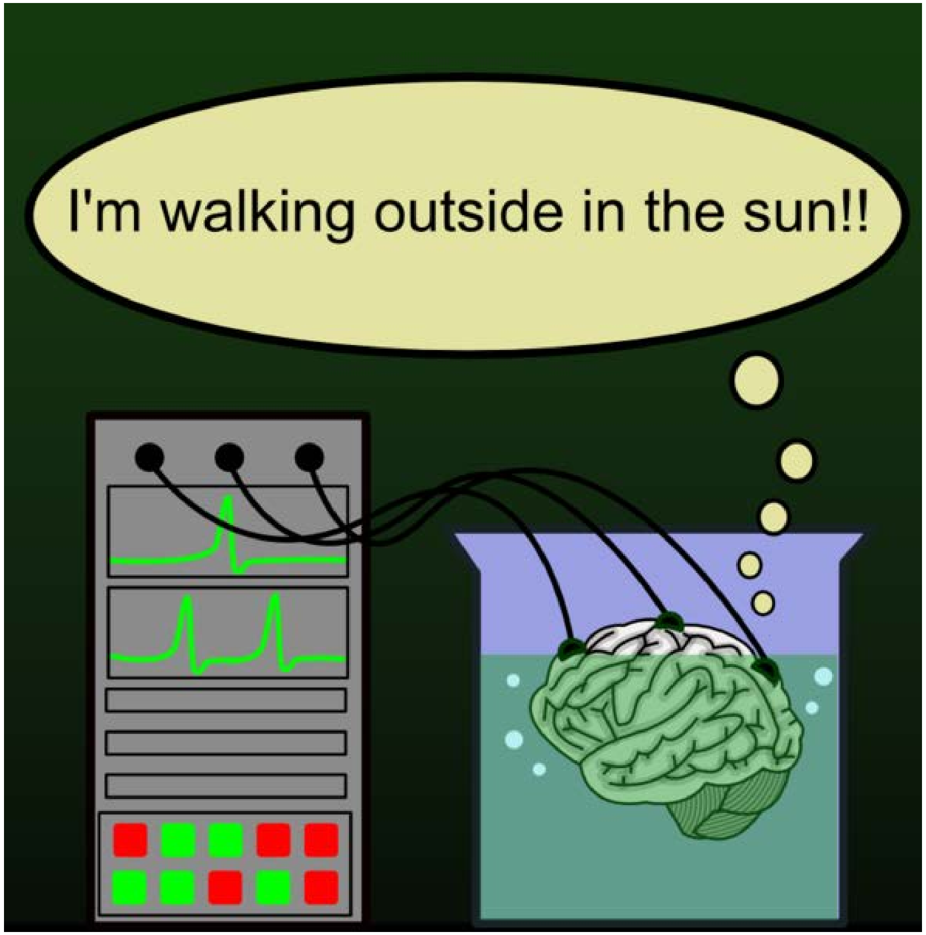
Introduction to simulation

- What is the reality
- Models
- History
- Clasification of the simulation models
- Basic elements on a simulation model
- Simulation model examples

