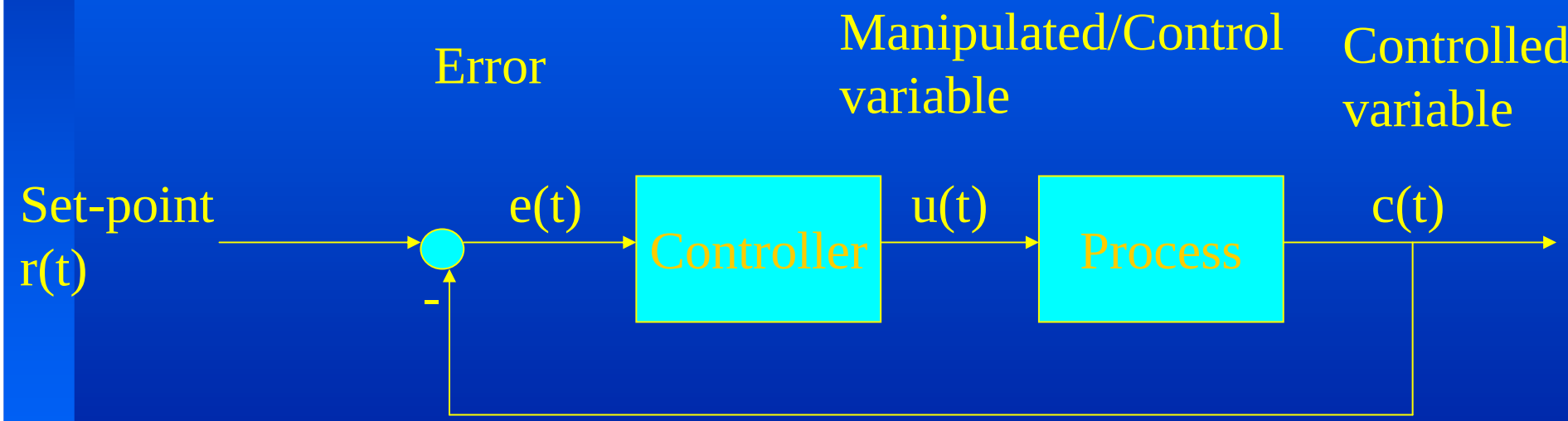
Neural network based control

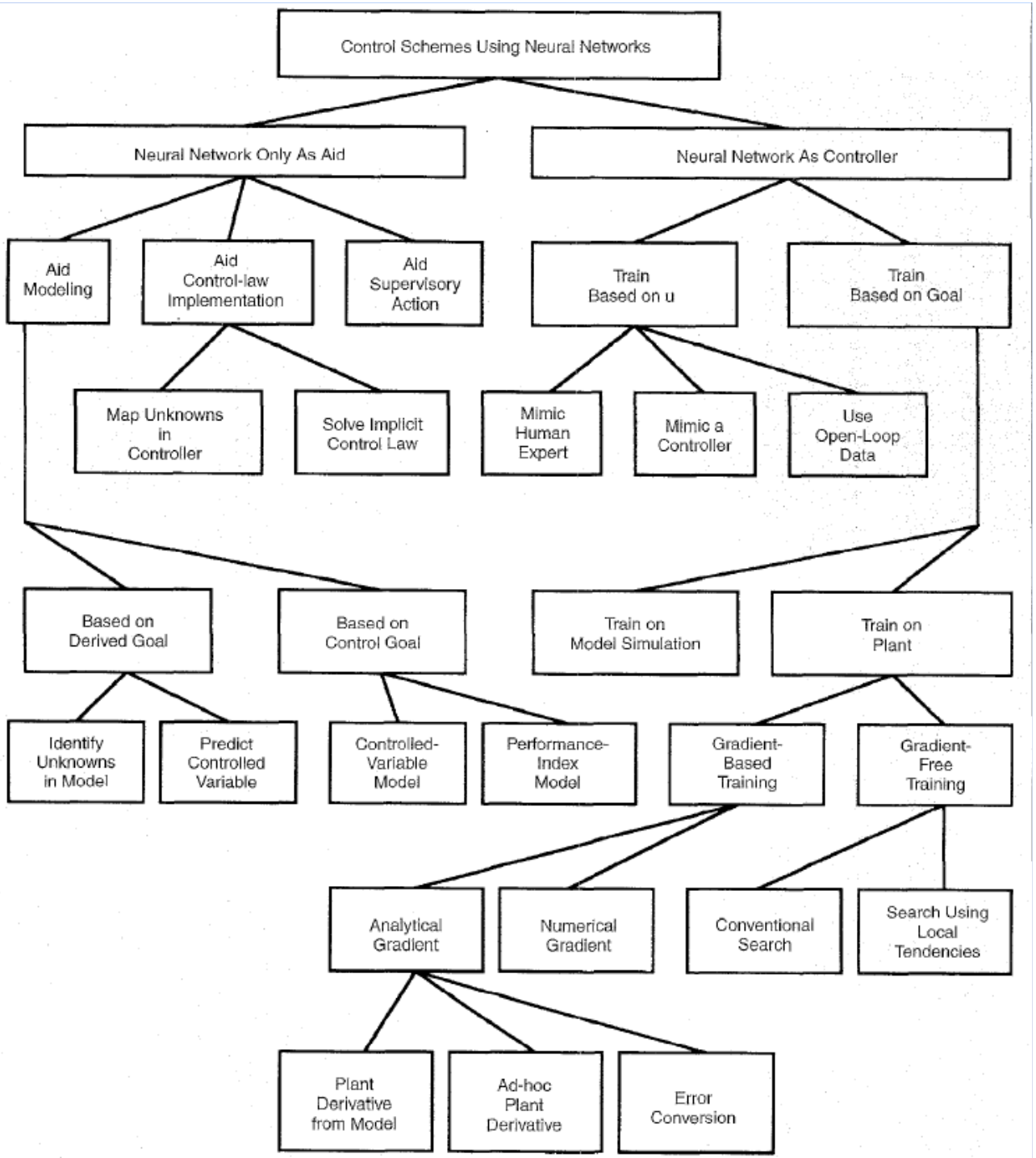
Reference:

M. Agarwal (1997): A systematic classification of neural-network-based control, IEEE Control Systems Magazine, Vol. 17, No. 2, str. 75-93.

Feedback control

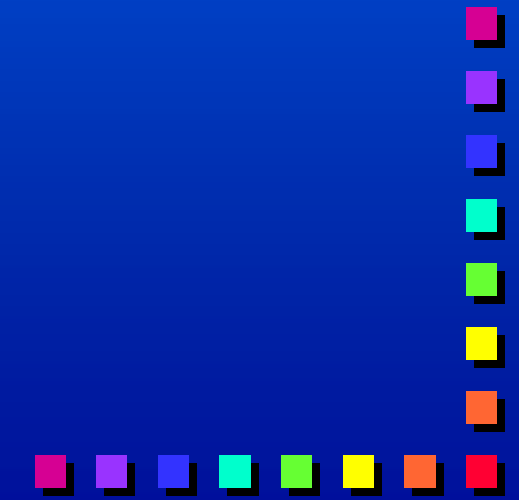


Neural network based control



Most frequently used control algorithms with neural networks

- Various model based predictive control algorithms (usefull in practice)
- Various forms of adaptive control (rarely used in practice)



Basics of predictive control

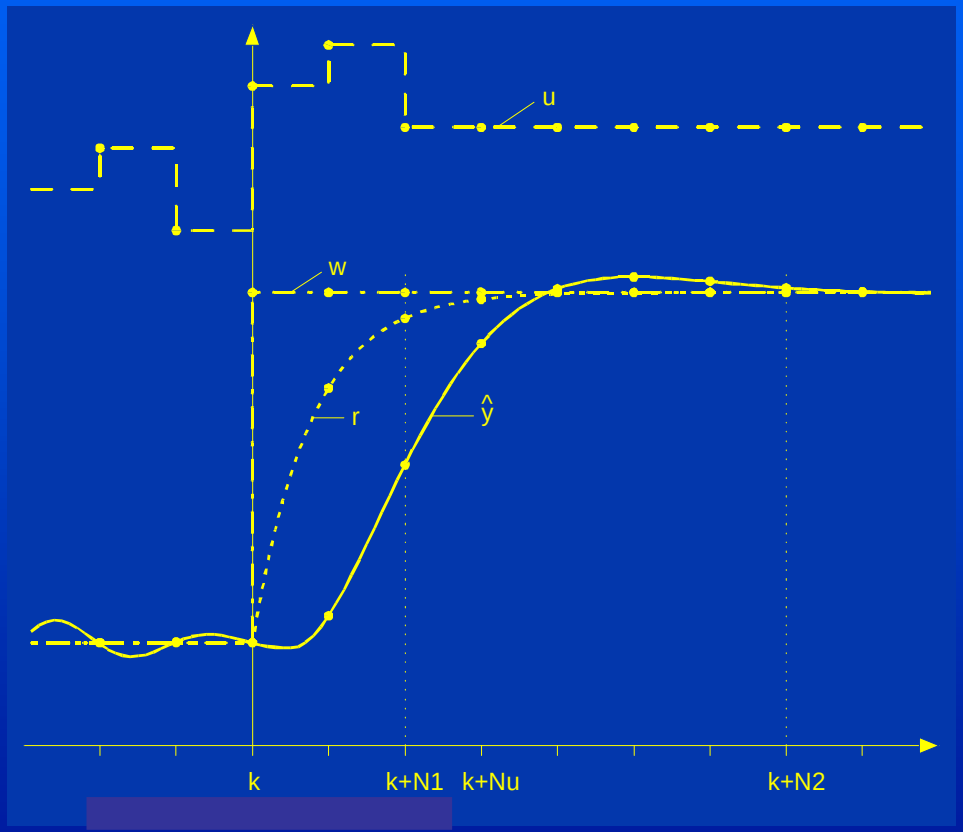
- At every *k*: calculation of prediction $\hat{y}(k+j) \quad j=N_1,\ldots,N_2$
- We set $r(k+j)$
- $\Delta u(k+j)$ for $j=0,\ldots N_u$ minimize

$$J=\sum_{j=N_1}^{N_2}(r(k+j)-\hat{y}(k+j))^2+\beta\sum_{j=0}^{N_u-1}(\Delta u(k+j))^2$$

- For control it is used only

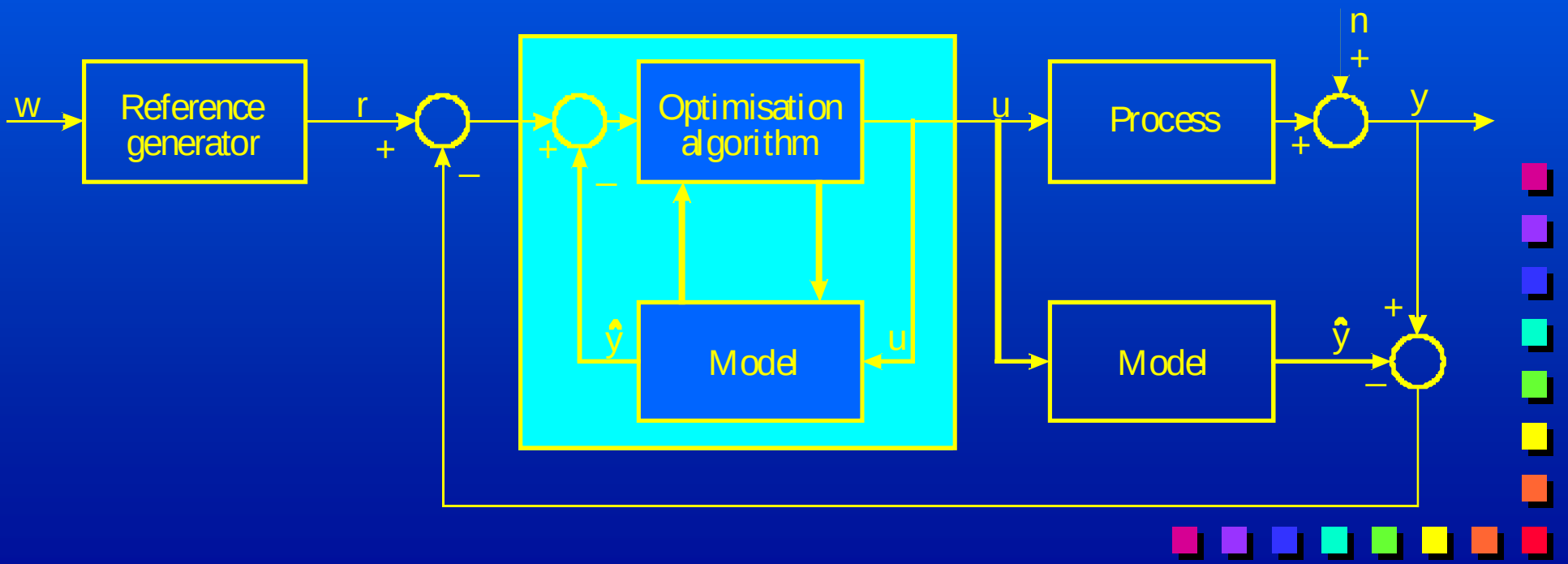
$$\Delta u(k)$$

Moving horizont strategy



The concept of Model-based Predictive Cotnrol (MPC)

