Model building using engineering principles
Introduction

Katalin Hangos

University of Pannonia
Department of Electrical Engineering and Information Systems

2019.03.22.

All models are wrong ...

... some are useful !

George Box

Contents

The concept of a model

What is a model?

- "A model (**M**) for a system (**S**) and an experiment (**E**) is anything to which **E** can be applied in order to answer questions about **S**" (Minsky, 1965)

Engineering models

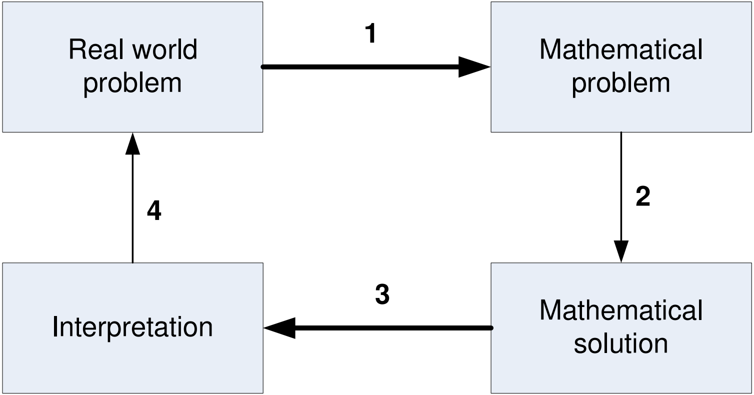
- "A mathematical representation (**M**) of a physical system (**S**) for a specific purpose (**P**) and experiment (**E**)"

Model application areas

1. system design
   - good accuracy
   - mostly static
2. control design
   - dynamic (time-dependent)
   - accurate description of the main dynamic processes
3. monitoring, troubleshooting and diagnosis
   - dynamic (time-dependent)
   - not very accurate but selective
4. simulation and operator training
   - great level of details
   - good accuracy
5. safety and risk analysis
   - mostly static
   - stochastic

The modelling process

A circular iterative process



Model classification

a **Mechanistic** vs. Empirical
- use first engineering principles
- conservation of mass, energy, etc.
- consider physical laws for the mechanisms

b Stochastic vs. **Deterministic**
- application area: control, monitoring, diagnosis

c **Lumped** vs. Distributed
- no state dependency (perfectly stirred volumes, concentrated parameter)

d **Dynamic** vs. Steady state
- application area: control, monitoring, diagnosis

e **Continuous** vs. Discrete (time and range space)

f **Linear** vs. **Nonlinear**

Example: gravitational tank

Mechanisms

- in- and outflow
- gravitational outflow (driven by the hydrostatic pressure)

Modelling assumptions

F1 perfectly stirred

F2 only water

F3 gravitational outflow

F4 constant cross section A

F5 constant density (ρ)

Example: gravitational tank

Conservation balances: overall mass balance

$$\frac{dm}{dt} = v_b - v_k \tag{1}$$

Constitutive equations

- $m = A \cdot h \cdot \rho$ (water level h is measurable)
- $v_B = v_B^* k_B$ (binary valve k_B is measurable)
- $v_K = K \cdot h \cdot k_K$ (gravitational outflow, binary valve k_K is measurable)

Example: gravitational tank

Model equation with measurable signals:

$$\frac{dh}{dt} = \frac{v_b^*}{A\rho} k_b - \frac{K}{A\rho} h \cdot k_K \tag{2}$$

State space model form

- state variable: h level
- input variables: binary valves k_B and k_K
- output variables: h level