Kursusoversigt

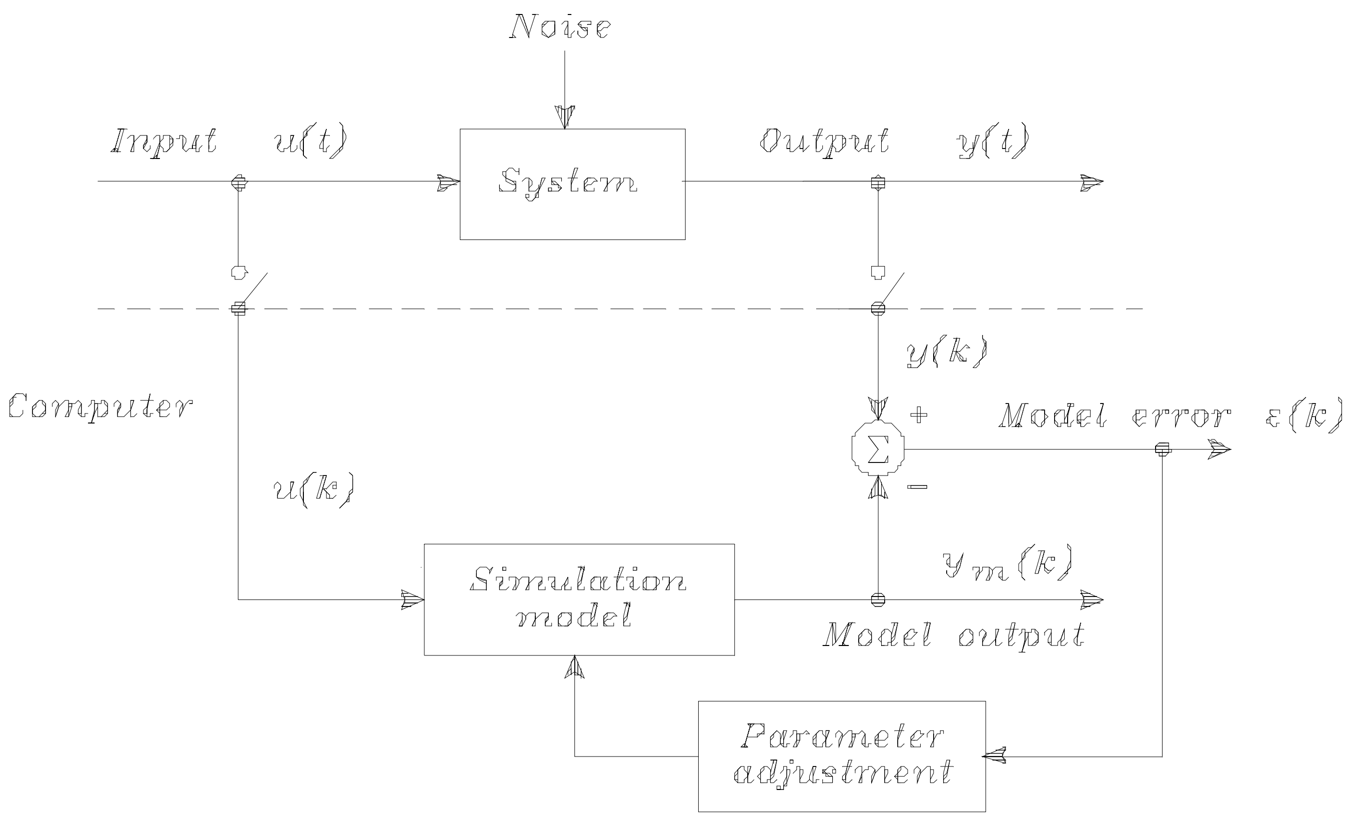
Plan for de enkelte minimoduler:

1. Introduktion, metode og procedure for eksperimentel modelbestemmelse. Grafisk modeltilpasning. System identifikation
2. Modellering, modelbeskrivelse og simulering
3. Senstools til parameterestimering
4. Parameter nøjagtighed og følsomhed. Frekvensdomænet
5. Design af inputsignaler.