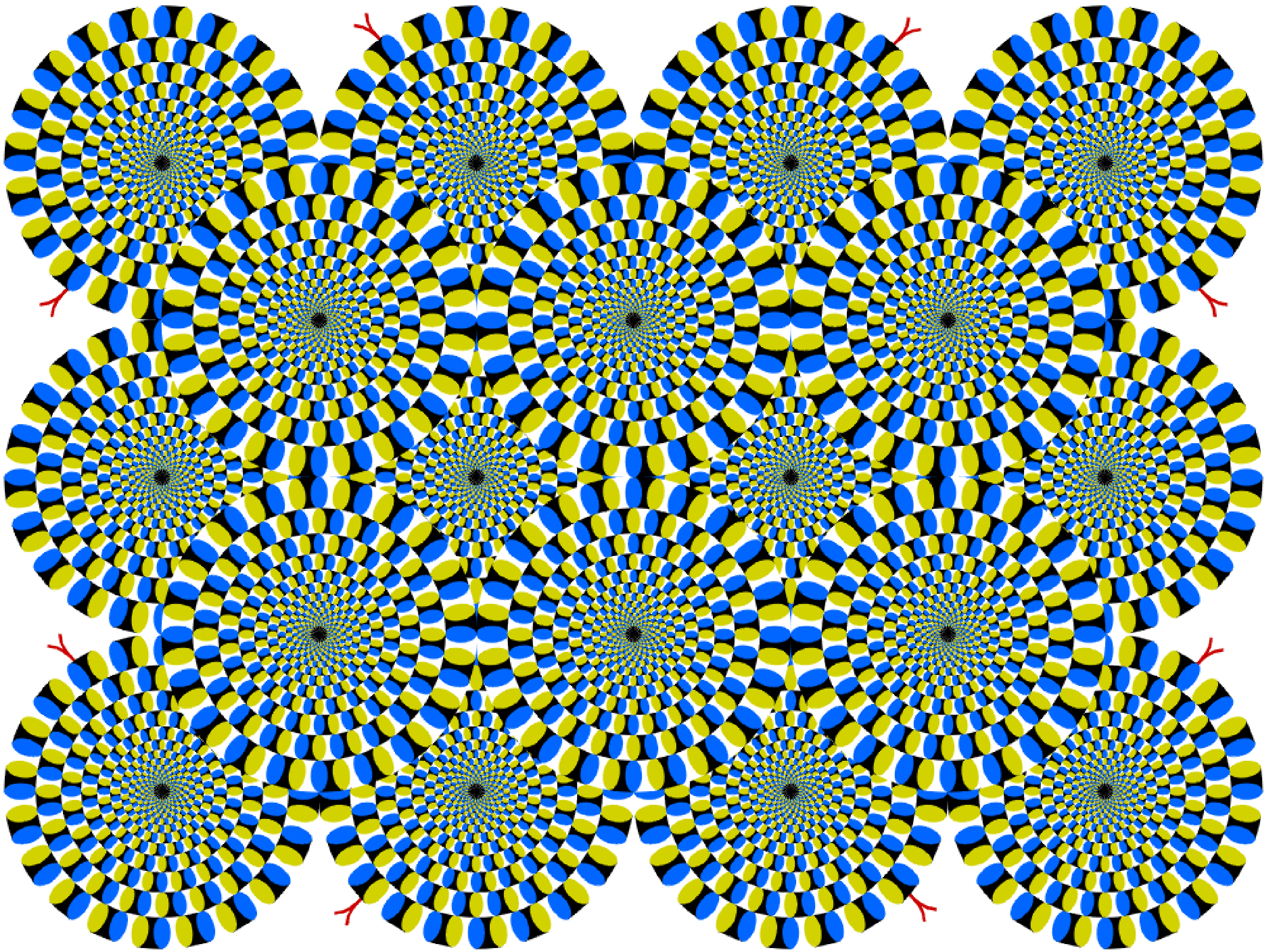
SIMULATION;
AN INTRODUCTION

Pau Fonseca i Casas, pau@fib.upc.edu

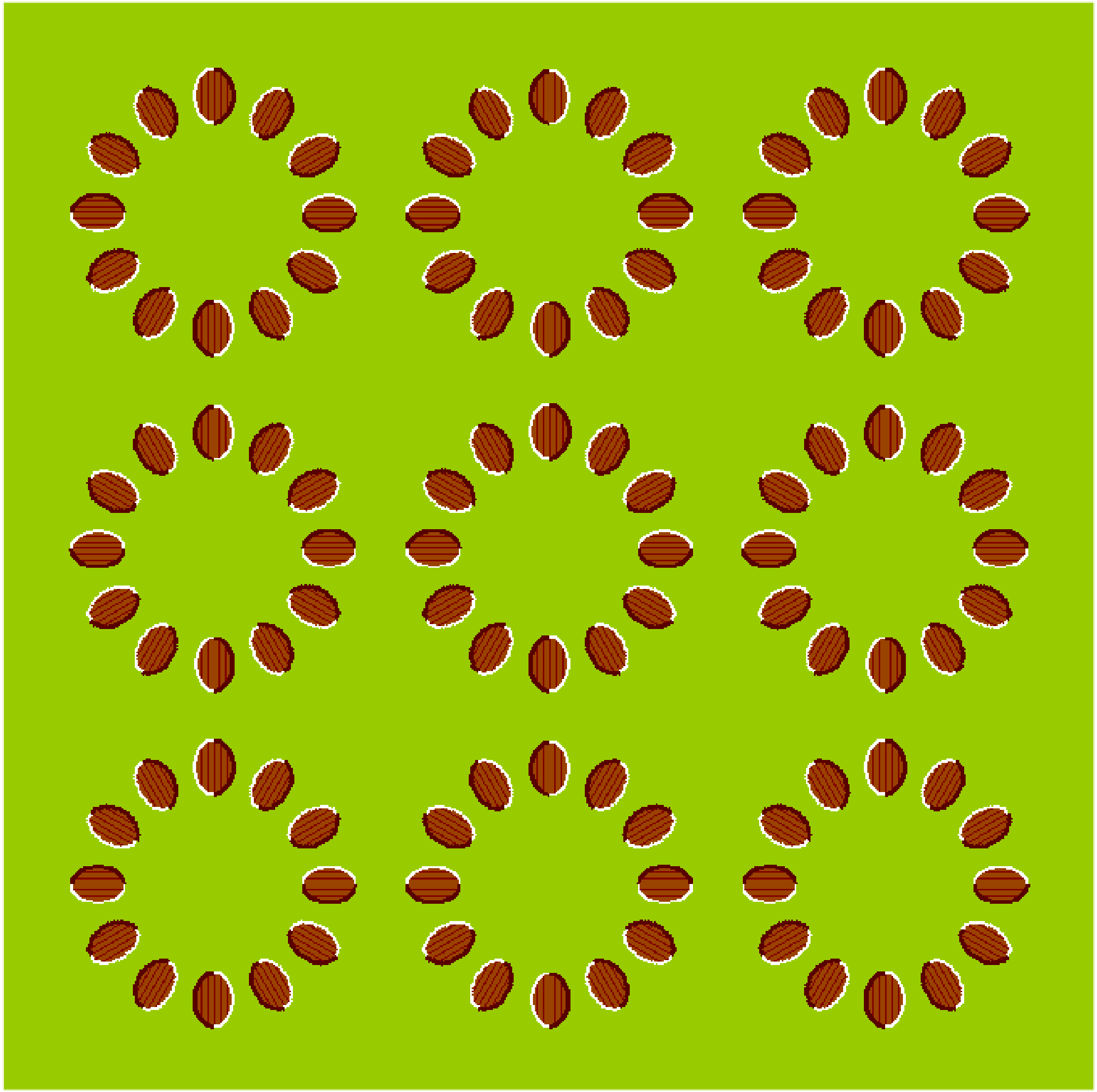
Reality



What is the reality?

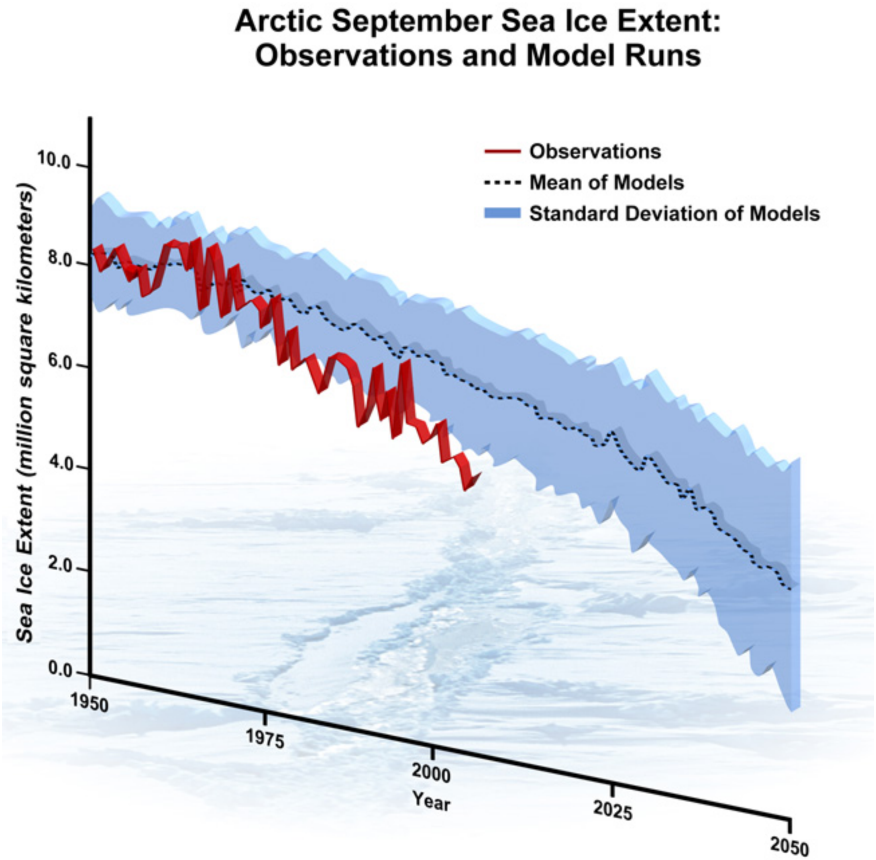


What the scientists do?



