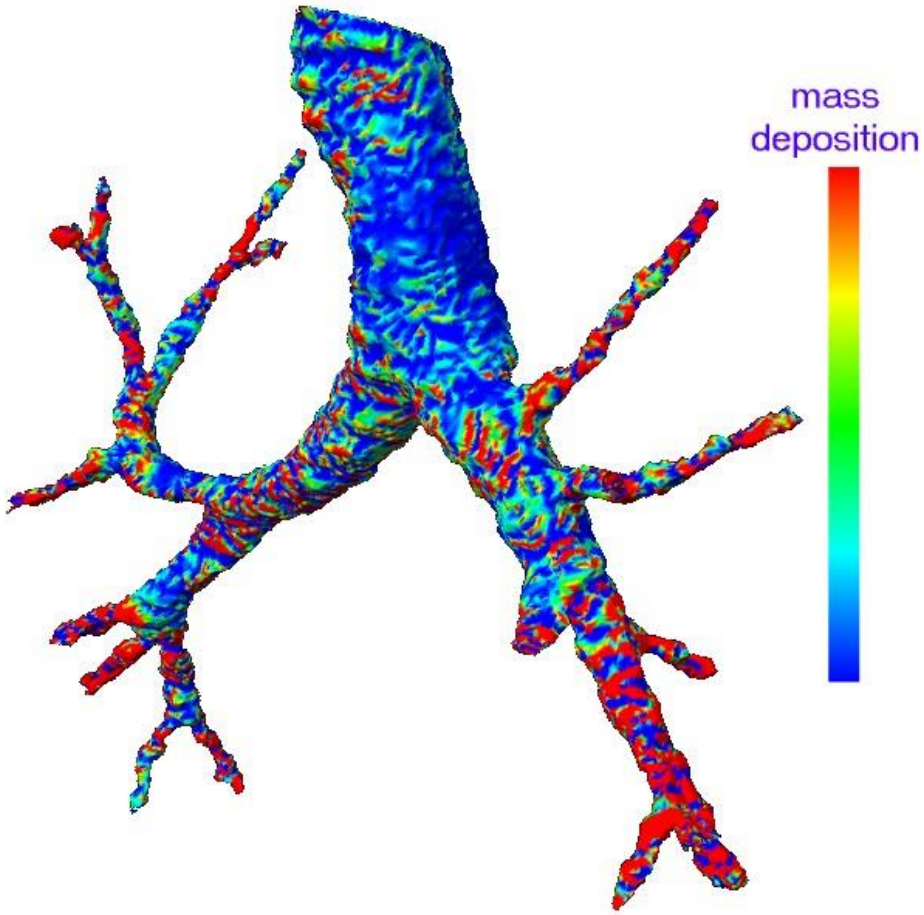
Astronomy

Simulation of the turbulence in a forming star:



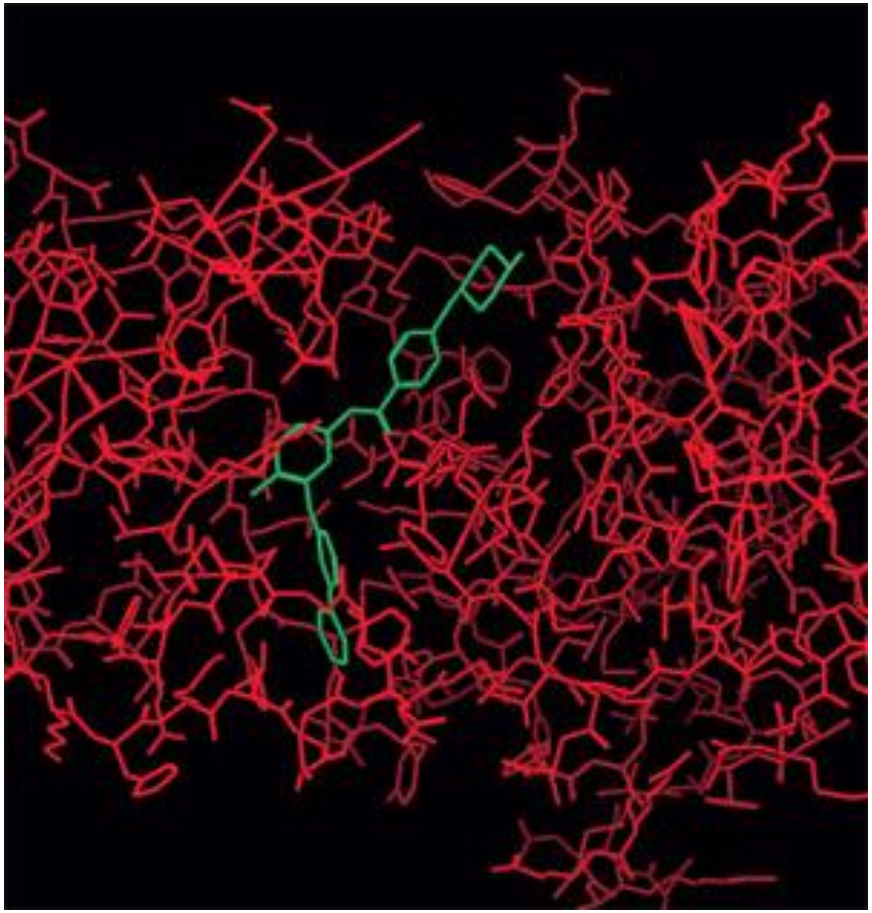
Medicine

Absorption of water vapour in the lungs:



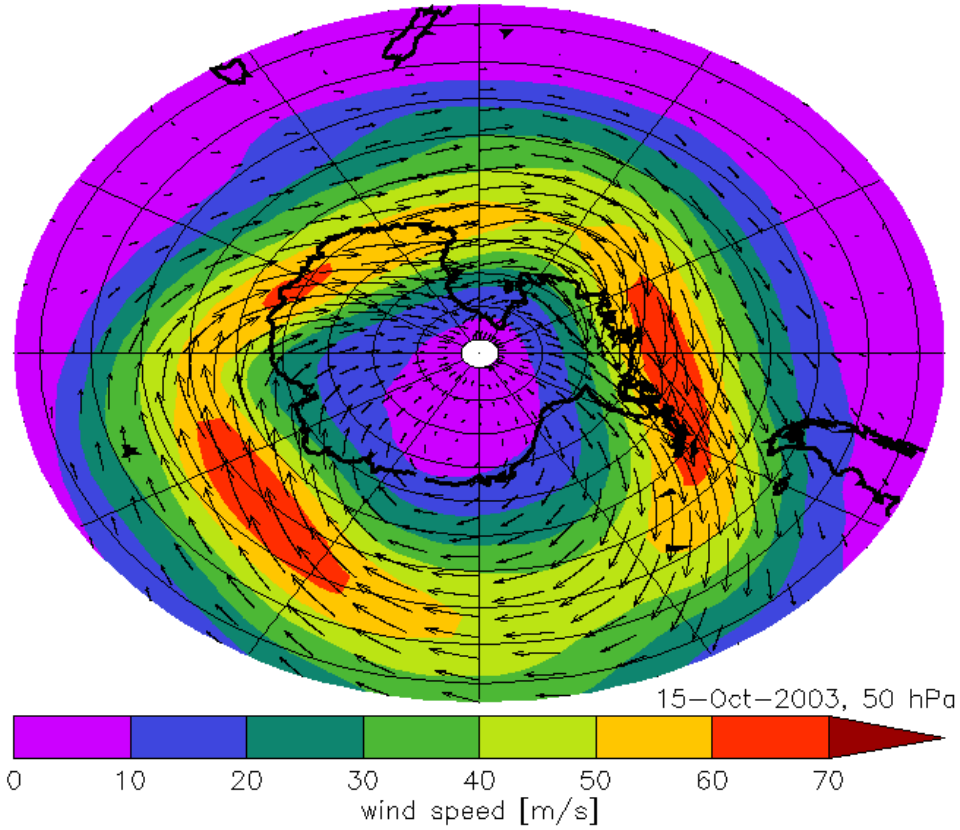
Pharmacology

Designing drugs that fit to specific molecules:



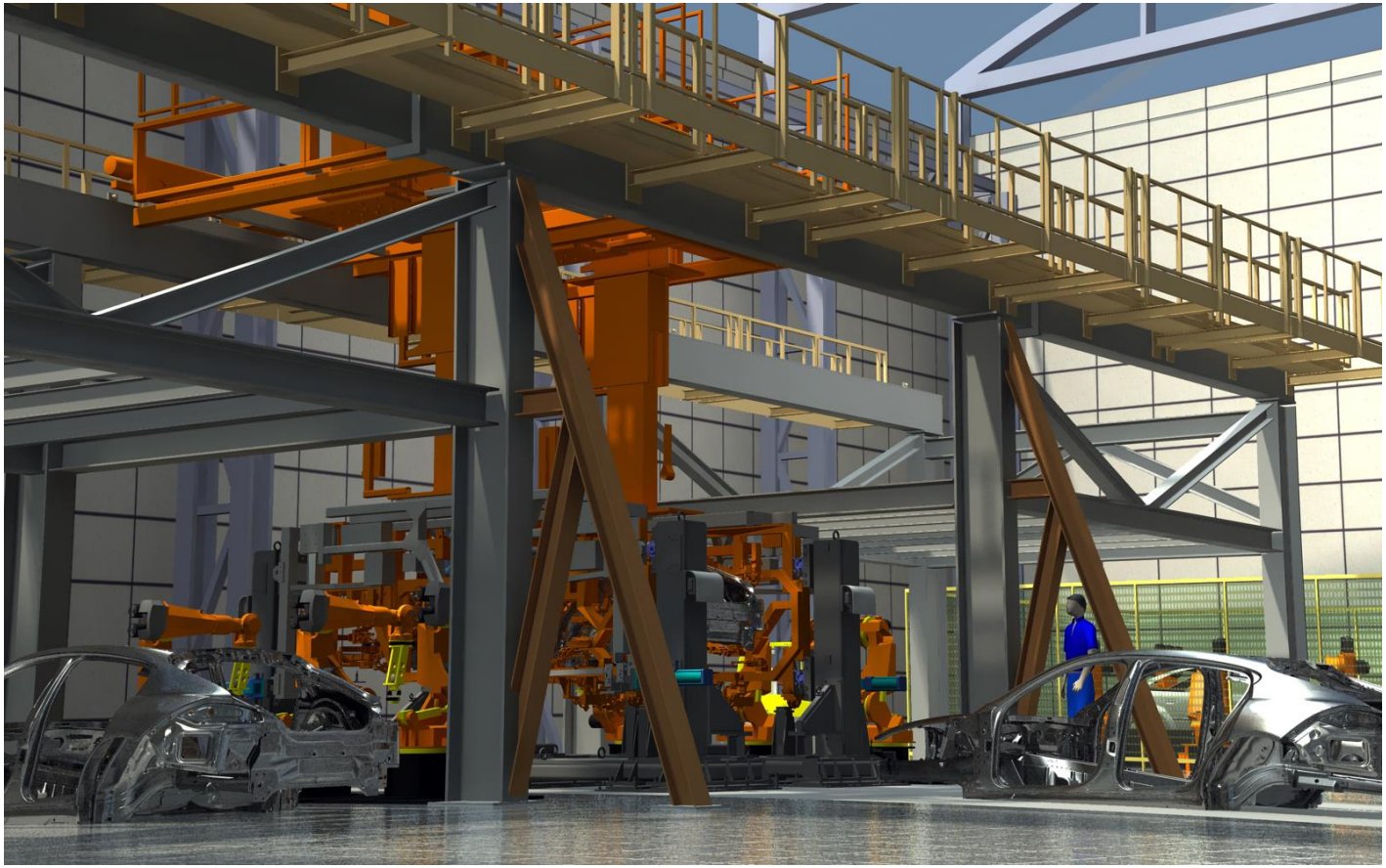
Ozone Hole

Studying the hole in the ozone layer:



Digital Factory

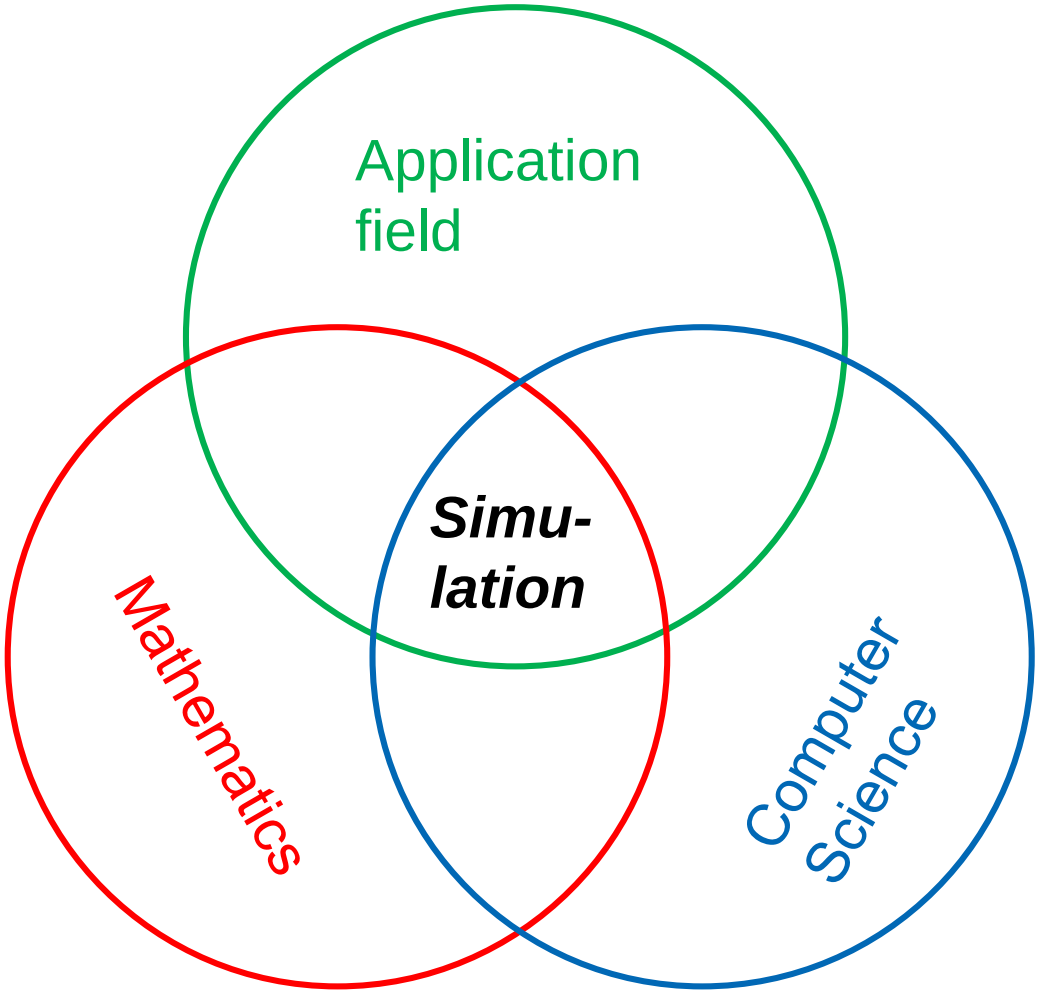
Design and virtual test of a factory before construction:



Crash Tests

Improving the safety of automobiles:

Simulation is Interdisciplinary



What Simulation is Not

Simulation is NOT generating pictures.

- (That is Computer Graphics.)
- CG can be used to illustrate the results of a simulation.
- Also Visualisation & Animation

Simulation is NOT Computer Games.

- However, some Computer Games contain simulations.

Simulation (in the scientific / engineering sense) is used to …

- discover things about the world,
- design systems.

Advantages of Simulation

Advantages of simulation:

- Doesn't interrupt running system
- Doesn't consume resources
- Test hypotheses
- Manipulate parameters
- Study interactions
- Ask "what if" questions

When to use Simulation

When to use simulation:

- Study internals of a complex system
- Optimise an existing design
- Examine effect of environmental changes
- System is dangerous or destructive
- Study importance of variables
- Verify analytic solutions (theories)
- Test new designs or policies
- Impossible to observe/influence/build the system

Difficulties of Simulation

Difficulties of simulation:

- Provides only individual, not general solutions
- Manpower: Time–consuming
- Computing: Memory– & time–intensive
- Difficult: experts are required
- Hard to interpret results
- Expensive!

A Classic Example

The bank model:

- Customers arrive at random intervals at a bank.
- There is only one cashier.
- Customers must wait in a queue.
- Service times at the cashier are also random.

