Neural network based control

Reference:

Feedback control
Neural network based control
Most frequently used control algorithms with neural networks

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

- At every $k$: calculation of prediction $\hat{y}(k+j)$ $j=N_1,...,N_2$
- We set $r(k+j)$
- $\Delta u(k+j)$ for $j=0,\ldots,N_u$
- For control it is used only $\Delta u(k)$

Moving horizon strategy
The concept of Model-based Predictive Control (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)
Validation of residuals (one-step-ahead prediction)
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

Closed-loop response (blue) and set-point (red)

Control signal

Time