As an example

- Climatic change

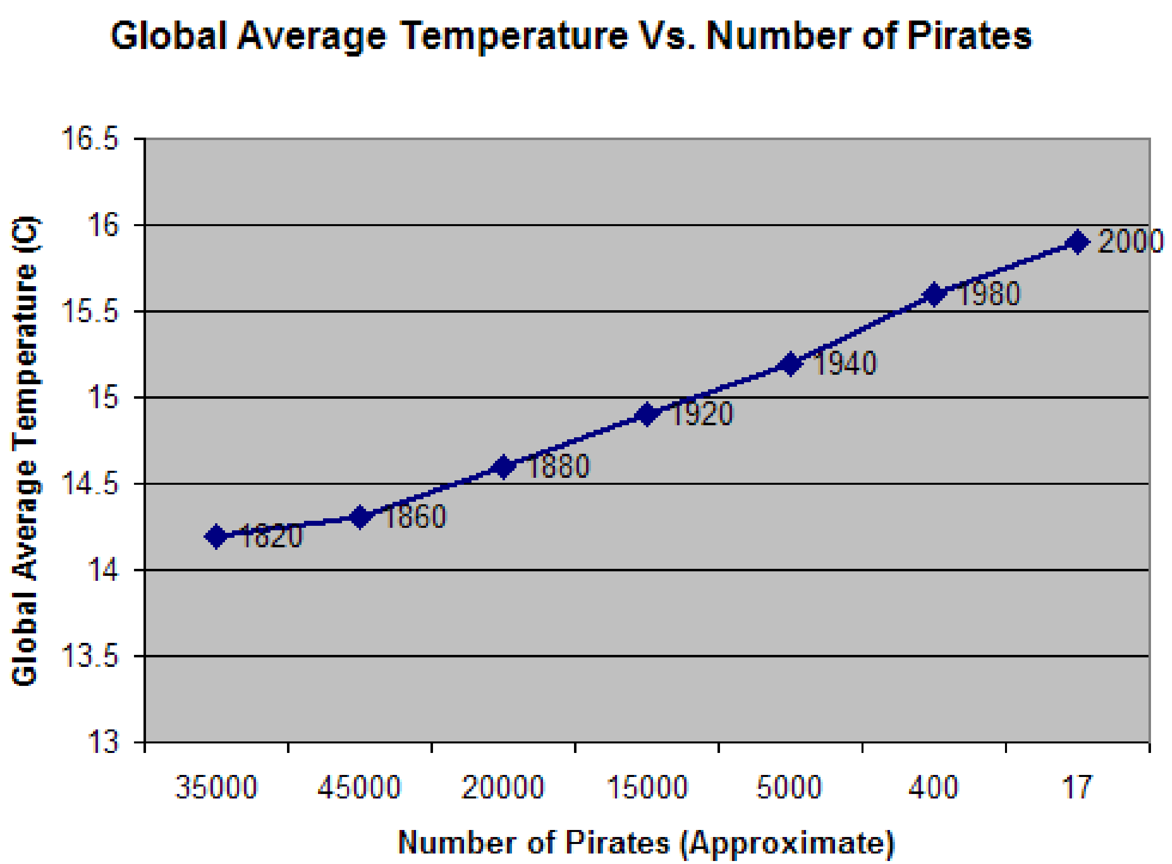


But…

- It is not so easy…

But…

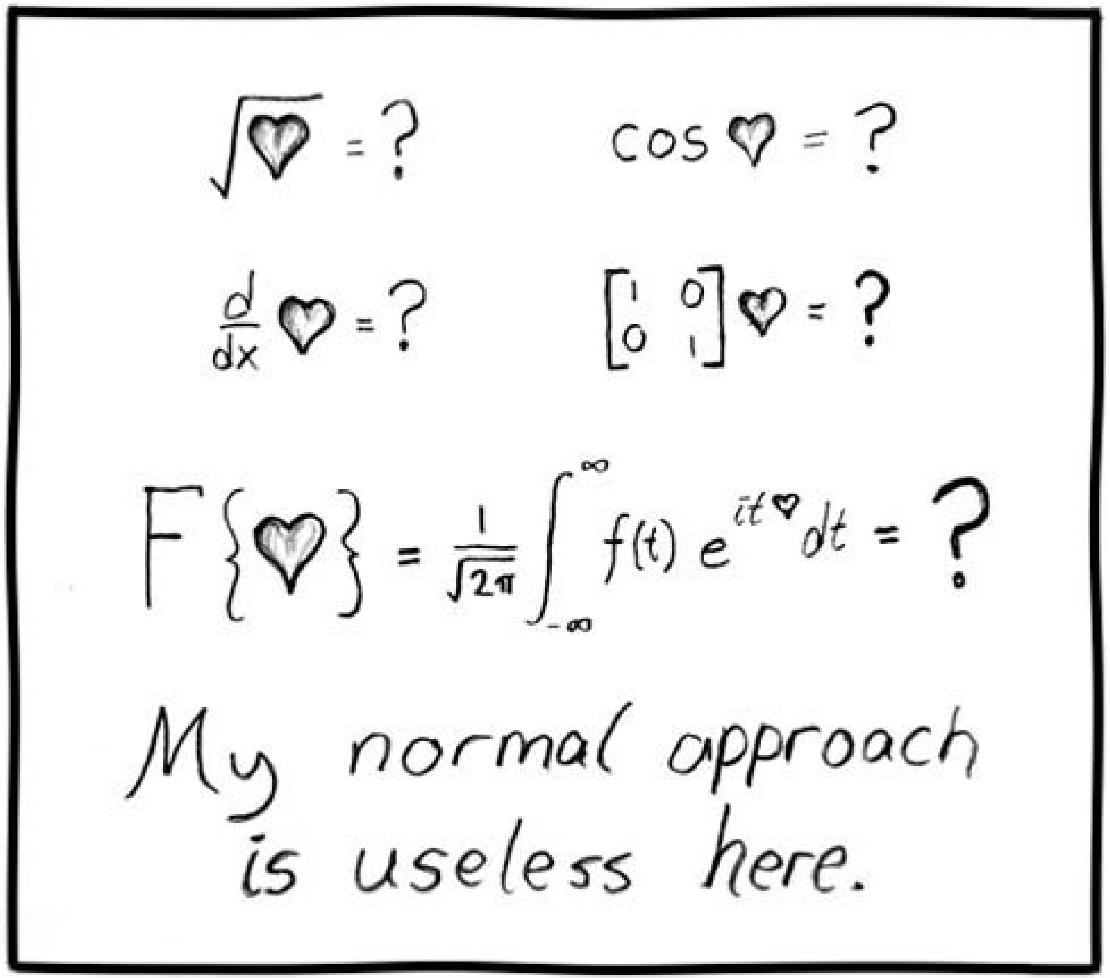
- Definitivaly, it is not to easy…



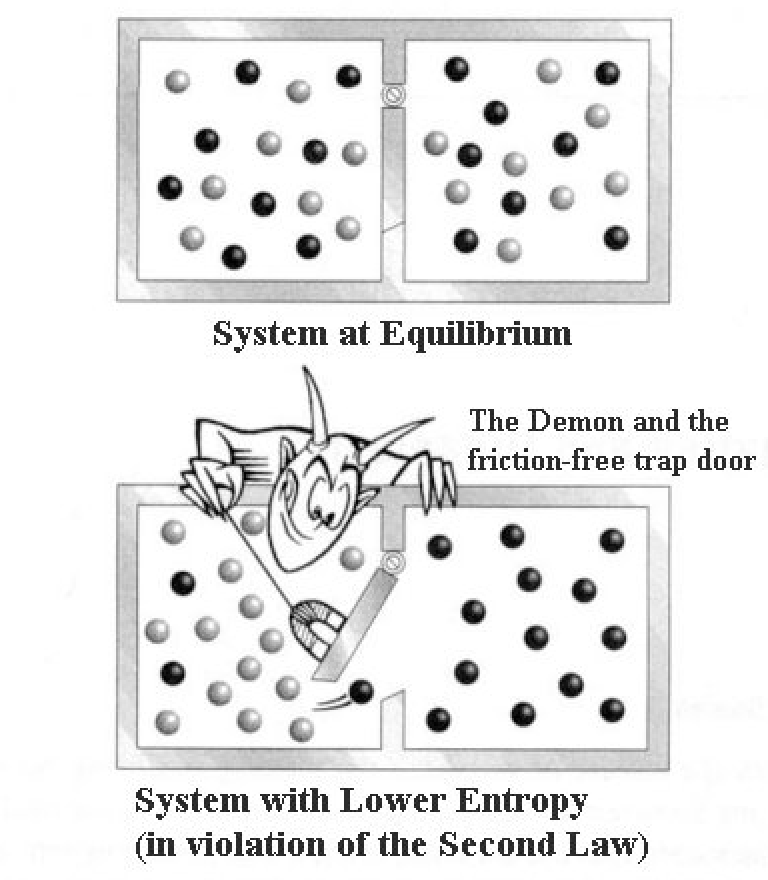
Models

Any kind of models.

What is a model?

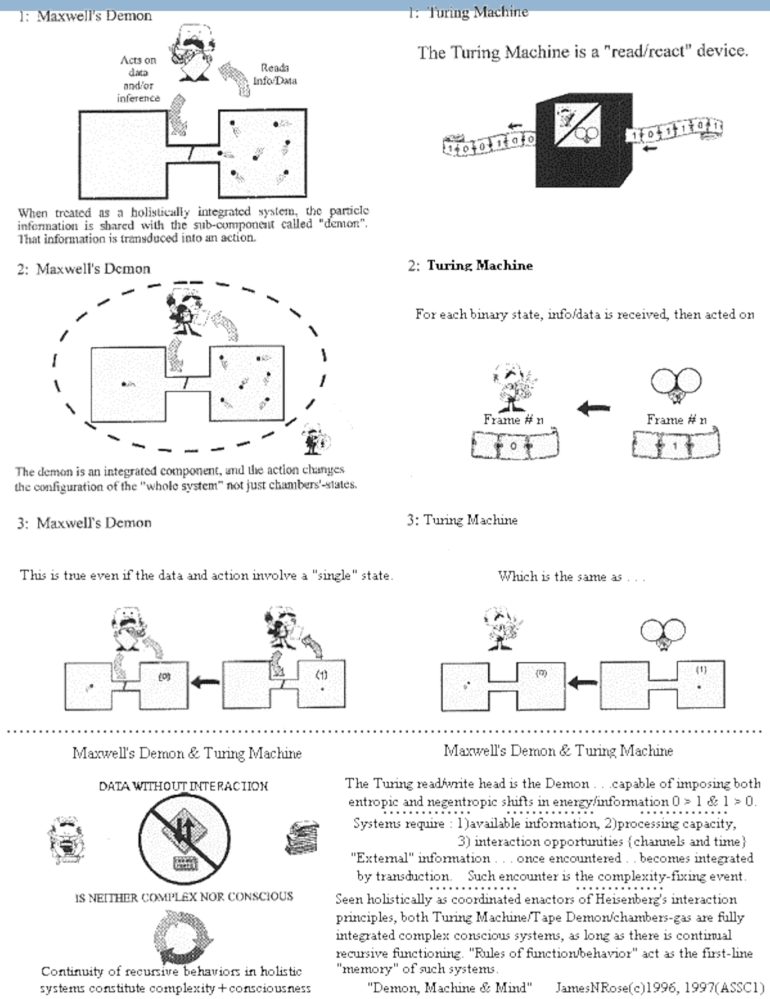


Models, experiments...