Measured inter–arrival times (seconds):

- *25, 111, 56, 232, 97, 452, 153, 45, ...*

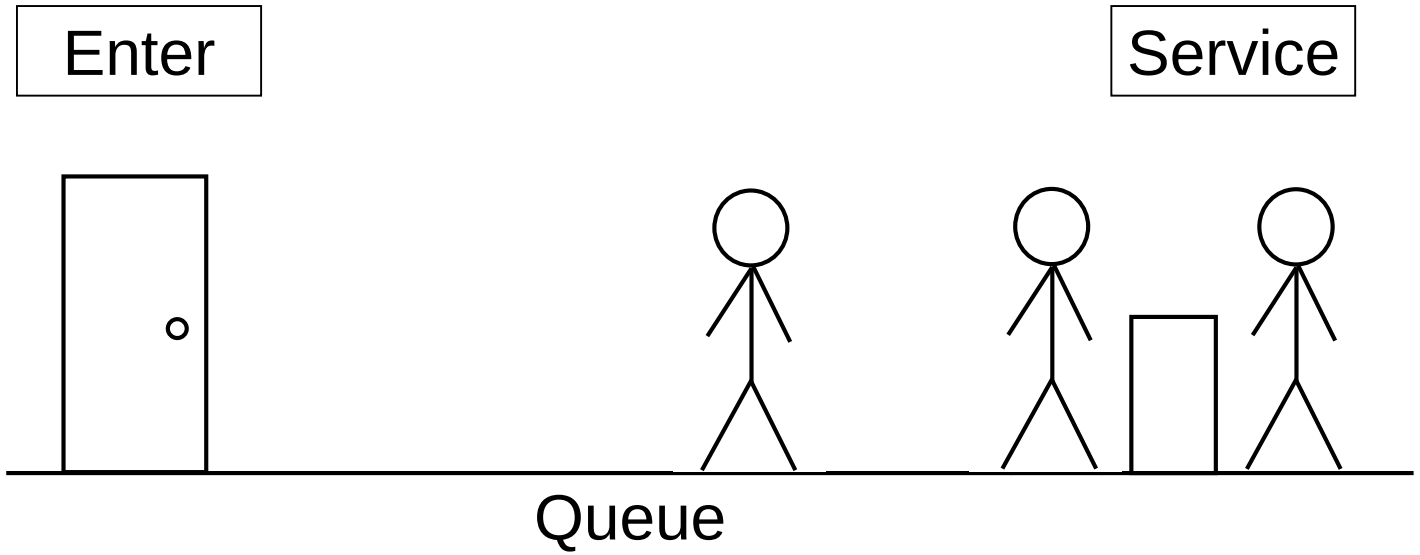
Measured service times (seconds):

- *45, 32, 11, 61, 93, 56, 30, ...*

A Classic Example

Compute...

- the average length of the queue,
- the probability that the cashier is busy.



A Classic Example

During the First World War, the population of fish in the Adriatic Sea went down.

This was surprising, because, owing to the war, there was less fishing going on (so you would think the number of fish would go up).

Volterra, an Italian mathematician, built a mathematical model to find out what was happening...

A Classic Example

Consider an area in which hares and foxes live.

Denote the population of hares by *h* and of foxes by *f*.

- Foxes must eat hares in order to survive.
- Hares have an unlimited supply of food.

The resulting equations are:

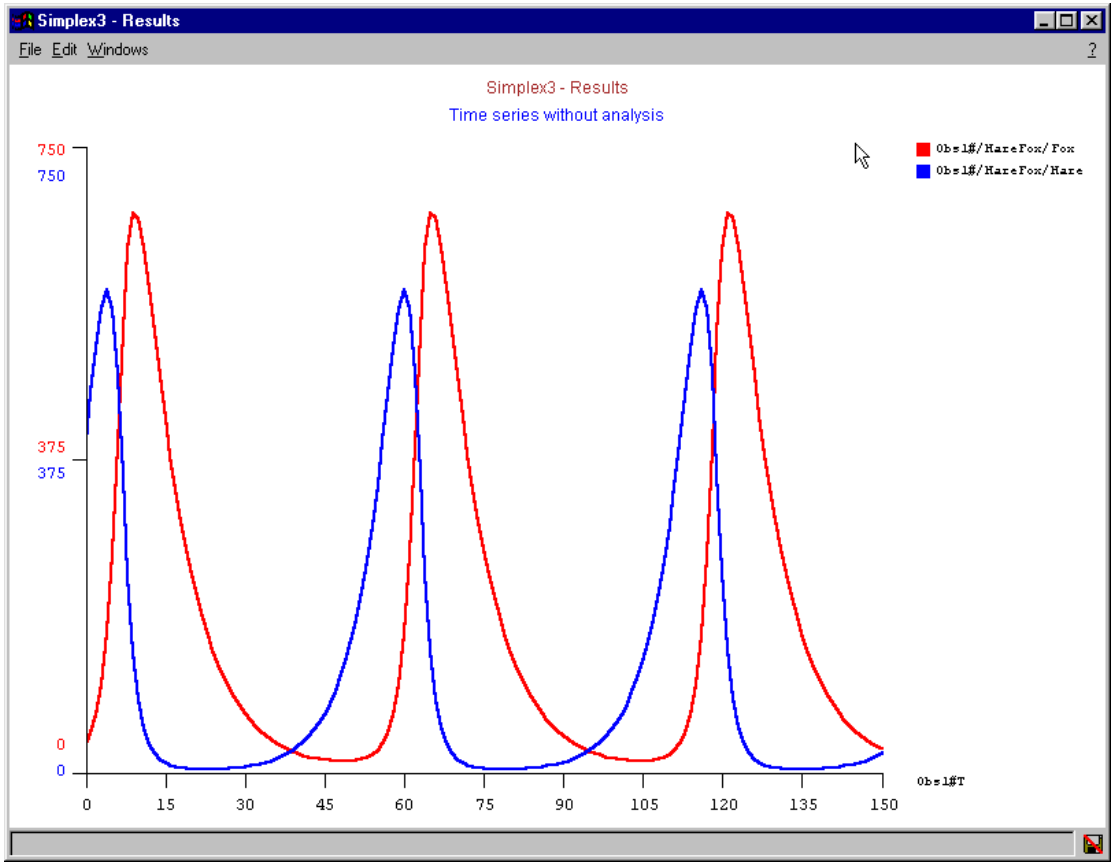
$$\frac{dh}{dt} = a \cdot h - c \cdot h \cdot f \qquad \frac{df}{dt} = -b \cdot f + c \cdot h \cdot f$$

