

Accurate H-infinity-norm estimation via finite-frequency norms of MIMO local parametric models

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Accurate \mathcal{H}_∞ -Norm Estimation via Finite-Frequency Norms of MIMO Local Parametric Models

ERSNI 2021

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Background

Identification for control:

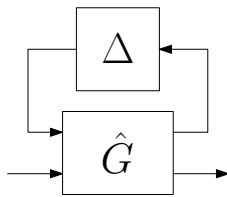
Given model \hat{P} , uncertainty Δ
 \Rightarrow Model set \mathcal{P}

Design controller that performs well for $\forall P \in \mathcal{P}$.

Problem

Model uncertainty bound γ is crucial for performance:

$\|\Delta\|_\infty \ll \gamma$: Conservative
 $\|\Delta\|_\infty > \gamma$: No guarantees
 $\|\Delta\|_\infty \leq \gamma$: Guarantees

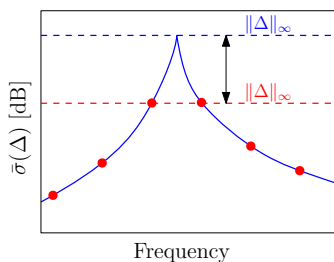


Aim: Accurate and reliable \mathcal{H}_∞ -norm estimation

Traditional Approach

FRF-based algorithms:
at-grid estimation

\Rightarrow inter-grid errors



This Research Local Modeling Techniques

Key idea: include inter-grid behaviour by local modeling techniques [1], [2]

$$Y(k) = \Delta(\xi_k)U(k) + T_\Delta(\xi_k) + V(k)$$

$\Delta(\xi_k)$ and $T_\Delta(\xi_k)$: smooth over frequency
 Exploit local smoothness: approximate Δ , T_Δ locally by parametric $\tilde{\Delta}_k$, $\tilde{T}_{\Delta,k}$

$$\Delta(\xi_{k+r}) \approx \tilde{\Delta}(\xi_{k+r}) = D_k^{-1}(r)N_K(r) \quad (\text{LMFD})$$

$$T_\Delta(\xi_{k+r}) \approx \tilde{T}_{\Delta,k}(\xi_{k+r}) = D_k^{-1}(r)M_K(r) \quad (\text{LMFD})$$

valid on domain Ω_k

\mathcal{H}_∞ -norm Estimation

Key idea: Estimating global \mathcal{H}_∞ norm through local \mathcal{L}_∞ -norms of local models:

Step 1 Finite-frequency \mathcal{L}_∞ norm: $\gamma_k = \sup_{\omega \in \Omega_k} \tilde{\Delta}_k(\xi)$
 Conversion to LMI using generalized KYP lemma [3]:

$$F(\tilde{\gamma}_k) = \begin{bmatrix} A & B \\ E & 0 \end{bmatrix}^* (\Phi \otimes P + \Psi \otimes Q) \begin{bmatrix} A & B \\ E & 0 \end{bmatrix} + \begin{bmatrix} C & D \\ 0 & I \end{bmatrix}^* \begin{bmatrix} I & 0 \\ 0 & -\tilde{\gamma}_k^2 I \end{bmatrix} \begin{bmatrix} C & D \\ 0 & I \end{bmatrix} < 0.$$

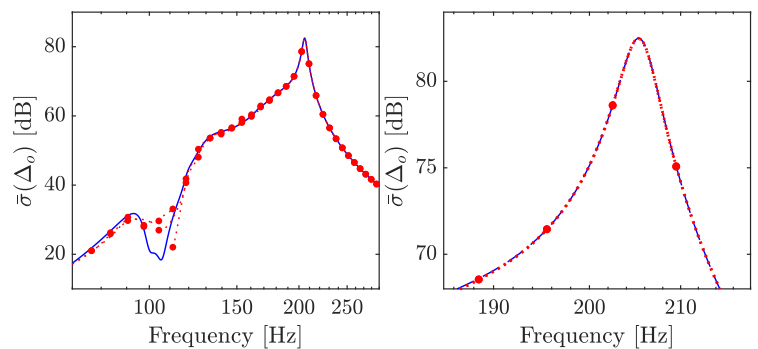
Accurate and reliable finite-frequency \mathcal{L}_∞ -norm computation

Step 2 Global \mathcal{H}_∞ norm: $\|\Delta\|_\infty \approx \max_k \gamma_k$

Results: 2x2 MIMO System

2x2 MIMO Mechanical system
 Required: $\|\Delta\|_\infty$
 \Rightarrow only FRF data available

	$\ \Delta\ _\infty$ [dB]
True	82
Traditional	78
This poster	82



Accurate \mathcal{H}_∞ -norm estimate using limited data

References

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- [3] T. Iwasaki and S. Hara, Generalized KYP lemma: Unified frequency domain inequalities with design applications, IEEE Transactions on Automatic Control, vol. 50, no. 1, pp. 41-59, 2005.