- Nonlinear process is modelled with a black-box model (neural network, fuzzy model, neuro-fuzzy model)



Neural network based MPC example

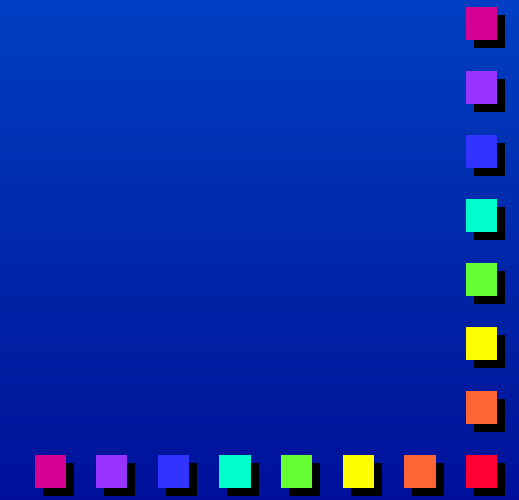
Mathematical model of the process with parameters

$$y(k) = y(k-1) - 0.5\tanh\left(y(k-1) + u(k-1)^3\right)$$

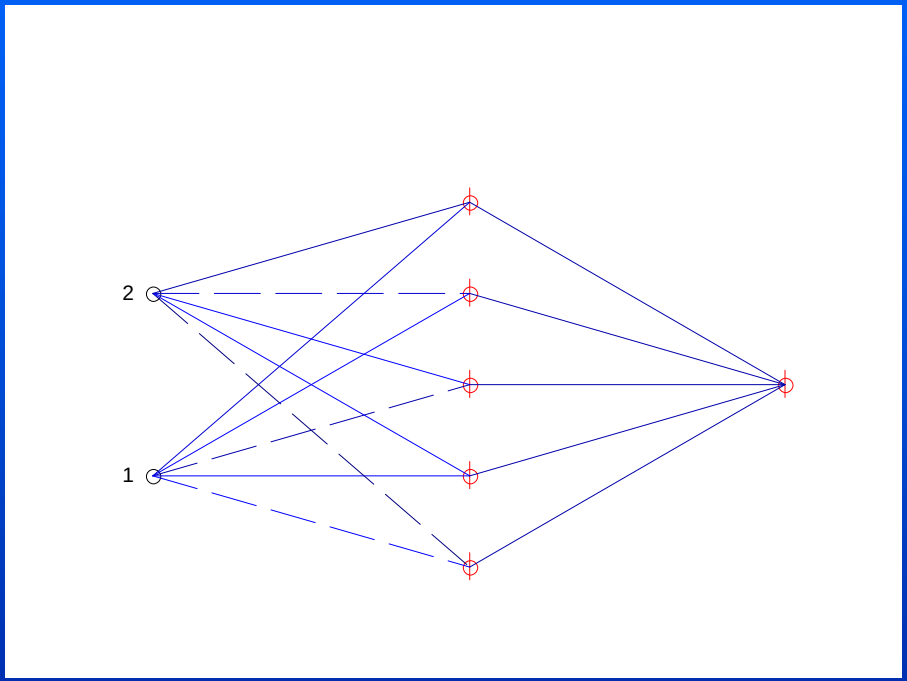
u – input signal

y – output signal

Step 1: Identification of process in operating range



Neural network, regressors, structure and parameters



Used software:
NNSYSID Toolbox for Matlab

Regressors:
y(k-1), u(k-1)

