Local Rational Method with prior system knowledge: with application to mechanical and thermal systems

Enzo Evers [1], Bram de Jager [1], Tom Oomen [1]

[1] Eindhoven University of Technology, Department of Mechanical Engineering, Control Systems Technology group
PO Box 513, 5600MB Eindhoven, The Netherlands, e-mail: e.evers@tue.nl

1 Background

Frequency Response Function (FRF) identification is fast, inexpensive and accurate, and often used in applications. These FRFs are used either directly, e.g., for controller tuning or stability analysis, or as a basis for parametric identification. Identification of FRFs has been substantially advanced over recent years, particularly by explicitly addressing transients errors. The Local Polynomial Method (LPM) [1] exploits the assumed smoothness of the transient response and approximates locally the transfer function by a polynomial such that the transient can be removed.

2 Problem

Consider the output of a LTI system in the frequency domain

$$Y(k) = G(e^{i\omega_k})U(k) + T(e^{i\omega_k}) + V(k) \quad (1)$$

where $G(e^{i\omega_k})$ is the frequency response function of the dynamic system, $Y(k), U(k), V(k)$ are the output, input and noise terms and k denotes the k-th frequency bin. Where $T(e^{i\omega_k})$ accounts for the transients of both the system response and the noise. An extension of the LPM, the Local Rational Method (LRM) [2, 3] approximates the terms $G(e^{i\omega_k})$ and $T(e^{i\omega_k})$ in (1) such that in the local window

$$Y(k+r) = \frac{N_{k+r}}{D_{k+r}}U(k+r) + \frac{M_{k+r}}{D_{k+r}} + V(k+r) \quad (2)$$

As a consequence of the rational parameterization, the local estimation problem is no longer linear in the parameters which poses additional challenges. The aim of the present paper is to investigate alternative parametrizations, which are also recovered as a special case of the LRM, yet are linear in the parameters while exploiting the advantages of rationally parametrized model structures.

3 Approach

Enabling a convex optimization while maintaining the rational parameterization is done by pre-specifying the system poles based on prior knowledge. Consider again a local window around a DFT bin k such that locally

$$G(e^{i\omega_{k+r}}) = \sum_{b=1}^{Nb} \theta_{G_b} B_b(e^{i\omega_{k+r}}),\ T(e^{i\omega_{k+r}}) = \sum_{b=1}^{Nb} \theta_{T_b} B_b(e^{i\omega_{k+r}}) \quad (3)$$

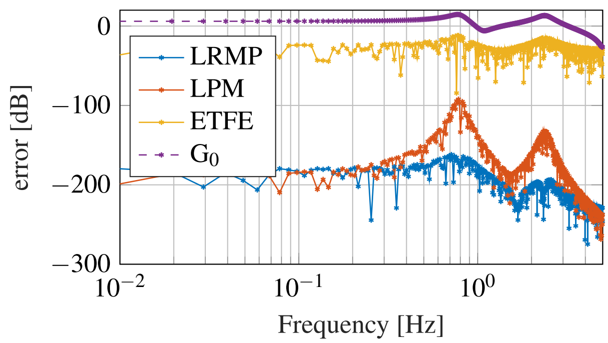

Figure 1: Estimation error of the Local Rational Method with Prior knowledge (LRMP) versus the LPM and classical method (ETFE). G_0 denotes the true system.

with basis functions $B_b(e^{i\omega_{k+r}})$ and parameters $\theta_{G_b}, \theta_{T_b}$. If the basis functions B_b contain the true system dynamics of $G(w_{k+r})$ and $T(e^{i\omega_{k+r}})$, then the basis in (3) can approximate the system in the local window arbitrarily well.

4 Result

A resonant system with two resonance modes is used for simulation. The discrete system has two sets of complex conjugated poles at $z_1 = 0.8359 \pm 0.4540i, z_2 = 0.0673 + \pm 0.8581i$. An orthonormal basis is composed of single complex poles, e.g., $\zeta = [0.8359 + 0.4540i, 0.0673 + 0.8581i]$ where ζ are a subset of the poles of the true system. The result in Fig. 1 shows an improved estimation accuracy for both resonance modes. Extensive simulations reveal that the method is robust for inaccurate ζ and for real poles occurring in thermal systems.

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References

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