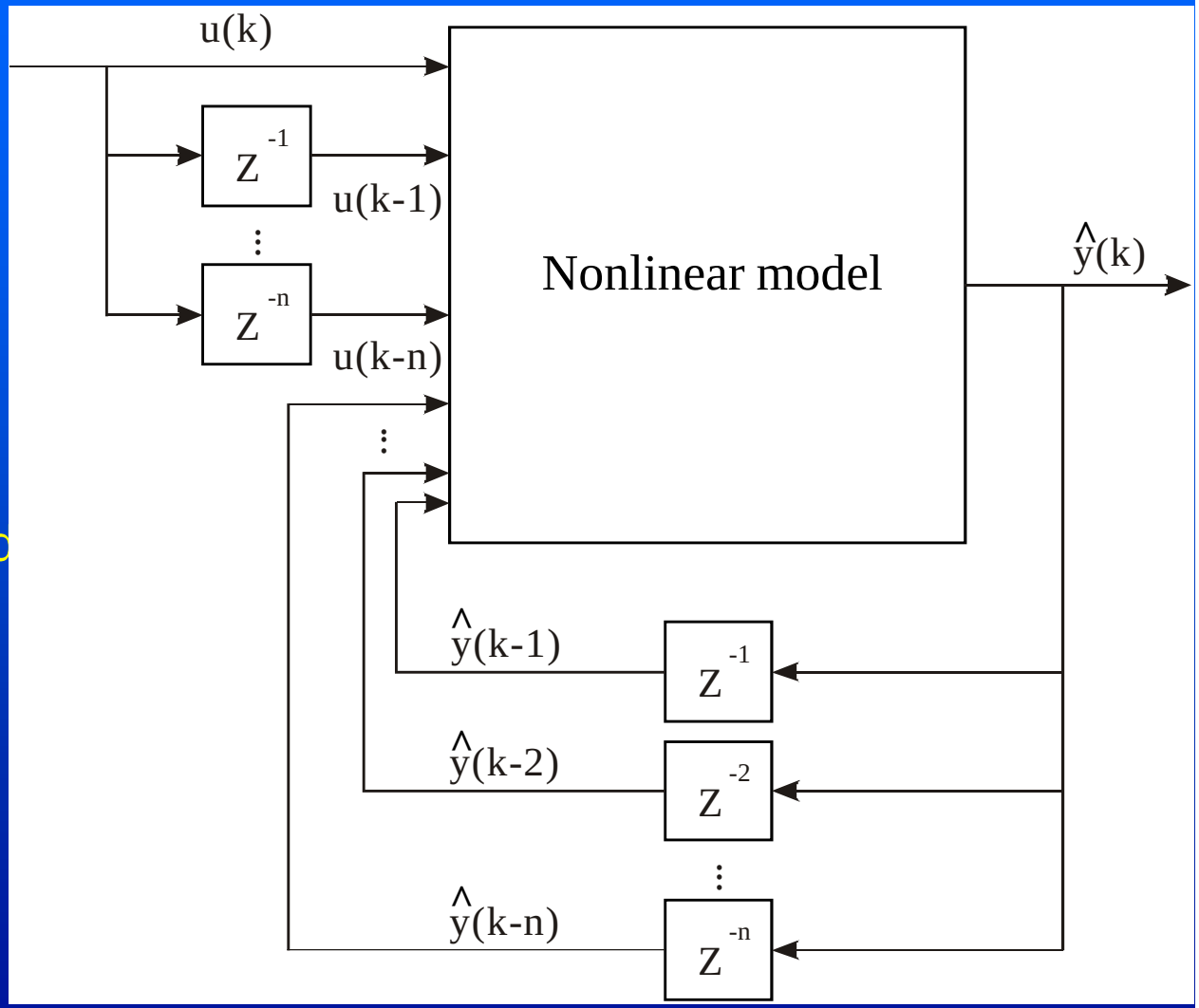
Dynamic Systems Identification
Part 2 - Nonlinear systems

Reference:

J. Sjöberg et al. (1995):Non-linear Black-Box Modeling in System Identification: a Unified Overview, Automatica, Vol. 31, 12, str. 1691 - 1724.

Nonlinear dynamic systems

- Static models
  - Input/output data
  - Interpolation or extrapolation
- Dynamic model
  - Input/output data expanded with delayed input and output data
  - Learning for one-step-ahead prediction
  - Validation for multi-step-ahead prediction