(These are the so-called *Lotka–Volterra* equations.)

A Classic Example

Simulation results for parameters…

- $h(0) = 400$
- $f(0) = 37$
- $a = 0.175$
- $b = 0.125$
- $c = 0.001$
- $0 < t < 150$



Semester Assignment – The Sims

We are looking at a family of mom, dad and son.

Their moods depend on various factors:

- Mom's mood depends on her husband and son and on the family's savings.
- Dad’s mood depends on his wife and on his employment status.
- The son’s mood alternates between in love and heartbroken.

The family's peace is fragile:

- They are often on the verge of falling apart by either the parents getting divorced or being broke.

Semester Assignment – The Sims

You are a family therapist

- Keep the family peace until the son goes off to college.

Your suggestions are:

- Buy flowers for mom
- Have a drink
- Play the lottery
- Arrange a date for the son
- Work overtime
- Take a part–time job

Semester Assignment – The Sims

Create a simulation model for the described scenario.

- Use it to predict the family behavior.

Your task as a therapist is …

- to devise a strategy for applying the interventions.

The strategy must …

- maximize the probability of keeping the family together for seven years.

Semester Assignment – The Sims

Use your model to answer questions.

- For how long will the father be unemployed on average?
- How much money will be spent on damaged school property?

What is the probability that…

a) the family will be broke before college starts?
b) the parents will get a divorce?
c) they stay happy for seven years?

Semester Assignment – Star Trek

The Enterprise is trapped in a gravity well emanating from a nearby rift in the space–time continuum and is being slowly dragged into it.

- If we get too close to it, the ship will be destroyed.
- The warp engines are damaged. The repair crew has to be treated for plasma burns intermittently.
- A nearby shower of antimatter particles will hit us, causing damage to our shield. Deadly Theta radiation will penetrate the shields if they are not at full power.
- The USS Saratoga received our distress signal and will arrive at our position in just under five hours.
- The power produced by the engines can either be used to recharge the shields, or to keep the distance to the rift.

We must survive until that time or repair our warp engines.

Semester Assignment – Star Trek

You are the Enterprise science officer.

Your task:

- Devise a strategy for distributing the energy available between shields and engines which maximizes the survival probability.

Create a simulation model for the scenario.

- Use it to predict the survival probability of the crew.

Semester Assignment – Star Trek

Use your model to answer the captain's questions:

- What will the shield energy level be after 2 hours?
- How many antimatter particles will hit the shield?

What is the probability that...

a) the Enterprise will be rescued by the USS Saratoga?
b) the engineering team will repair the warp drive?
c) the crew will die of Theta radiation poisoning?
d) the ship will be destroyed because by loss of shields?

Comprehension Questions

Some questions from today's lecture:

- Explain some different types of simulation.
- What are some advantages of simulation?
- What are some disadvantages of simulation?
- In what situations is simulation typically used?