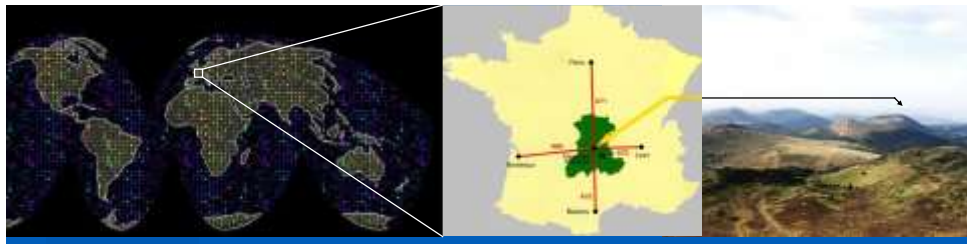

Part I
Introduction to Modeling & Simulation
Stochastic Discrete Event Simulation

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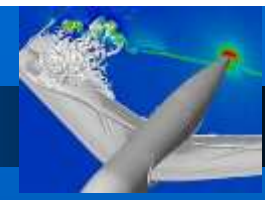
Part I.A
Simulation ?

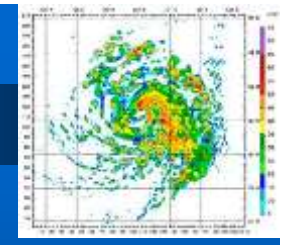


Aeronautic air tremble
© 2006 ONERA

- **In Computer Science:**
  Simulation is the imitation of the operation of a system or a real world process over time.
- **The system is a collection of interacting objects (cf. dictionary definition)**
- **The system can be existing or not :**
  - **« A priori » modelling (non existing)**
  - **« A posteriori » modelling (existing)**

2

And what about Models ?



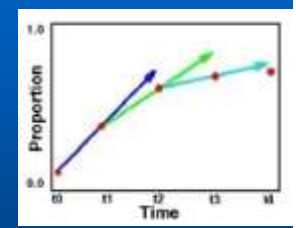
- A **model** is a representation of a **system**
- In Matter, Mind and Models (published by MIT Press in 1965) by Marvin L. Minsky we find the following definition :

> To an observer B,
> an object A* is a model of an object A
> to the extent that B can use A*
> to answer questions that interest him about A

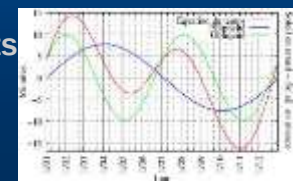
- It implies that :
  - A model is built with an intended **goal** in mind.
  - A the model should be complex enough to answer the **questions** raised.

3

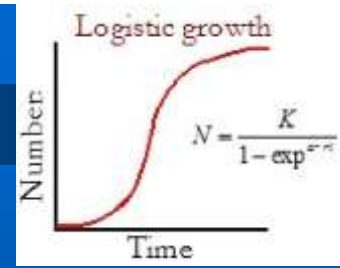
Continuous vs. Discrete Simulation



- The **system state** is defined by a collection of **variables** that describe a system at any time :
  - With a discrete **event** simulation, the model **state variables** change only at discrete points in **time**
  - In a continuous simulation the systems state changes continuously according to a mathematical model (equation or set of equations)
- We can find **combined simulation** with both discrete and continuous components
- Remark: At the quantic level, everything is finally **discrete.**



Continuous vs. Discrete (Analytical vs. Algorithmic)

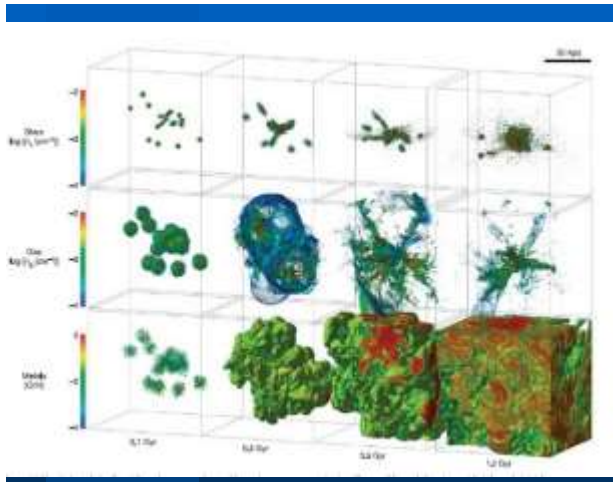


- **Analytical Model :** the model rely on a mathematical "formula" often named "closed form" mathematical solution – named analytical solution.
  - Advantage: a fast computing of the solution
  - Drawback: limited to a small set of systems

- **Computer Simulation Model** : we rely on a simulation algorithm to compute a solution for which we do not have an "Analytical solution"
  - Drawback: often slow to compute solutions.
  - Advantage : fits with all types of systems

5

Ex: Simulations of galaxies



Sept. 27th 2012,
Two astronomers have made one of the largest ever conducted simulations in astrophysics to model the growth of galaxies.
Masao Mori (LA Univ.) and Masayuki Umemura (Tsukuba Univ.) are able to simulate galaxy evolution since 300 million years after the Big Bang until today.
Their results show that galaxies may have evolved much faster than previously thought.