The merits of the method

- a simple fundamental approach, illustrated graphically
- continuous-time models with physically significant parameters
- any model structure is appropriate, linear and non-linear, distributed and lumped parameters, time delay etc.
- stochastic aspects are reduced to a minimum
- robustness to violations of theoretical assumptions and approximations
- a sensitivity approach useful for choice of model structure, for experiment design, and for accuracy verification
- all in all, compatibility with physical insight
- the method and the presentation is developed with generally preferred learning styles in mind

Parameter estimation principle



The model parameters are adjusted until minimum of the model error, i.e. the deviation between the sampled system output and the simulated model output.

Procedure for experimental modelling

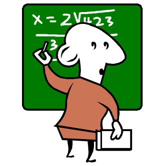
1. **Model structure determination:**The model structure is determined from basic physical laws and empirical considerations. A simulation program is constructed.
2. **Experiment design:** In particular, a good input signal is important. I is either chosen from common-sense considerations, or designed as a signal optimizing characteristic parameter sensitivity measures.
3. **Experiment:**The process is excited by the input signal, and corresponding sequences of input and output signal values are sampled and stored in a computer.
4. **Parameter estimation:**The simulation model parameters are adjusted until minimum of the deviation between the sampled system output and the simulated model output (the model error). As a measure for this deviation is used a performance function containing the sum of the squared deviations at the sampling instants.
5. **Model validation:** The correctness of the model structure and the accuracy of the parameter estimates are evaluated, based on the model fit and characteristic parameter sensitivity measures

Applications

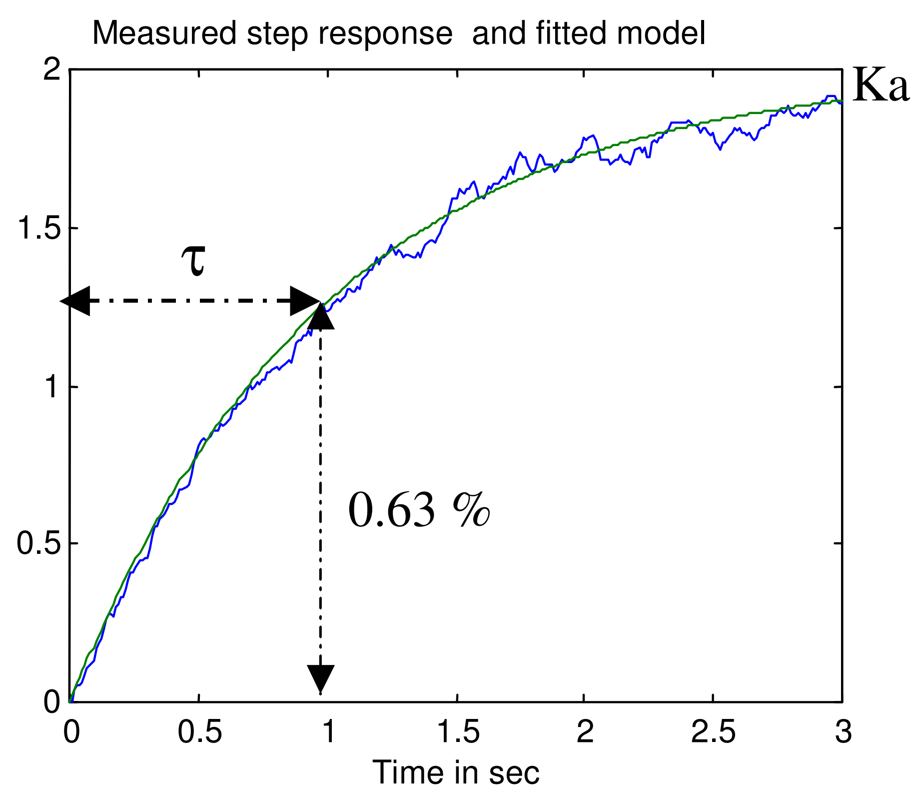
Senstools and the sensitivity approach for experimental modelling has been applied in numerous research and student projects. Examples are:

- ✓ ships and marine systems
- ✓ wind turbines,
- ✓ loudspeakers
- ✓ induction motors and DC-motors
- ✓ heat exchangers
- ✓ human tissue for hyperthermia cancer therapy
- ✓ kidney and cerebellar blood flow.