- Source: http://universe-review.ca/R01-02-z1-information.htm

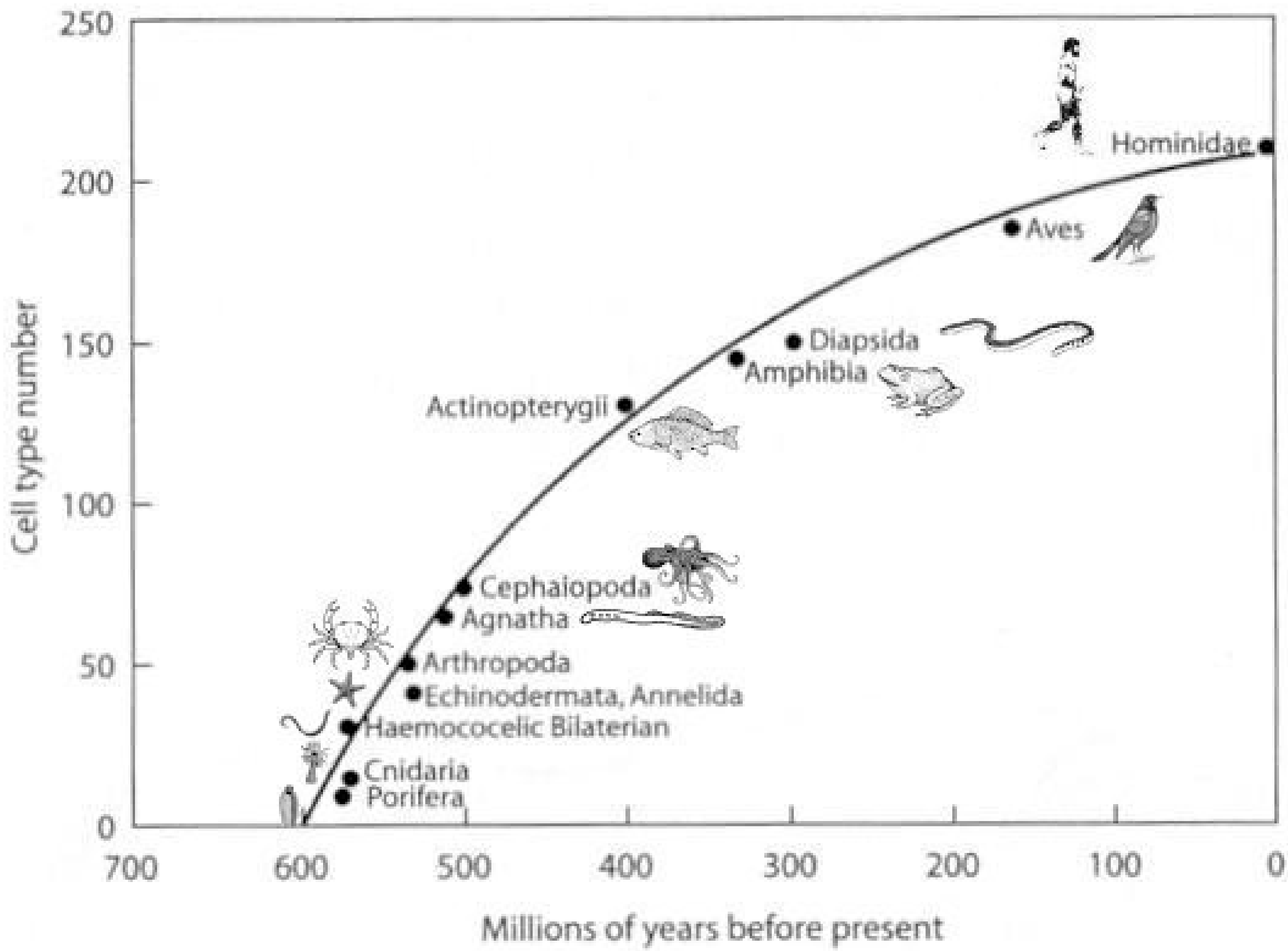
- Source: http://www.ceptualinstitute.com/uiu_plus/turingdemon.htm



Complexity

Complexity As	Definition	Example(s)	Problem
Size	Larger size means higher complexity	Size of body or genome	Some simple organisms have larger genome size than human's
Entropy	More variation signifies more complex message	HHH… has no variation and zero entropy, the random sequence DXW… has lot of variation	The most complex object is in between most orderly and complete randomness
Algorithmic Content	Shorter computer program to describe the object corresponds to lesser complexity	HHH… requires very short description, garbled message cannot be compressed	Random object leads to high information content
Logical Depth	Complexity is measured by how difficult to construct the object	HHH… is very easy to construct, while a specific message requires more work	It is difficult to measure the difficulty
Fractal Dimension	Higher fractal dimension equals to higher complexity	The coastal line is more complex than a straight line	There are other kinds of complexity not defined by fractal dimension
Degree of Hierarchy	Complexity is equated to the number of sub-systems	Organ to cells to organelles to macro-molecules to …	It is difficult to separate the whole into parts

Complexity


Cell type number
250
200
150
100
50
0
700
600
500
400
300
200
100
0
Millions of years before present
Hominidae
Aves
Diapsida
Amphibia
Actinopterygii
Cephalopoda
Agnatha
Arthropoda
Echinodermata, Annelida
Haemococelic Bilaterian
Cnidaria
Porifera

Complexity

System	Structure	Alphabetical Arrangement	Natural System	Order	Information
Randomness	random	HSIA TESHO SR I	molecules in the air	none	none
Order	periodic	HHHHHHHH HHH	crystal	lot	none
Complexity	aperiodic	HORSE THIS A IS	Nucleotides C, T, A, G	some	some
Specified Complexity	aperiodic	THIS IS A HORSE	Viable genes to produce proteins	lot	lot

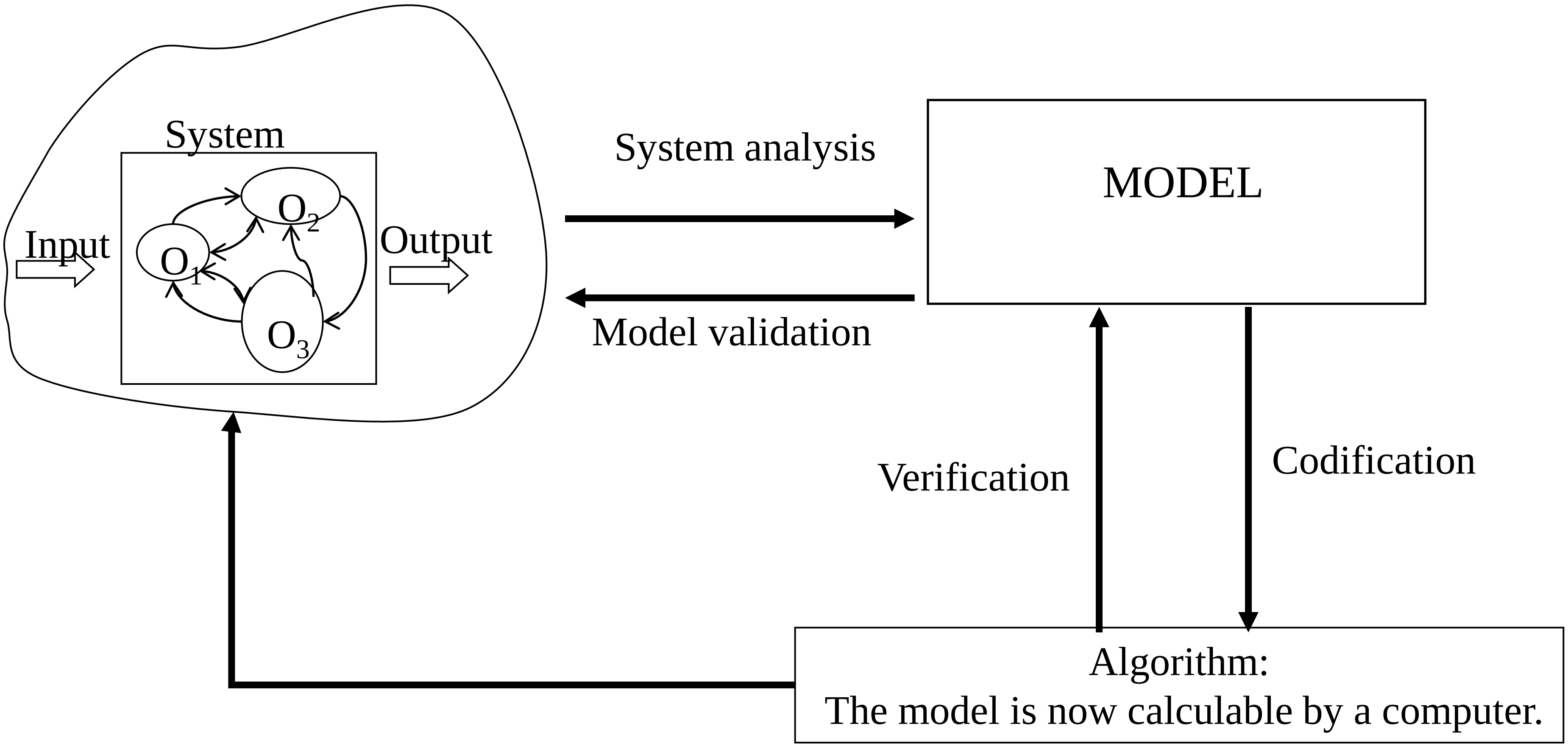
Kind of models

- Deterministic models
  - EDO's
  - Simplex
- No deterministic models
  - Queuing models (MEIO)
  - Markov models
  - Monte Carlos simulation models
  - Discrete simulation models
  - Continuous simulation models

Simulation

- *"We will define simulation as the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system and/or evaluating various strategies for the operation of the system.*" R. E. Shannon.

Models creation



Obtaining the answers.