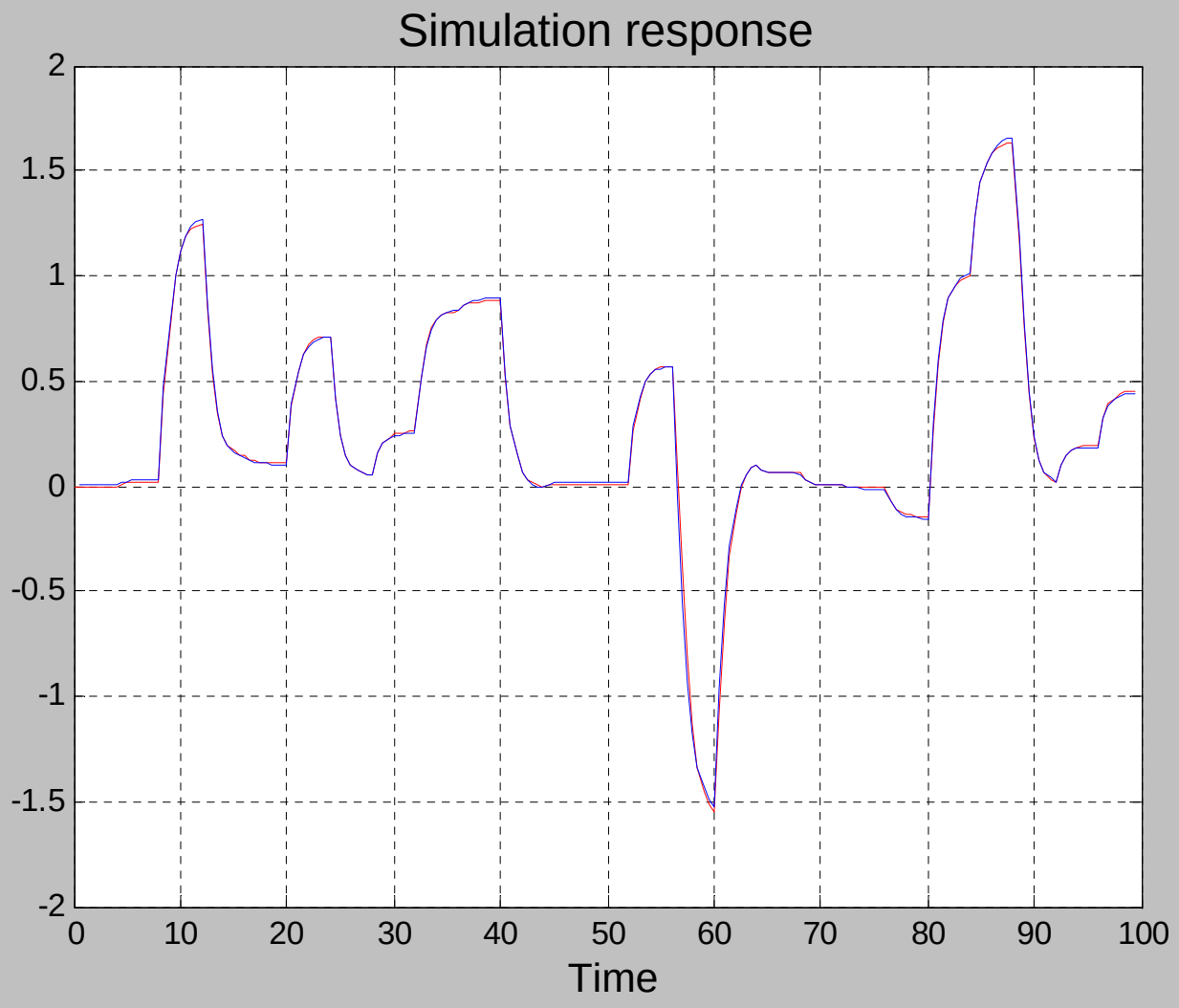
Structure:
ARX (model error method)