Graphical model fitting – time domain

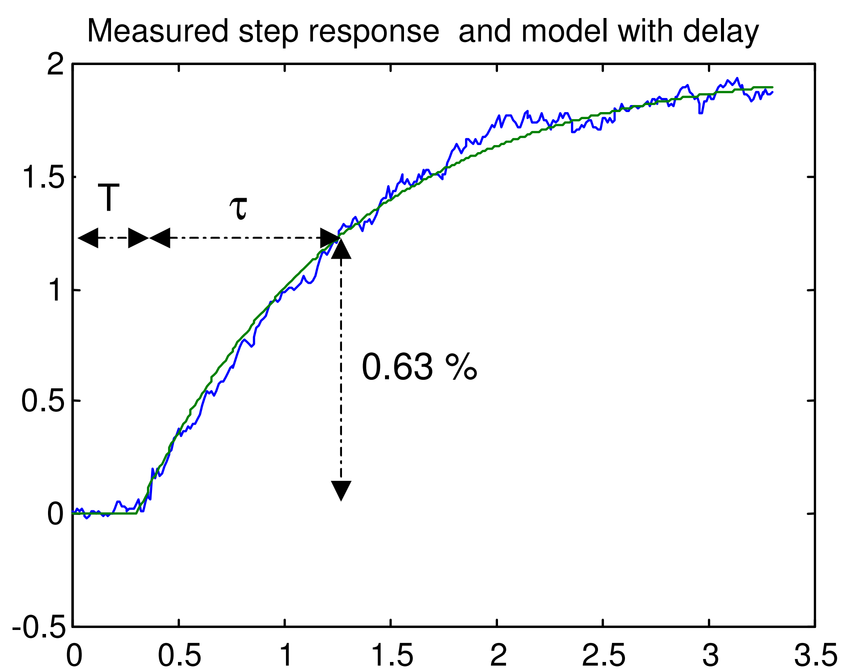


Determination of K and τ by fitting a first order model to measured step response