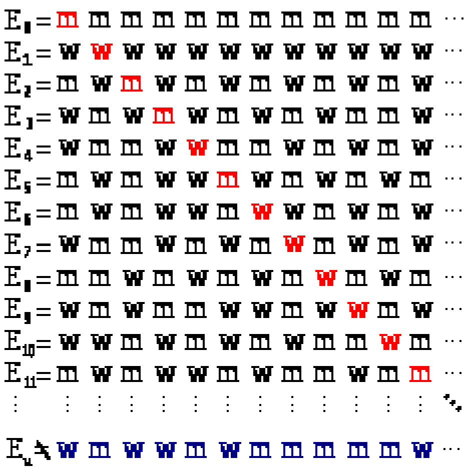
Implementation of the solutions.

Models are important

- Galileo Galilei
- Johannes Kepler
- Sir Isaac Newton
- Max Planck
- Albert Einstein
- Werner Heisenberg
- Niels Bohr
- Erwin Schrödinger
- Stephen Hawking

The language are also important

- Pitàgores de Samos
- Aristòtil
- Fermat
- Gottfried Leibniz
- Georg Cantor
- Lewis Carrol
- Hilbert
- Gödel
- John von Neumann



And the tool…

- Hero of Alexandria
- Ramon Llull
- Al-Jazari
- Leonardo
- Alan Turing
- George Stibitz

History

The origins of Operations Research

The development of the computers

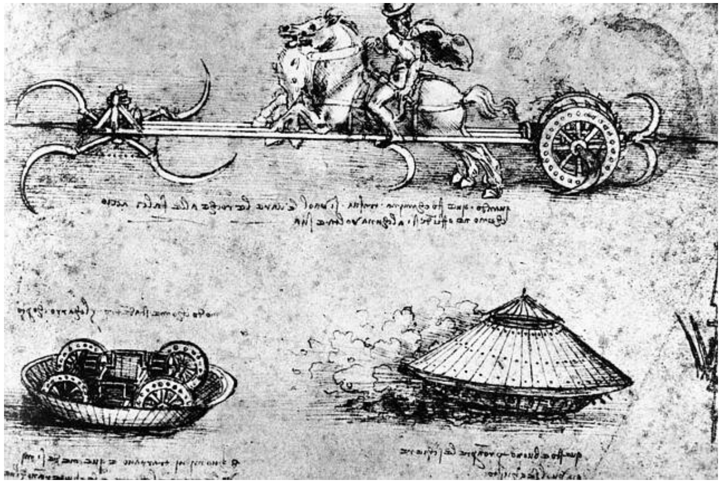
- Development of the computers during the 60's.
- Can treat problems till then untreatable..
- The increase of the calculus power of the computers allows that several scientific disciplines can use now computers. One of these disciplines is Operation Research.

The Punic Wars

- Applications of Archimedes based on their scientific knowledge in the defense of the city of Syracuse against the Romans (Second Punic War).
- The catapult, or an ingenious system of mirrors to burn enemy ships concentrating sunlight on them.

Leonardo's talent

- Leonardo Da Vinci, perhaps one of the most universal scientist that has ever existed, used his scientific knowledge as a military engineer.
- Leonardo was the first to develop a tank or a submarine.



Narcís Monturiol i Estarriol

- By the way…
- “Ictineo I” replica at the Museu Marítim in Barcelona.

Penny Post

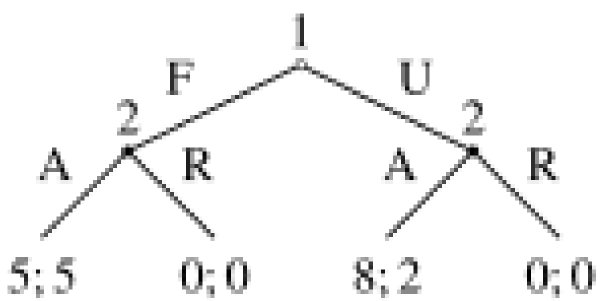
- The "Penny Post" was a system that allows you to send postal letters from a penny (UK).
- **Charles Babbage** was one of the earliest proponents of operations research, through research that was developed to determine the costs related to the transport and planning of the "Penny Post".

Lanchester Laws

- Later Frederick **William Lanchester** developed the "Laws of Lanchester" to determine the forces of a “predator prey system” that was applied to military clashes in the framework of the First World War. These laws were intended to predict the behavior of the air battles. In 1916 he published his ideas about air battles in a book entitled "Aircraft in Warfare: the Dawn of the Fourth Arm", including in the form of differential equations the Lanchester Laws.

Game theory

- In 1928 **John von Neumann** published his work on game theory. This work provided the mathematical foundations for linear programming.



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	Trair	1 \ 10	5 \ 5

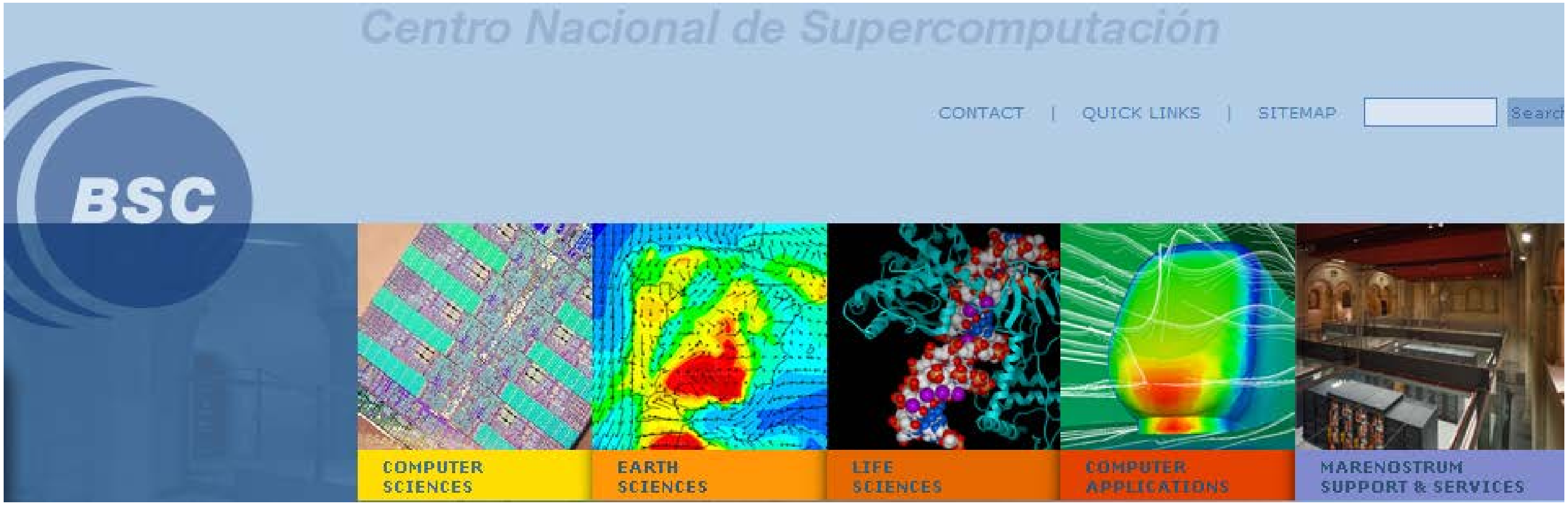
The problem of the diet

- Another interesting application was raised by George Joseph Stigler, in the late 30's and early 40's, "the problem of diet." This issue arose from concerns about the U.S. military to ensure adequate nutritional requirements at the lowest possible cost for their troops.

