The Identification Problem

Flexible Dynamics in High Precision Mechatronic Systems

Movement + Flexibilities = Position-dependent z(ρ), y(ρ)

Need for accurate model P(ρ), for model-based controller design K(ρ)

Challenge in Local Approach

Assume position-independent dynamics, i.e. A(ρ) = A
⇒ local model is large MIMO

Estimate Modal MIMO LTI model from local data

Exploit Modal structure for accurate interpolation

Approach: Estimate Modal MIMO model from FRFs

Challenge min J(θ): J(θ)

Proposed solution: Matrix Fraction Description P = D⁻¹N
enables SK and IV to find global optimum [1].

Main Challenge
Find unconstrained MFD parametrization:

P(θ, ξ) = D⁻¹ (θ, ξ)N(θ, ξ), θ ∈ R^nθ

such that each model is equivalent to a mechanical system, i.e.,

P(θ, ξ) ∼ L[ξ^2I + D_m ξ + Ω^2]⁻¹R

and find an explicit way to perform the transformation.

Result

The Matrix Fraction Description: D(d/dt, θ)y(t) = N(d/dt, θ)u(t),
with D ∈ R^nθ x nθ, N ∈ R^nθ x nu, given by the polynomial matrices

[D(ξ)]i = ξ^η_i - \sum \alpha_ijk \xi^{k-1}, (i ≠ j)

[N(ξ)]i = - \sum \beta_ijk \xi^{k-1}, (all modes observed)

is equivalent to a mechanical system:

D_m Ω^2 q(t) + D_m d/dt q(t) + Ω^2 q(t) = Ru(t), y(t) = Lq(t),

D_m, Ω ∈ R^{nm x nm}, R ∈ R^{nm x nu}, L ∈ R^{ny x nm}, if for some nm ∈ N the structure indices η_i and ν_i, i = 1, ..., ny, are such that, η_i ≥ 0, Σ_ν_i η_i = n_m and,

(R1) η_i = 2n_m, (even order)

(R2) (a) ν_i = c_i, c ∈ {1, 2}, η_i ≥ 2, (all modes observed)
(b) max |η_i - η_j| ≤ 2, (unconstrained θ)
(c) ν_i = max(η_max - c, η_i) - 1, η_max = max(η_i), (rel. deg. is 2)

(R3) n_y, n_u ≤ n_m (no oversensing nor overactuation).

Transformation through matrix algebra (ask me!)

Experimental Example

1. Estimate MFD model with SK [1].
2. Directly obtain mechanical parameters from MFD!

\[ L = \begin{bmatrix}
0.16 & -0.85 & 0.63 \\
-0.18 & -0.53 & -0.37 \\
\end{bmatrix}
\]

\[ \Omega = \begin{bmatrix}
151.2 & 0 & 0 \\
0 & 21.1 & 0 \\
0 & 0 & 46.3 \\
\end{bmatrix}
\]

Ongoing research

• Accurate, fast & user-friendly identification tools
• Non-parametric LPV system identification
• Inferential & position-dependent iterative learning and feedforward control [2].