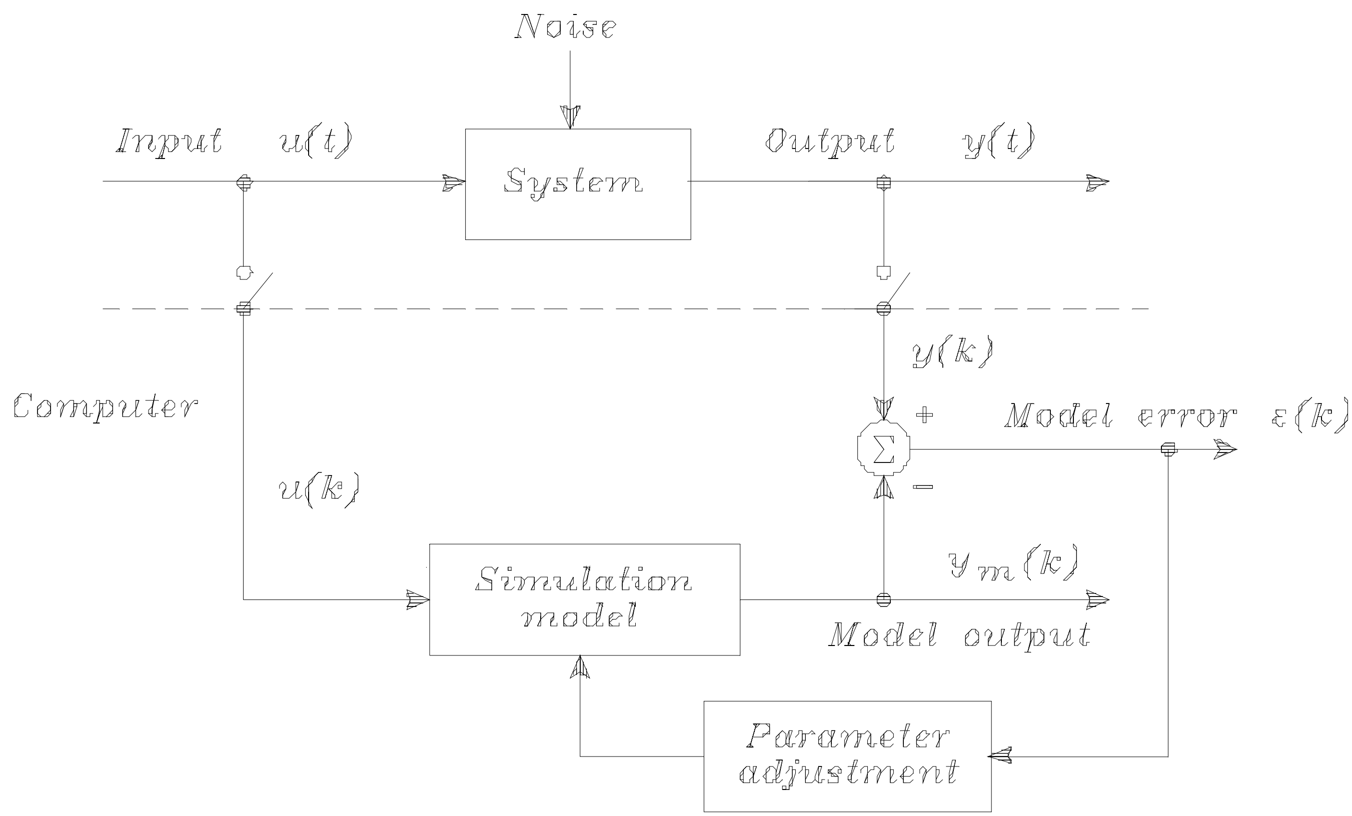


Graphical model fitting – time domain

Fitting a first order model with time delay to measured step response



System identification principle



The model parameters are adjusted until minimum of the model error, i.e. the deviation between the sampled system output and the simulated model output.

System identification methods

The methods are characterizes by model type:

A. Linear discrete-time model: Classical system identification

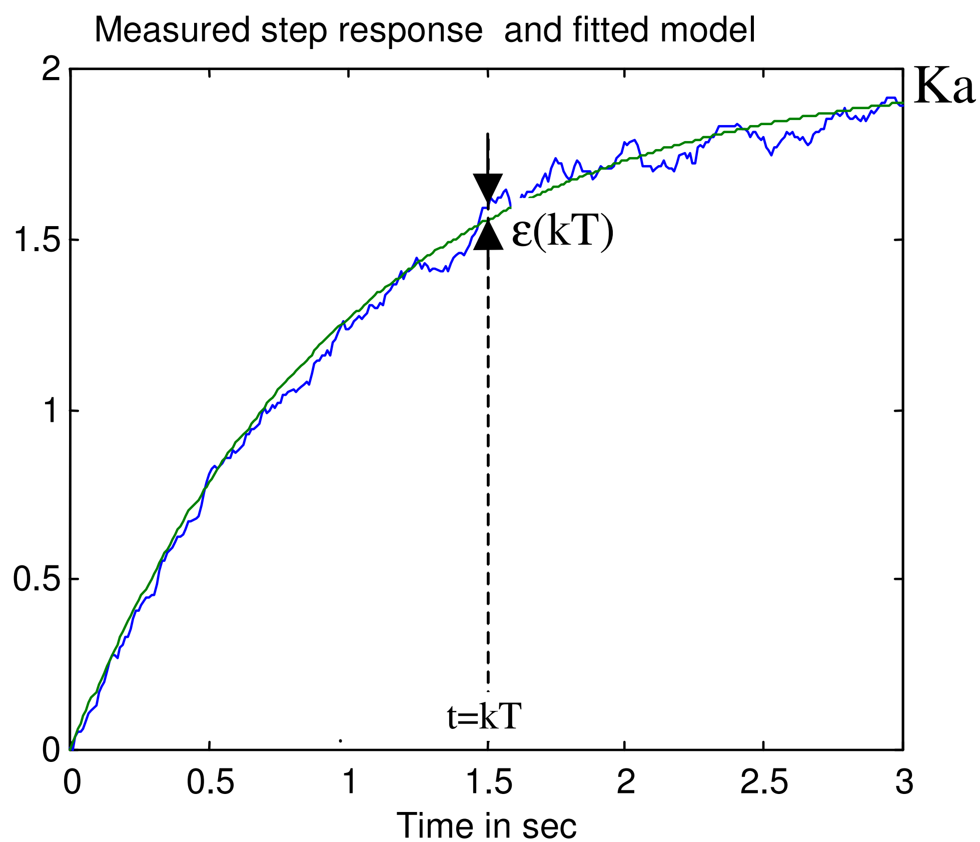
B. Neural network: Strongly nonlinear systems with a complicated structure

C. General simulation model: Any mathematical model, that can be simulated e.g. with Matlab. It requires a realistic physical model structure, typically developed by theoretical modelling. The method: direct estimation of physical parameters