The Second World War

- The research station of **Bawdsey**
- The **"Circus Blackett."**
  - Convoys.
  - Protection of aircraft bombers.
  - Antisubmarine mines.
- **Frank Yates** and agriculture.
- **George Bernard Dantzig.**

Now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2 Jaguar - Cray XT5 QC 2.3 GHz
3 Pleiades - SGI Altix ICE 8200EX, Xeon QC 3.0/2.8 GHz
4 BlueGene/L - eServer Blue Gene Solution
5 Blue Gene/P Solution
6 Ranger - SunBlade x6420, Opteron QC 2.3 Ghz, Infiniband
7 Franklin - Cray XT4 QuadCore 2.3 GHz
Jaguar Chases Roadrunner, but Can't Grab Top Spot on Latest List of World's TOP500 Supercomputers
Fri, 2008-11-14 05:56
The 32nd edition of the closely watched list of the world's TOP500 supercomputers has just been issued, with the 1.105 petaflop/s IBM supercomputer at Los Alamos National Laboratory holding on to the top spot it first achieved in June 2008.
The Los Alamos system, nicknamed Roadrunner, was slightly enhanced since June and narrowly fended off a challenge by the Cray XT5 supercomputer at Oak Ridge National Laboratory called Jaguar. The system, only the second to break the petaflop/s barrier, posted a top performance
APPRO
AMD Opteron
Xtreme-X2 Supercomputer
Reduce TCO with Green Architecture
Statistics
Charts
Development
Top500 List:
11/2008
Statistics Type:
Vendors
DELL
Scale out to 1000TF of computing power
Innovation that matters.
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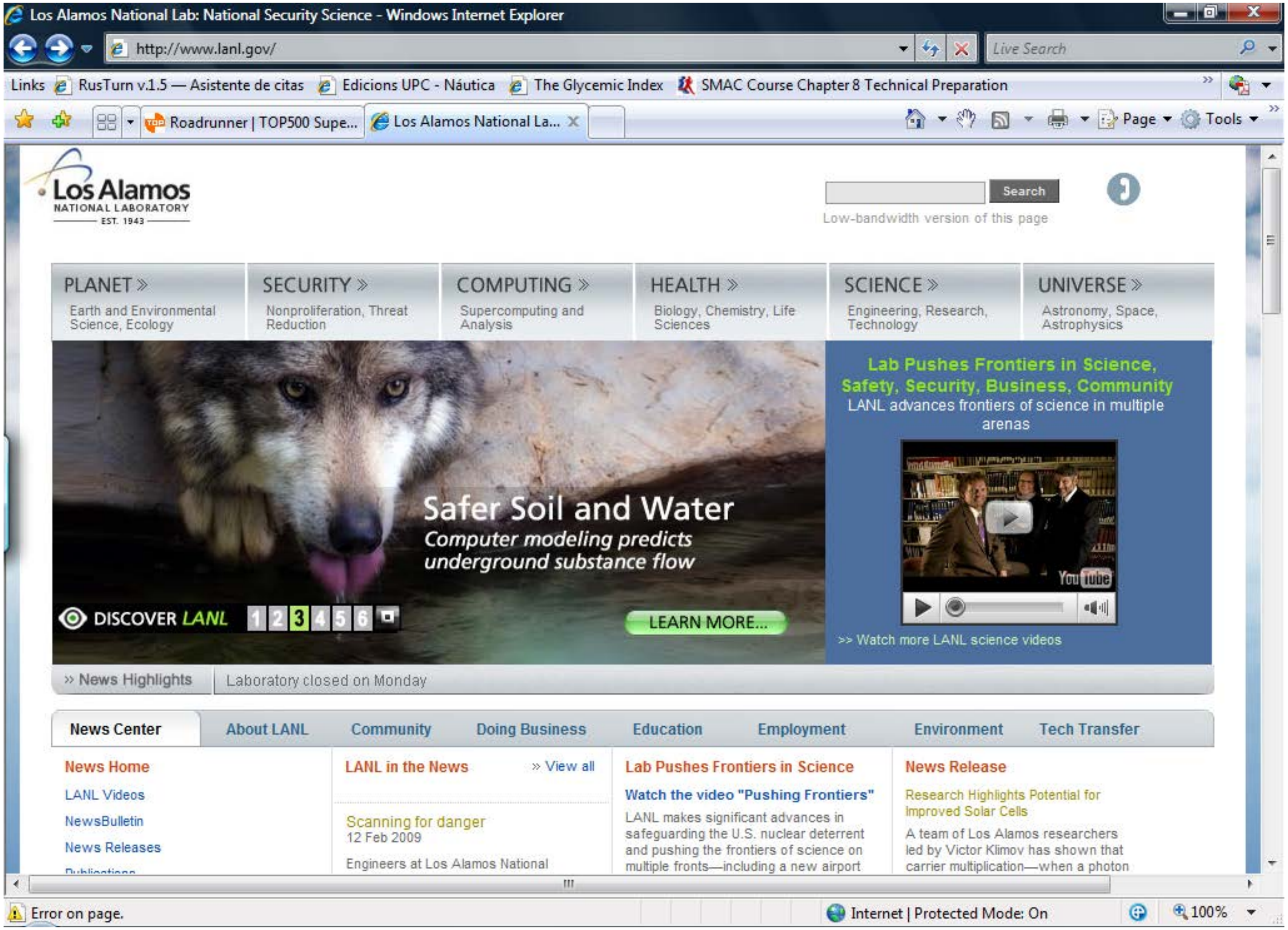
Now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Classification of the simulation models

Basic criteria to classify the different simulation models we can find.

Regarding the actors involved

- **Person - Person**: Simulations of a social nature studying on reactions of people or groups. For example: Training for job interviews.
- **System**: Simulations where a is reproduced physically a physical system (or chemical, biological, etc.), under controlled conditions.

Regarding the actors involved

- **Person – computer:** Simulations where the person answers some questions raised by the computer. For example: Training through financial strategy games, flight simulators, etc..
- **Computer:** Do not require interaction. From an entry, a program (set of decision rules) transforms the output obtained. Normally respond to stochastic systems.

Regarding the paradigm

- ***Monte Carlo*:**
  - Time usually is not involved, are based on randomness and probability. As an example the calculus of the PI value.
  - *It is possible to find some examples of these methods on:*
    - *http://landau.mines.edu/~jscales/inverse/node154.html*
    - http://www.angelfire.com/wa/hurben/buff.html
- **Continuous simulations:**
  - Systems that uses algebraic or differential equations that depend on the time continuously. As an example *Tom i Jerry* (or *predator - prey*) systems.
- **Discrete event simulations:**
  - They are characterized by the existence of blocks of time in which “nothing happens“. Only certain events causes a modification in the state variables. For example: study of a toll or an ATM.

Simulation model examples

System simulation, Person by person simulation, computer simulation.

System simulation

Mòdul de la estació espacial internacional.

System simulation

Mòdul de la estació espacial internacional.

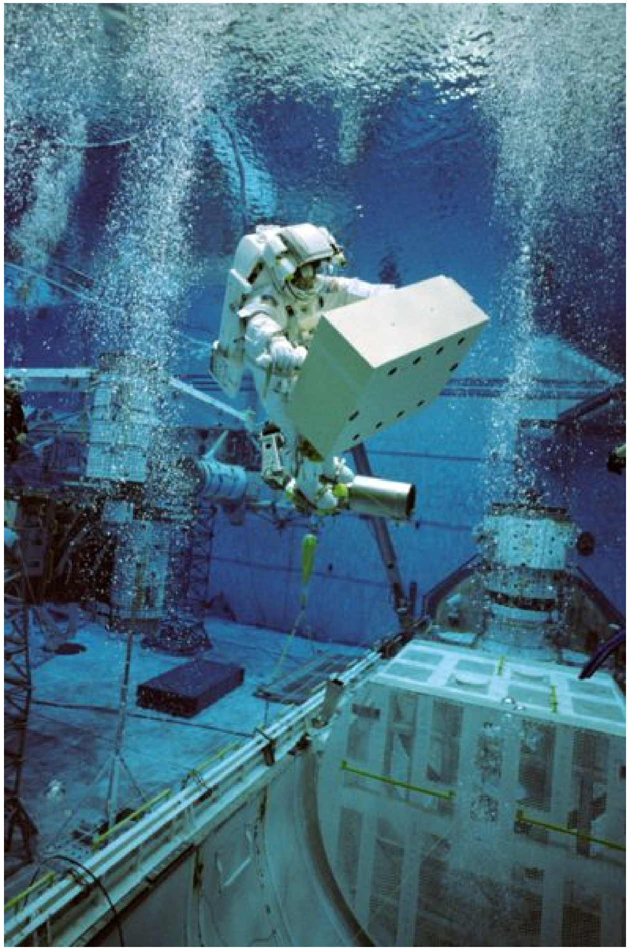
System simulation: FMARS

- In order to help develop key knowledge needed to prepare for human Mars exploration, and to inspire the public by making real the vision of human exploration of Mars, the Mars Society has initiated the Mars Analog Research Station (MARS) project. The Flashline Mars Arctic Research Station is the first station in this project.