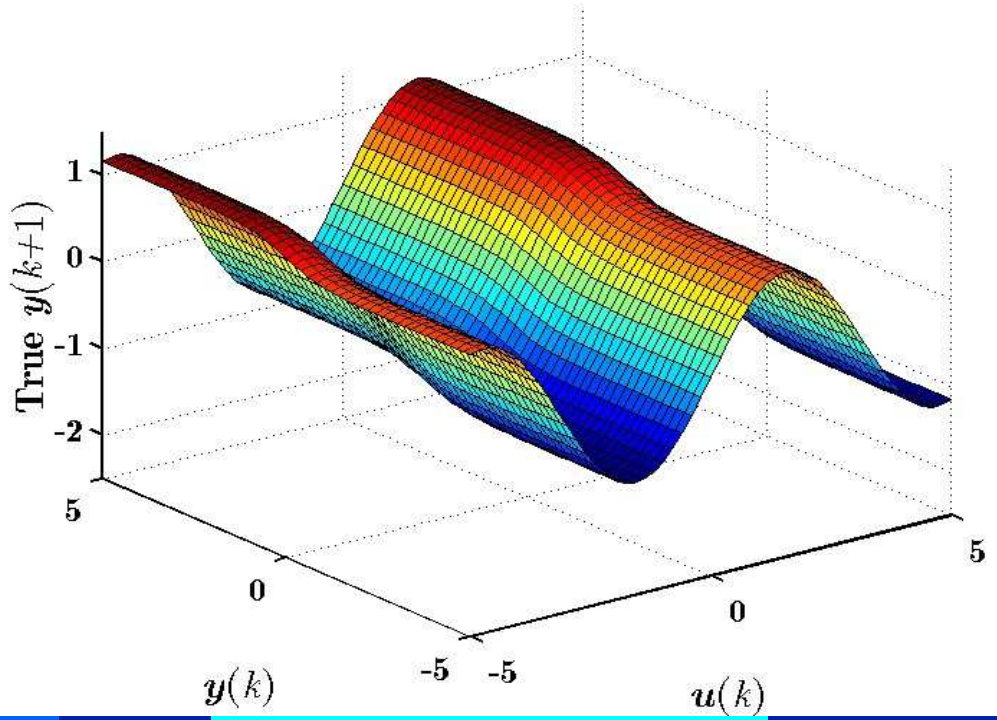


$$\hat{y}(k) = f(\hat{y}(k-1), \hat{y}(k-2), ..., u(k-1), ...)$$

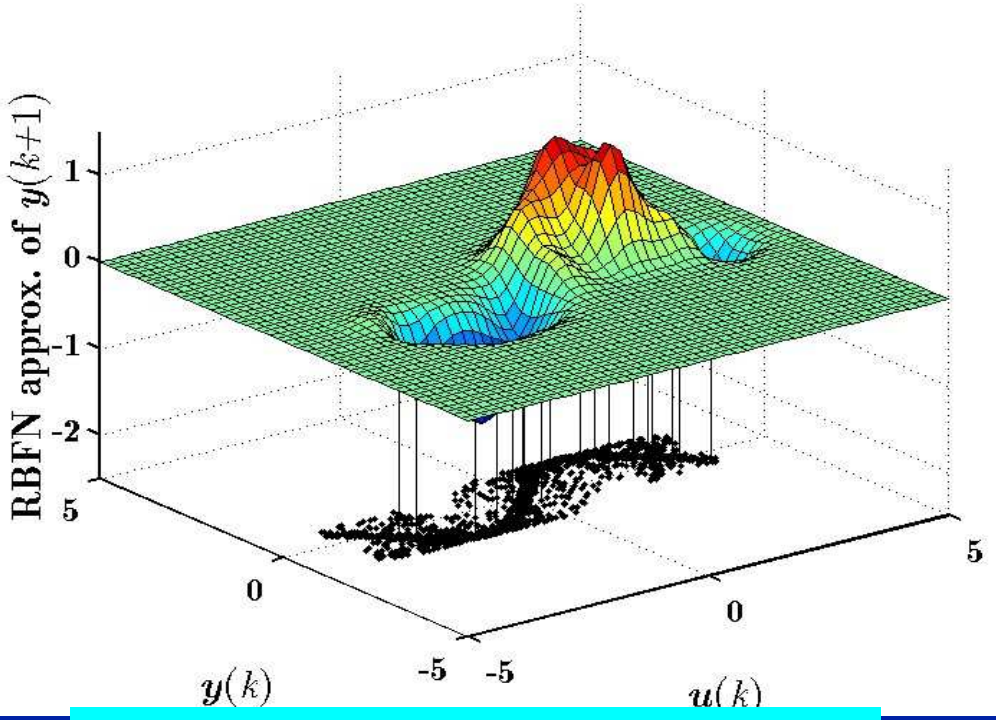
RBF network – Example

$$y(k+1) = 0.2\tanh(y(k)) + \sin(u(k))$$

2207 I/O data, 20 basis functions distributed randomly in operating area



Original function



Approximation with 20 basis functions

Experimental modelling of nonlinear systems

- 1990s: ANN = nonlinear systems identification
- Rule:

  Do not estimate what you already know!
- White box model, grey box model (physical modelling, semi-physical modelling), black box model
- Nonlinear black-box models: artificial neural networks, fuzzy models, wavelet models, etc.

Experimental modelling of nonlinear systems

- Used terms (system theory vs. ANN/Machine learning:
  - estimate, identify = train, learn
  - validate = generalize
  - model structure = network
  - estimation data, identification data = training set
  - validation data = generalization set
  - overfit = overtraining

Some practical concerns about nonlinear systems identification

- Identification procedure cannot/must not be fully automatised!
- Neccessary: S/W, I/O data.
- We need experience on similar identification cases.

  Computer simulations of similar cases.

Examination assignment

Select a discrete nonlinear system of the 1st order, identify it and make a written report. The report should contain the following items:

- Mathematical model of the original system with all parameters;
- Simulation scheme or Matlab code that enables rerun of data acquisition (no masks);
- Show the nonlinearity of the system in 3D plot;
- Estimation signal and response, sampling time;
- Validation signal and response, sampling time;

- Histograms of magnitudes and input/output data pairs;
- Type of neural network and optimisation method;
- Figure of the final network structure;
- Values of parameters (weights);
- Figure of comparison between original system simulation response and model simulation response on validation signal.
- Simulation residuals validation on validation data
  (the figure of residuals, residuals histogram, ϕee, ϕue).

Experiments should be repeatable based on your report only.

Reports should not be longer than 6 pages.