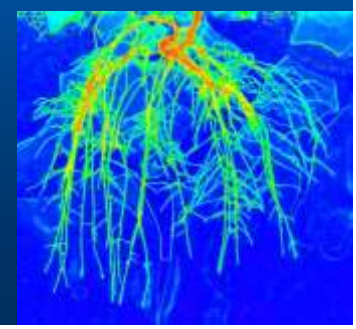
6

ISIMA - F2 (inside)

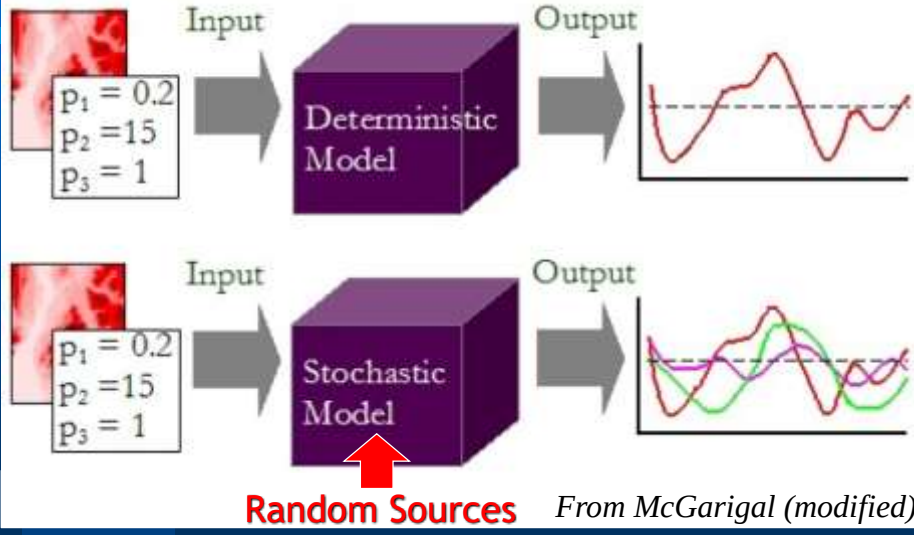
7

Simulations
Deterministic vs. Stochastic

- **Deterministic** simulation : the output of the model is precisely determined by its structure and its parameter values
- **Stochastic** modeling : use of a random source
  - New scientific barriers to break are sometimes behind our best deterministic models
  - The assessment of stochastic parallel simulations is tough and this domain is less studied

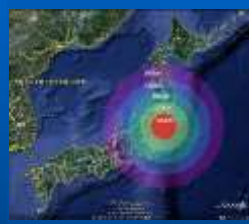


Simulations - Deterministic vs. Stochastic (continued)



From McGarigal (modified)

Monte Carlo (MC) simulation: Every simulation making a smart (stochos) use of a random source can be considered as MC simulation




- **Stochastic** models of normal **plant** operation
- System reliability Monte Carlo models
- Simulation of ground motion using stochastic method
- Nonstationary stochastic model of earthquake motions…
- Shock wave modeling…

Blaise Pascal University

In various domains

We still need to increase reliability…

- Analytical and deterministic models are very fast and can be preferred in many cases

BUT : they can be imprecise in some conditions

In the 1990s Mulhouse FRANCE

First fully electronic automated commercial plane, Automatic landing test with no pilot, no eletro-mechanic controls or cables.
Crash during auto landing…

- Monte Carlo (MC) simulations helps increasing model precisions with spatial constraints but they can be very slow
- In many industries stochastic models are more widely used for risk assessment (and to take into account rare & random events
- Quantitative risk analysis can be improved with Monte Carlo simulations

Pharmaceutical Industry & Drug discovery

Ex: problems with the Mediator drug in France (and with more than 200 other drugs)

Exemple of Improvements :

- Multi-scale stochastic drug release model
- Stochastic model for the origin and treatment of tumors containing drug-resistant cells
- Comparison of stochastic models to to predict the influence of drug distribution, enzyme heterogeneity…
- …