Model de sistema: FMARS

- http://www.fmars2009.org/

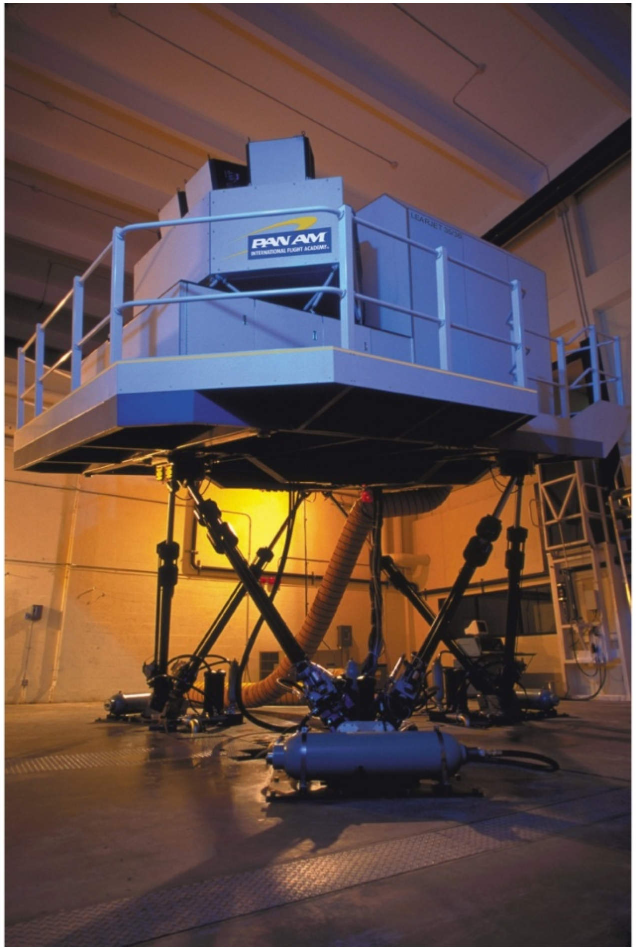
System simulaton



System simulation

Person – computer simulation

Person – computer simulation



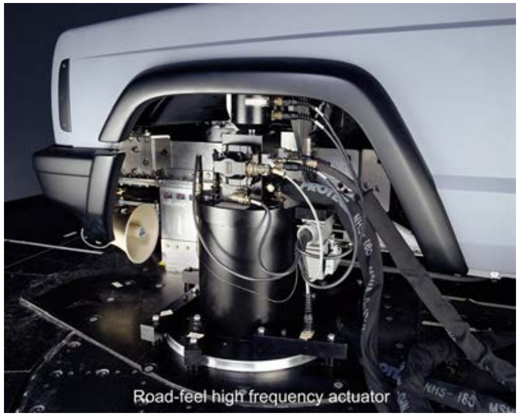
Learjet simulator
Pam Am International Flight Academy

Person – computer simulation

- Keesler AFB
- Air traffic control.
- Simulations of the radar tower.

Person – computer simulation

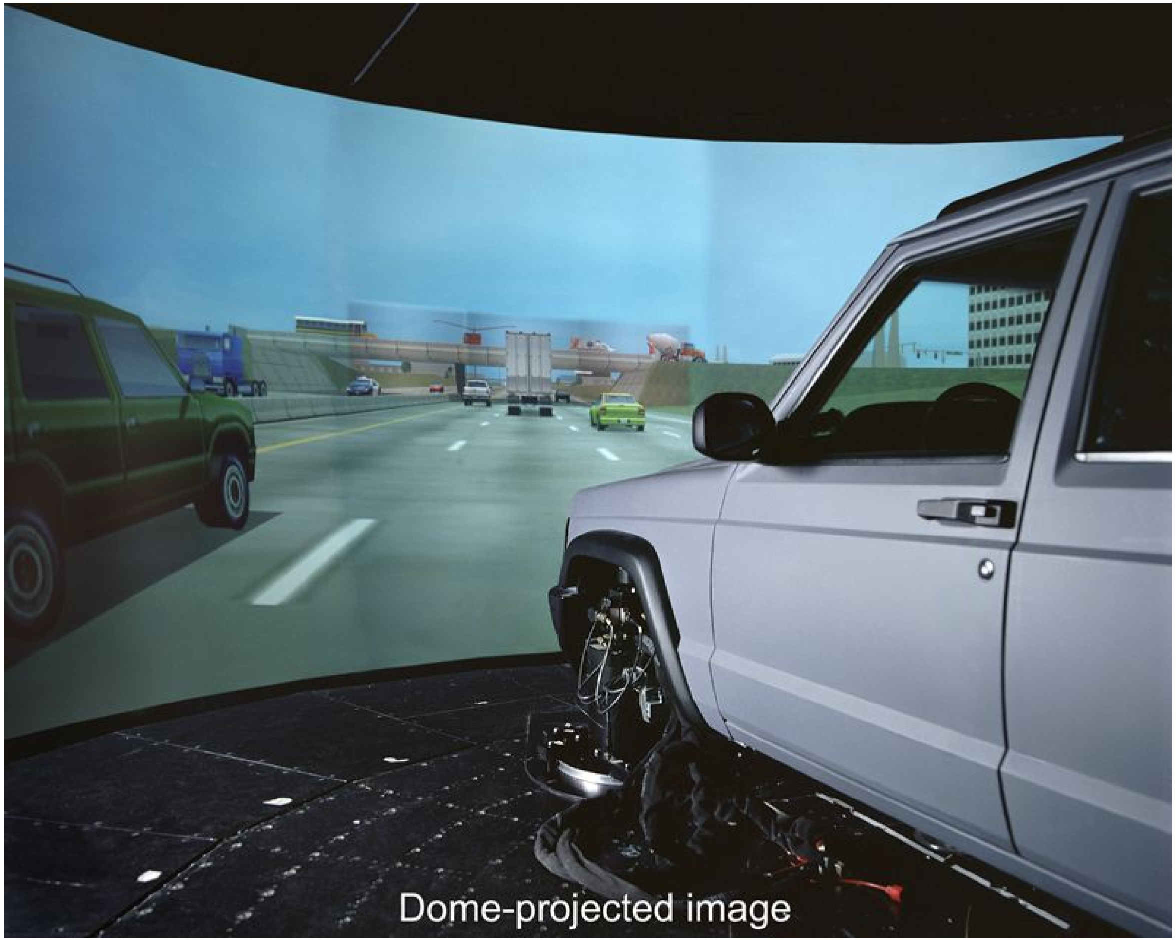
Jeep Cherokee cab in dome



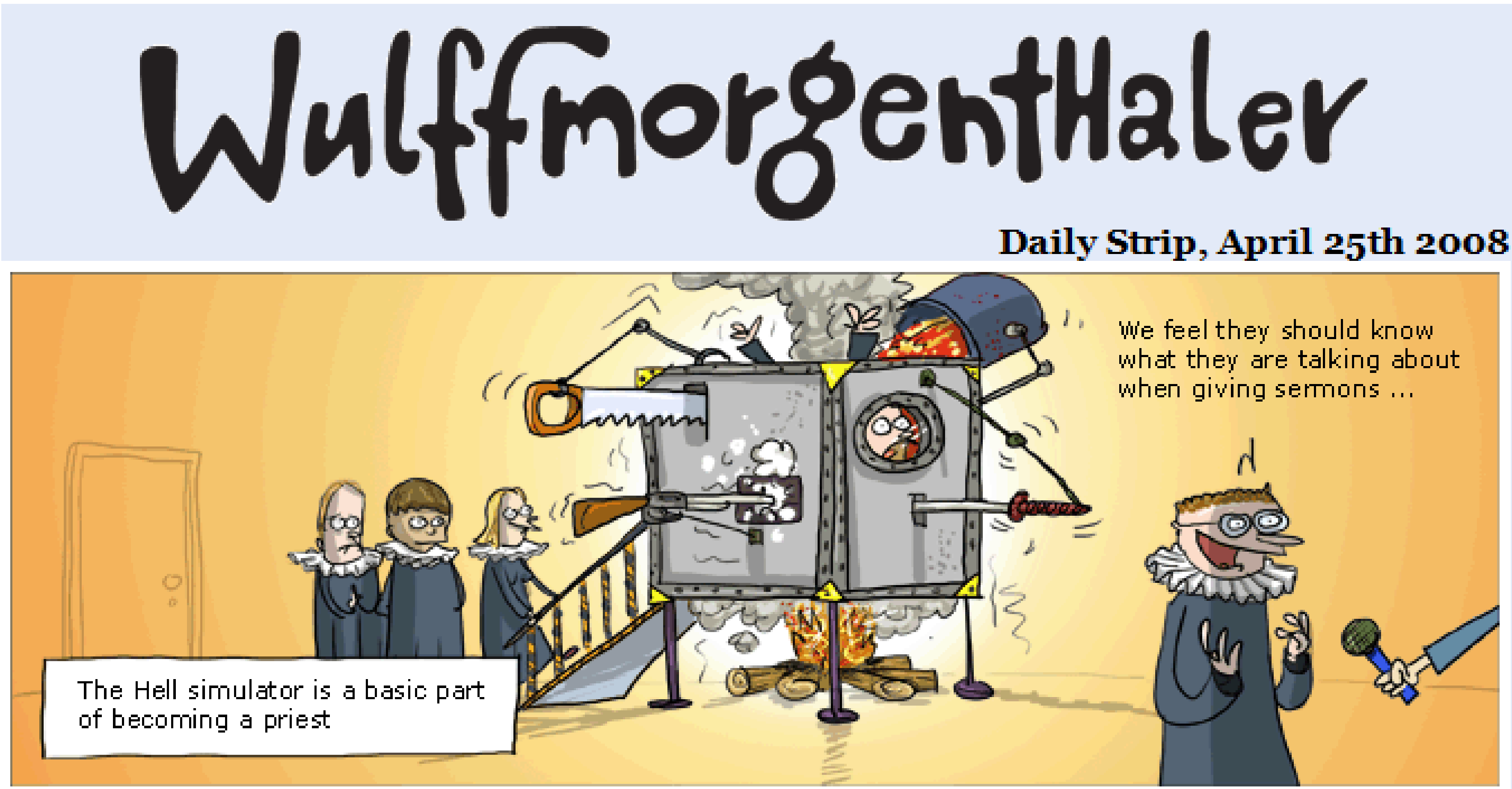
Road-feel high frequency actuator

NADS (National Advanced Driving Simulator)
University of Iowa, Iowa City, USA
http://www.youtube.com/watch?v=Bi_GkDqON_s