Optimisation method:
Levenberg-Marquardt

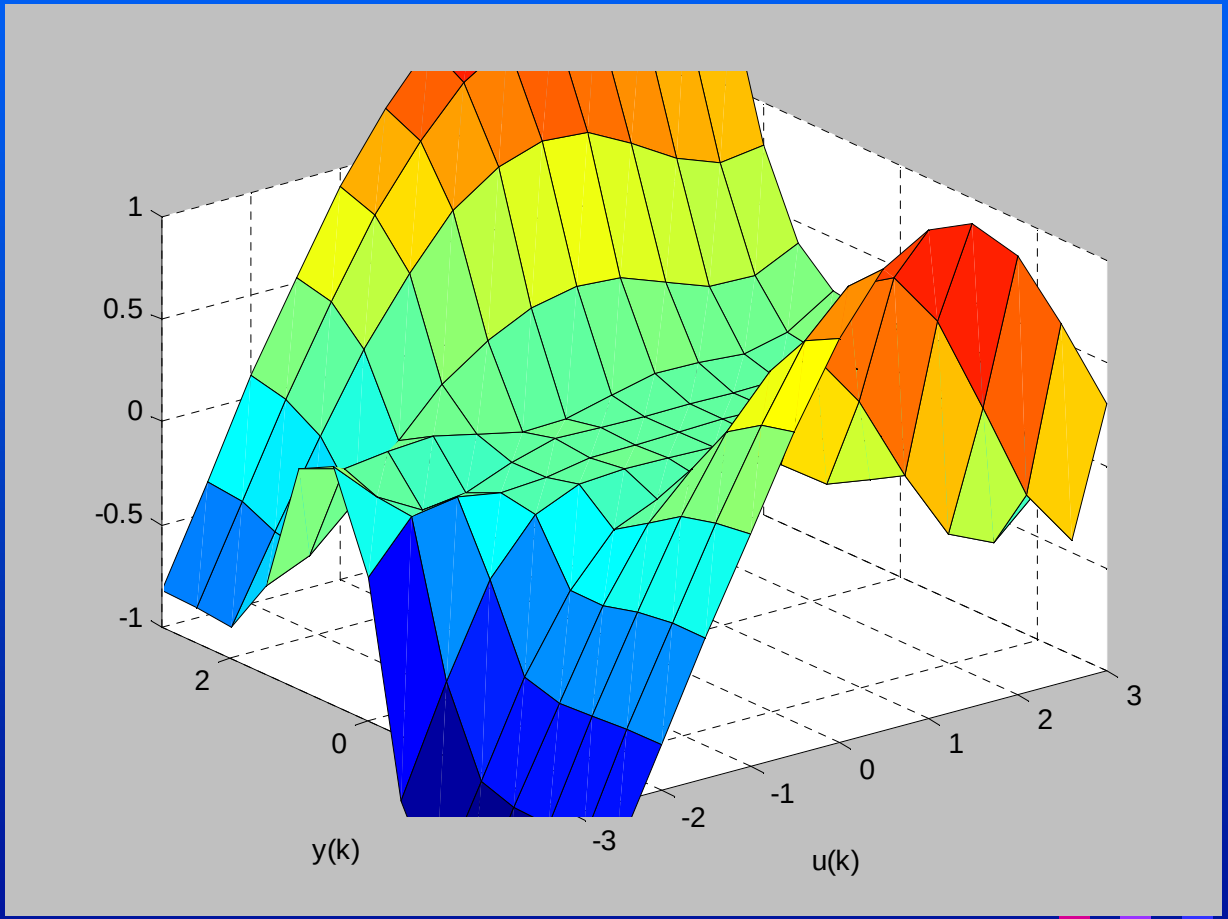
$$\mathbf{W}_1 = \begin{bmatrix} -0.5588 & -2.0621 & -1.9530 \\ 0.5155 & 0.0499 & -0.8670 \\ -1.5149 & 0.3190 & 0.4768 \\ 0.3366 & -1.2029 & 1.8379 \\ 0.8411 & 1.3841 & 1.7123 \end{bmatrix}$$

$$\mathbf{W}_2 = \begin{bmatrix} 1.2054 & 1.7784 & 0.0810 & 1.1704 & 1.4048 & -0.0580 \end{bmatrix}$$

Model response and original system's response on validation data (simulation, not one-step-ahead prediction)



Validation of residuals (one-step-ahead prediction)



