Introduction

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An introduction to modelling, Poznan, 18 November 2008
Outline

1) What is a model?

2) Why develop mathematical models?

3) How to develop and use mathematical models?

4) Conclusion

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1) What is a model?

A model is a simplified representation of a system.
1) What is a model?

A model is a point of view on a given system.
1) What is a model?

Models can be pictorial, sculptural, musical, conceptual, **mathematical**, …
1) What is a (mathematical) model?

- a mathematical model is a simplified representation of a system

- a mathematical model represents a system structure and behavior by a set of equations

- a mathematical model should be able to predict a system behavior given an initial state and system inputs over time

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1) What is a (mathematical) model?

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1) What is a (mathematical) model?

MODEL
- Mathematical structure: relationships between input variables, parameters, and state variables
- Set of parameters

Parameters are terms in the model that are fixed during a model run (a simulation) but can be changed in different runs as a method for conducting sensitivity analysis or to achieve calibration goals.

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1) What is a (mathematical) model?

Mathematical models can be categorised according to several criteria:
- static/dynamic
- for dynamic models: continuous/discrete time
- spatially explicit/non spatially explicit
- for spatially explicit models: raster/vector
- mechanistic/empirical

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Mechanistic versus empirical

A mechanistic model is a model that has a structure that explicitly represents an understanding of physical, chemical, and/or biological processes. Mechanistic models quantitatively describe the relationship between some phenomenon and underlying first principles of cause. Hence, in theory, they are useful for inferring solutions outside of the domain that the initial data was collected and used parameterise the mechanisms.

An empirical model is a model that has a structure determined by the observed relationship among experimental data. These models can be used to develop relationships that are useful for forecasting and describing trends in behaviour but they are not necessarily mechanistically relevant.
1) What is a (mathematical) model?

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- mechanistic/empirical

- stochastic/deterministic

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A stochastic model is a model that includes variability in model parameters.

A deterministic model is a model that provides a single solution for the state variables. Changes in model outputs are solely due to changes in input variables.
2) Why develop models?

- to provide predictions
Yahoo! Météo - Poznan

Météo > Pologne > Poznan

Aujourd'hui

- Formule 1
- Santé
- Football
- Voyages

Catégories Yahoo!
- Climatologie
- Météorologie
- Prévisions météo
- Sismologie
- Volcanologie

Cartes et Images
- Prévisions
- Satellite
- Maximales
- Minimales
- Précip.
MILPV
Communicating system
Potato Late blight

Regional observations by engineers of the French Ministry of Agriculture

Server
Models
Data bases
Expert system

Experimental network

Automatic weather stations

Farmer monitoring

Monitoring network

Jacques Rouzet
2) Why develop models?

- to provide predictions
- to describe and understand the structure of a system
- to gather existing knowledge
- to replace time-consuming or dangerous experiments
2) Why develop models?

- to provide predictions
- to describe and understand the structure of a system
- to gather existing knowledge
- to replace time-consuming or dangerous experiments
- to use as pedagogical tools
L'OSCILLATEUR HARMONIQUE EN RÉGIME LIBRE

Le système masse-ressort amorti

On simule le déplacement $x(t)$ d'une masse accrochée à un ressort élastique. Les frottements avec l'air sont modélisés par une force opposée à la vitesse $v$ où $\alpha$ désigne le coefficient de frottement.

Les paramètres sont la masse $m$ (kg), la constante de raideur $k$ (N/m) et le facteur de qualité $Q = \sqrt{km/\alpha}$ (sans dimension) inversement proportionnel au coefficient de frottement.

L'Applet JAVA

Tirez sur la masse en cliquant dessus avec la souris puis lâchez : vous observez les oscillations d'un oscillateur harmonique amorti.

Source code: oscillator1 Built with Processing.

Commandes:
3) How to develop and use mathematical models?

1) define the purpose of the model
2) define the considered system
3) identify the users of the model
4) write down the conceptual framework
5) choose a mathematical formalism
6) choose a programming environment (Excel VBA, Fortran, C/C++, S+, R, Mathematica, Mapple, MathLab, Scilab, …)
7) gather the available knowledge (or set up experiments)
8) write down equations

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3) How to develop and use mathematical models?

subsequent stages (some are optional)

9) estimate parameters using a data set
10) evaluate the predictive quality of the model
11) evaluate the usefulness of the model
12) perform a sensitivity analysis
13) perform an uncertainty analysis
14) use the model
15) go back to number 7 (sometimes, go back to 1!)

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CONCLUSION

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### What is a mathematical model?

### Why develop mathematical models?
How to develop and use mathematical models?
CONCLUSION

« All models are false, some are useful. »

George E. P. Box, cited ca. 12345 times by Daniel in his e-mail signature.

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