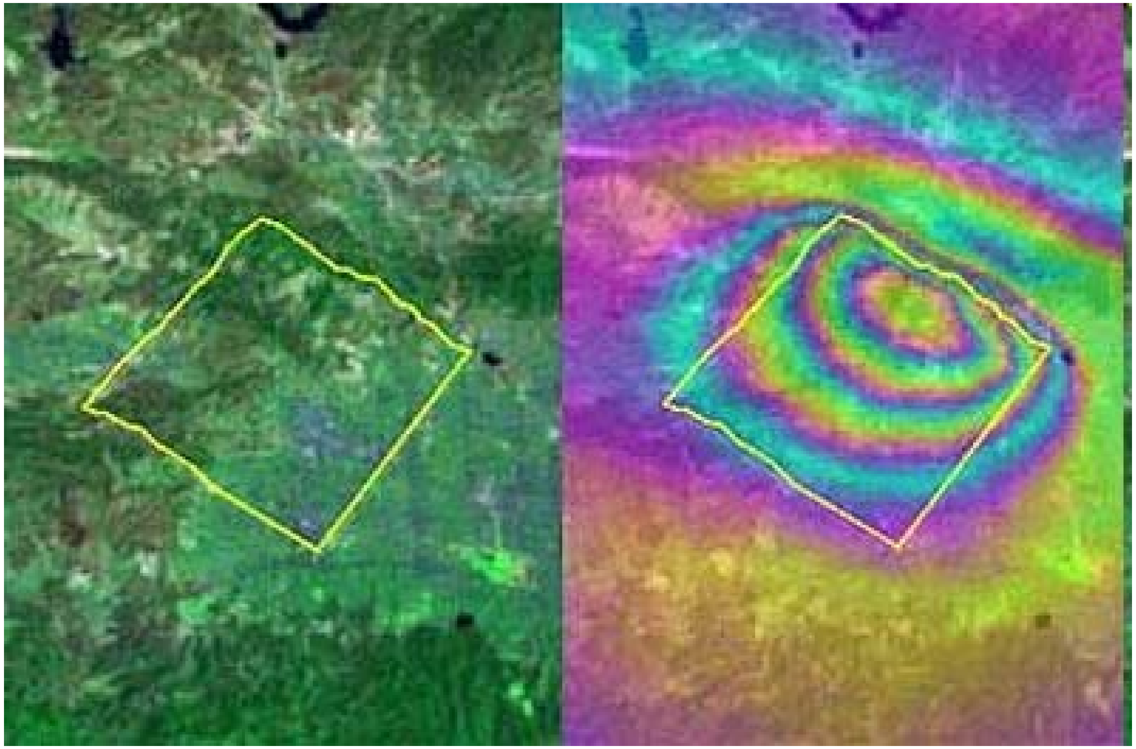
Person – computer simulation



Person – computer simulation !!



Computer simulation



Basic elements of a simulation model

The “LEGO®” pieces

Typical simulation objects

- Basic elements of a discrete simulation model:
  - Entity
  - Activity / Machines / Operations
  - Processes

Entity

- Element that is present on the system that receives one (ore more) actions.
  - There is no sense to define entities without actions. In that case they do not belongs to the model.
- It is needed to define its processes.
  - Each entity can participate in many (at least one) processes.
- It is needed to define the attributes of the entity.
  - Each entity own n attributes.

Entity

- Useful statistical information
  - Lifetime (time that the entity remains in the system).
  - Machines of its path.
  - Time spam in each machine.
- Type of entity
- Destinations route

Processes

- Set of operations performed on an entity in a subset of the simulation objects.
  - The subset cannot be empty
  - May contain all simulation objects
- Two ways to achieve this
  - From the point of view of the machines
  - From the point of view of the entities

From the point of view of the machines

- The model machines defines the movement of the entities
  - The best
    - Simple entities, less resources needed
  - The worse
    - More complex machines, they must contain the route logic.
    - It is difficult to add new type of machines.
    - The vision of the route is lost.

From the point of view of the entities

- The entities know its route
  - The best
    - Simple machines
    - Exists a complete vision of the model processes
  - The worse
    - More complex entities, more resources needed
    - It is needed an object to implement the entities

- As we can see, this approach is often the approach used in MAS systems.

Some examples

- From the point of view of the entities
  - GPSS/H®
  - SimProces®
  - LeanSim®
- From the point o view of the machines
  - Witness®

Some typical simulation objects

- Generators.
- Destructors.
- Machines (simple, complex).
- Resources
- Conveyors
- Routes
- Depending on the simulation engine many different objects can exists, that can represent a closer approach to the real system element (depending on the scope)

Generic features of the machines

- Some generic features of the “machines” can be:
  - State
    - Shows the state of the machine in each unit of time
    - Needed to define the different states of the machine
  - Number of elements in the queue
    - Showing the number of elements in the queue
  - Related statistical information
    - What statistical information we acquire?.
  - Object type
    - What represents this object?

Generic features of the machines

- Other features can be
  - Attributes
  - Signals
  - Breakdowns
  - Operation
  - Queues (maximum and minimum values)
  - Representation

Generic features of the machines

- It is needed to define what are the objects of the system that belongs to the model
- It is needed to define how these objects behave (define its states, signals, events, etc.).
  - SDL diagrams, Petri Nets, DEVS, it is needed a formal representation of the model elements

Generator

- Adds elements in the model
- We can define:
  - Time between generations *
  - Size of the generations *
  - Maximum quantity of elements to generate
  - Schedule
  - Etc.

Destructor

- Eliminates the entities of the model and actualizes its statistical information
- We can define
  - The time needed to perform the operation

Simple machine

- Is a resource that often have a delay related
- Only one entity by time spam can be served
- We can define
  - The delay *
  - The size (lot) of the entities *
  - The entity type to be served
  - The entity type that leaves the machine
  - Etc.

“Complex” machine

- In fact is a set of resources with a delay
- A set of entities by time spam can be served
- We can define
  - The number of entities to be served together
  - The delay *
  - The size (lot) of the entities *
  - The entity type to be served
  - The entity type that leaves the machine
  - Etc.

Resources

- Elements needed to do some activity
- They can be
  - Fixed, the resources are not spent
  - Consumables, the resources are consumed due to its use
- We can define
  - The number of resources *
  - The entity type that can use the resource
  - The machine type that use the resource
  - Etc.

Transports

- Elements that allows to represent the movement of entities from one place to another
- Often defined over a MATRIX, a PATH or a GRAPH
- We can define
  - The structure of the paths *
  - The delay related to the movement *
  - The number of entities that can travel from one point ot another
  - Etc.

Simulator

- The simulator have these elements (mot related to the system behaviour definition)
- Simulation clock
- Simulation engine
- Event list
- Entity
- Simulation objects library

How to build a simulation model

Some rules to keep in mind

Construction of a simulation model

- Entities identification
- Identification of the objects, simulation machines
- Identification of the processes
- Configuration of the simulation objects

Lean Simulation

- Also it is needed to define the paradigm and it is needed to build the elements of the simulation environment
  - Simulation clock
  - Simulation engine
  - Event list
  - Entity
  - Simulation objects library

Simulation study main stages

Formulation

- Problem formalization
- Data acquisition

Codification

- Codification of the model
- First tests and executions

Use

- Experiments design
- Executions of the simulation model in production environment

Some simulators

- http://www.eai.com/solutions/VF/
  - Virtual Factory
- www.lanner.com
  - Witness
- http://www.caci.com/
  - Gestora
- http://www.simprocess.com/
  - Simprocess i simscript.
- http://www.adeptscience.com/products/mathsim/vissim/
  - Vissim
- http://www.vensim.com/
  - Vensim