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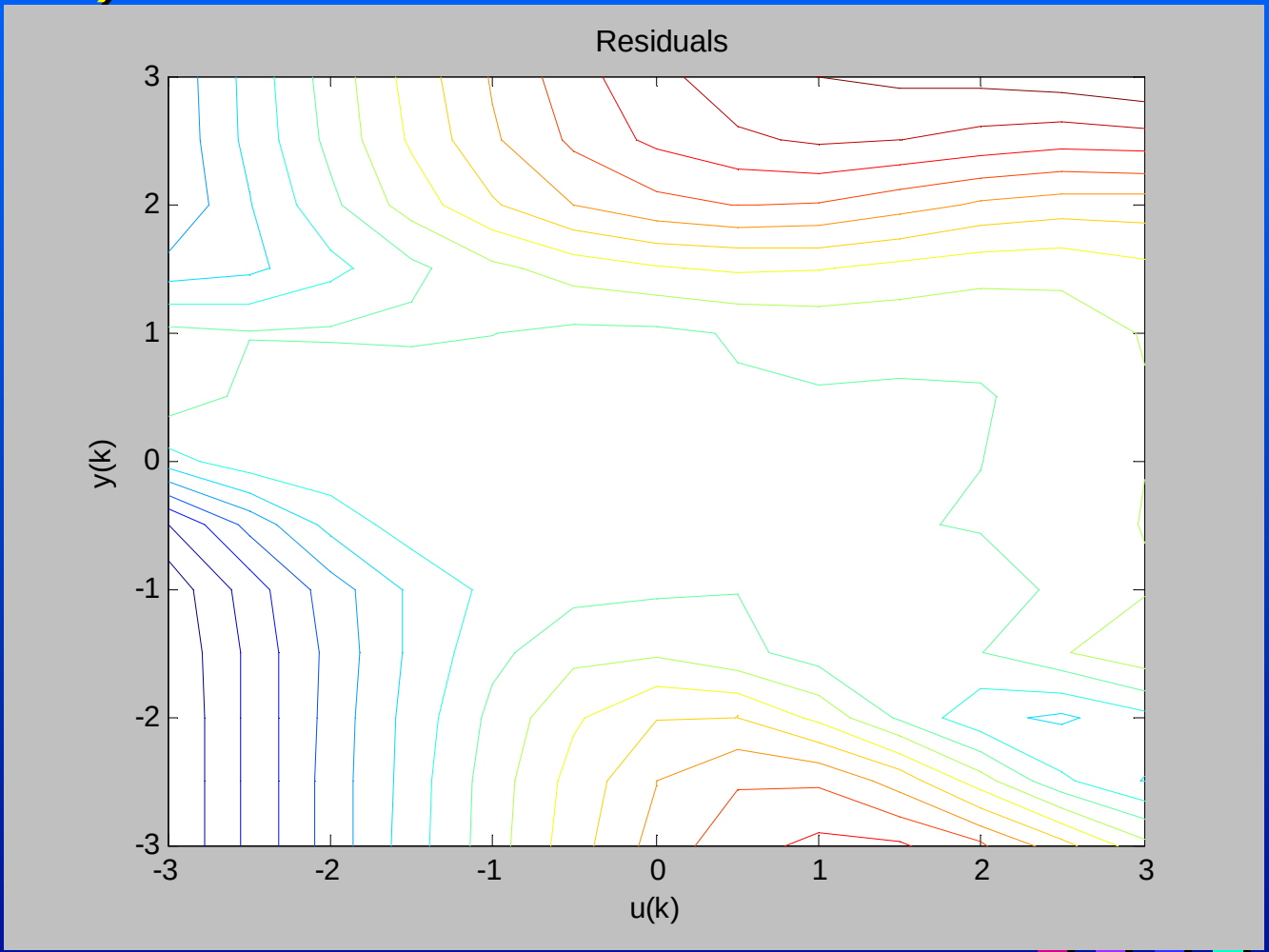
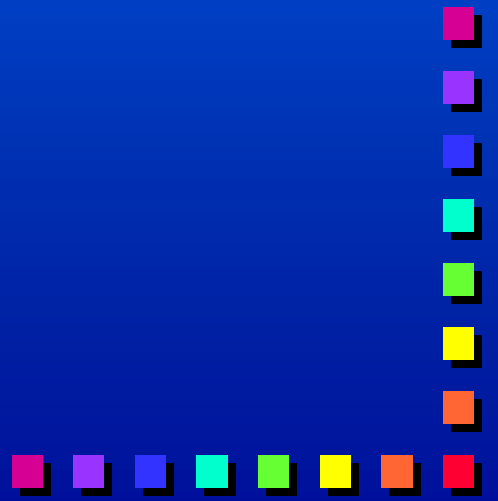


Step 2: Predictive controller design

- Selection of the predictive controller
- Cost function
- Controller parameters
- Some important properties
  - Computational requirements
  - Closed-loop robustness
  - Constraints handling
  - Guarantees

Step 3: Closed-loop validation



Closed-loop response of MPC based on neural network process model