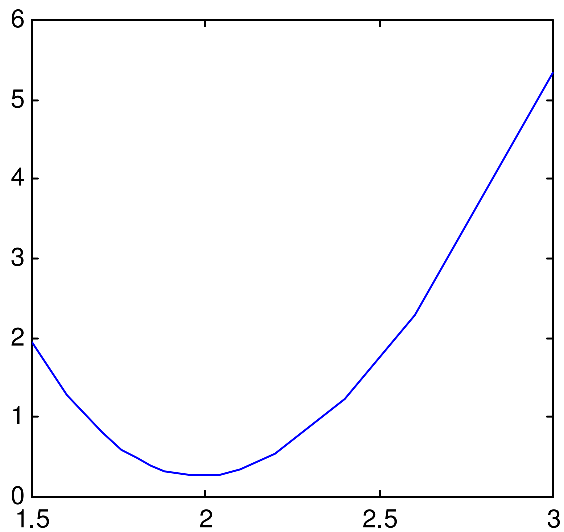
Computer fitting by minimization

$$P(\theta) = \frac{1}{2N}\sum_{k=1}^{N} \varepsilon^2(k,\theta)$$

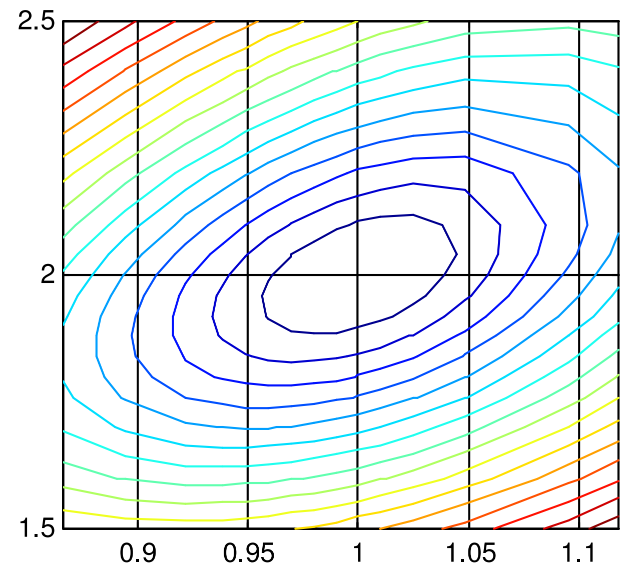
$$\theta_N = \arg\min_{\theta} P(u_N, y_N, \theta)$$



Performance function as a function of θ

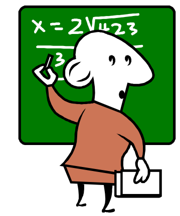


One parameter $\theta = \tau$



Two parameters $\theta = [K\ \tau]$

Finding minimum of a function



Condition for minimum

- First partial derivative (gradient vector) is zero
- Second partial derivative (Hessian) is positive definite

Numerical methods for minimum search

- Steepest descent
- Newton (DEMO)

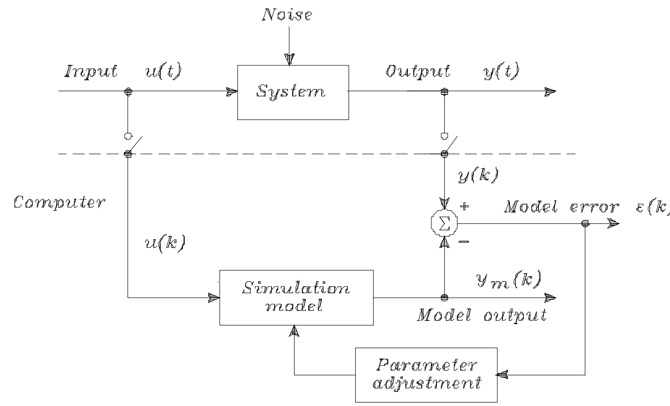
The Gauss-Newton method

Direct estimation of physical parameters

- Determination of model output (simulation)
- Determination of model gradient ψ by numerical differentiation
- Determination of gradient G and Hessian H from ψ
- Determination of parameter values minimizing the performance function P (Gauss-Newton algorithm)

Resumé

• The fundamental principle for system identification is



• It converts the parameter fitting problem to the problem of minimizing a performance function P

$$P(\theta) = \frac{1}{2N} \sum_{k=1}^{N} \varepsilon^2(k,\theta)$$

• This can be done by a Gauss-Newton procedure

• But it requires a simulation model. Next mm: simulation with Matlab