Blackbox identification of nonlinear MIMO systems

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Main research topic

Identification of nonlinear dynamical systems

Design:

- appropriate excitation signals
- models for nonlinear systems
- efficient estimation procedures

State Space Approach

- Linear systems: SS inherently MIMO compatible
- Formulation:

$$x(n+1) = A.x(n) + B.u(n)$$
$$y(n) = C.x(n) + D.u(n)$$

Step to nonlinear world

- Add static nonlinear terms:

$$x(n+1) = A.x(n) + B.u(n) + NL.w(n)$$
$$y(n) = C.x(n) + D.u(n)$$

$$w(n) = [x_1^2(n) \quad x_1^3(n) \quad \ldots \quad u^2(n) \quad u^3(n) \quad \ldots \quad y^2(n) \quad y^3(n) \quad \ldots]$$

Approach

1. Determine best linear approximation of the system: A,B,C,D
2. Calculate coefficients NL

But…

- Identification of NL?
- Observer canonical form: SISO (order N):

$$G(z) = \frac{\sum b_i z^{-i}}{\sum a_i z^{-i}}$$

$$A = \begin{bmatrix} -a_{N-1} & 1 & 0 & \dots & 0 \\ -a_{N-2} & 0 & 1 & \dots & 0 \\ \dots & \dots & \dots & \dots & \dots \\ -a_0 & 0 & 0 & \dots & 0 \end{bmatrix} \quad B = \begin{bmatrix} b_{N-1} - a_{N-1} b_N \\ \dots \\ b_1 - a_1 b_N \\ b_0 - a_0 b_N \end{bmatrix} \quad D = b_N \quad C = \begin{bmatrix} 1 & 0 & \dots & 0 \end{bmatrix}$$

Observer canonical form

$$\begin{cases} x_1(n) = b_0 u(n-N) + \ldots + b_{N-1} u(n-1) - a_0 y(n-N) - \ldots - a_{N-1} y(n-1) \\ \ldots \\ x_N(n) = b_0 u(n-1) - a_0 y(n-1) \end{cases}$$

$\rightarrow$ measurements of SS variables, including nonlinear terms!

Alternative (MIMO): Subspace Algorithms

Problems

- Similarity transform?
- Stability?
- Other nonlinear functions?
- Dynamical nonlinearities?