Introduction to Recursive Identification for Fault Detection and Parameter Estimation

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Lecture Main Topics

- Method for online fault diagnosis
  - **Parameter estimation methods**
- Application examples

Residual Generation Technique

- **Fault detection via parameter estimation**

Fault Detection via Parameter Estimation

Parameter Estimation

- Parameter estimation for fault detection
- The process parameters are not known at all, or they are not known exactly enough. They can be determined with parameter estimation methods
- The basic structure of the model has to be known
- Based on the assumption that the faults are reflected in the physical system parameters
- The parameters of the actual process are estimated on-line using well-known parameter estimations methods

Parameter Estimation (Cont'd)

- The results are thus compared with the parameters of the reference model obtained initially under fault-free assumptions
- Any discrepancy can indicate that a fault may have occurred

- **An approach for modelling the input-output behaviour of the monitored system will be recalled and exploited for fault detection**

Equation Error (EE) Approach

- SISO model

$$y(t) = \boldsymbol{\Psi}^T \boldsymbol{\Theta}$$

- Parameter vector

$$\boldsymbol{\Theta}^T = [a_1 \dots a_n,\ b_1 \dots b_n]$$

- Regression vector

$$\boldsymbol{\Psi}^T = [y(t-1) \dots y(t-n)\ \ u(t-1) \dots u(t-n)]$$

Equation Error Method

- *Equation error*

$$e(t) = y(t) - \boldsymbol{\Psi}^T \boldsymbol{\Theta}$$

- Model of the process (Z-transform)

$$\frac{y(t)}{u(t)} = \frac{B(z)}{A(z)}$$

- Estimated polynomials

$$e(t) = \hat{B}(z)u(t) - \hat{A}(z)y(t)$$

Equation Error Method (Cont'd)

- Estimation of the process model: **LS**

$$\hat{\boldsymbol{\Theta}} = [\boldsymbol{\Psi}^T \ \boldsymbol{\Psi}]^{-1} \boldsymbol{\Psi}^T y$$

- LS minimisation

$$\begin{cases} J(\boldsymbol{\Theta}) & = & \sum_t e^2(t) = \mathbf{e}^T \mathbf{e} \\ \frac{d \ J(\boldsymbol{\Theta})}{d \ \boldsymbol{\Theta}} & = & \mathbf{0}. \end{cases}$$

Equation Error Method (Cont'd)

- Estimation of the process model: **R**LS

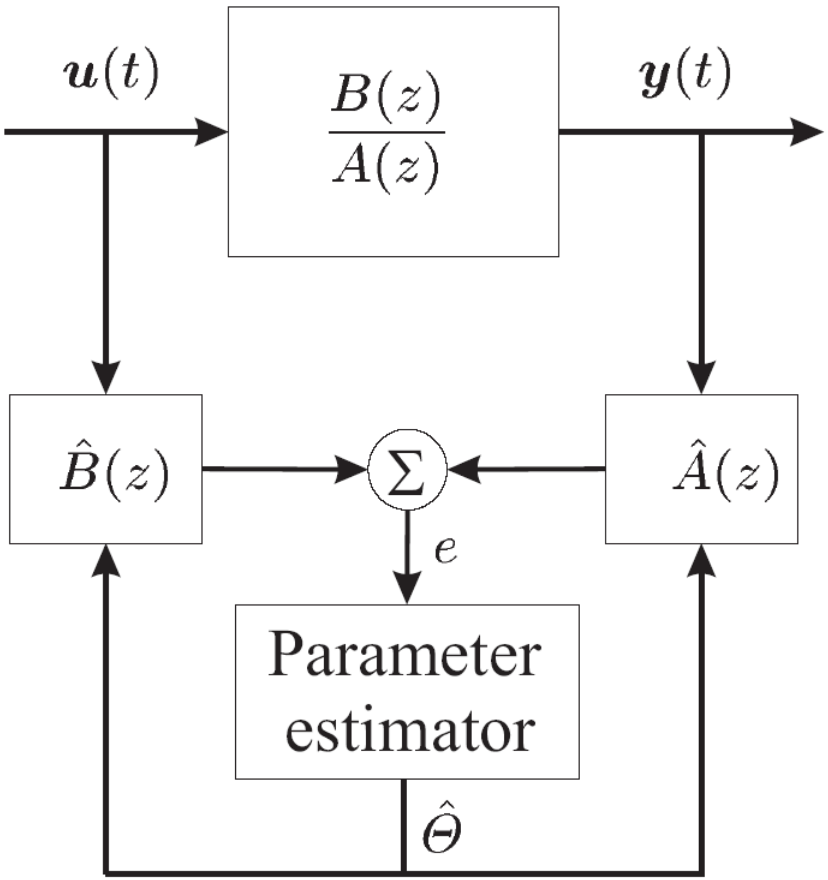
$$\hat{\boldsymbol{\Theta}}(t+1) = \hat{\boldsymbol{\Theta}}(t) + \gamma(t)\left[y(t+1) - \boldsymbol{\Psi}^T(t+1)\hat{\boldsymbol{\Theta}}(t+1)\right]$$

- Estimate recursive adaptation

$$\begin{cases} \gamma(t) &= \frac{1}{\boldsymbol{\Psi}^T(t+1)\boldsymbol{P}(t)\boldsymbol{\Psi}(t+1)+1}\boldsymbol{P}(t)\boldsymbol{\Psi}(t+1) \\ \boldsymbol{P}(t+1) &= \left[I - \gamma(t)\boldsymbol{\Psi}^T(t+1)\right]\boldsymbol{P}(t). \end{cases}$$

Note: see on-line estimation approach

Parameter Estimation via EE



- Recursive estimation of the transfer function polynomials
- Equation error
- Parameter estimation via recursive algorithm
- **RLS**