The Local Polynomial Method (LPM) for $\mathscr{H}_\infty$ Robust Control

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1 Introduction

Robustness is of vital importance in feedback controlled systems. Since an estimated plant model $\hat{P}$ may not capture the actual plant behavior P_0, a model set $\mathscr{P}$ should be used instead for designing a robust controller. $\mathscr{P}$ is spanned by a nominal model $\hat{P}$ and a measure of uncertainty Δ. On the one hand, $\mathscr{P}$ has to include the actual plant behavior P_0 for performance and stability guarantees, but on the other hand, an overly large set results in a conservative controller.

In [1], it was shown that a well-chosen dual-Youla-Kučera representation is beneficial to incorporate control performance criteria in the identification step. This allows for a straightforward design of a performant robust controller when an estimate of $\|\Delta\|_\infty$, i.e. the size of the model set, is available.

Although different methods exist for model error modeling, it was shown recently that frequency-response-based methods can underestimate Δ significantly [2]. This is mainly due to the presence of sharp peaks in $\Delta(\omega)$, which can easily be missed when frequency resolution is limited (Figure 1). The ensuing underestimated $\|\Delta\|_\infty$ results in overly optimistic controller designs.

2 Exploiting LPM for Robust Control

The Local Polynomial Method (LPM) is a recent method to obtain nonparametric noise and Frequency Response Function (FRF) models using either periodic or arbitrary excitation signals [3]. This is done by exploiting the smoothness of the FRF $P(\omega_k)$ and the leakage/transient contribution $T(\omega_k)$ over the frequency and modeling each of them as low-order polynomials around every measured frequency ω_k:

$$P(\omega_{k+r}) = \sum_{m=0}^{M} p_m(k) r^m \text{ and } T(\omega_{k+r}) = \sum_{m=0}^{M} t_m(k) r^m. \quad (1)$$

The polynomial coefficients $p_m(k)$ and $t_m(k)$ are fitted to the measured system input $U(\omega_k)$ and output $Y(\omega_k)$ spectra by considering $Y(\omega) = G(\omega)U(\omega) + T(\omega)$ in a small bandwidth around each frequency ω_k.

3 Application

The LPM can be used in different steps of robust controller design, as will be illustrated on an industrial Active Vibration Isolation System (AVIS) (Figure 1).

On one hand, the LPM can be used to reduce leakage in FRF measurements, and to estimate the noise spectrum nonparametrically. In that respect, the LPM can outperform classical windowing techniques significantly [4].

On the other hand, one can apply the LPM to measurements on the *error system* Δ. By examining the local models (1), one can also get information on Δ in-between the measurement frequencies. This allows for a realistic view of $\|\Delta\|_\infty$, which allows to design controllers that are more robust.

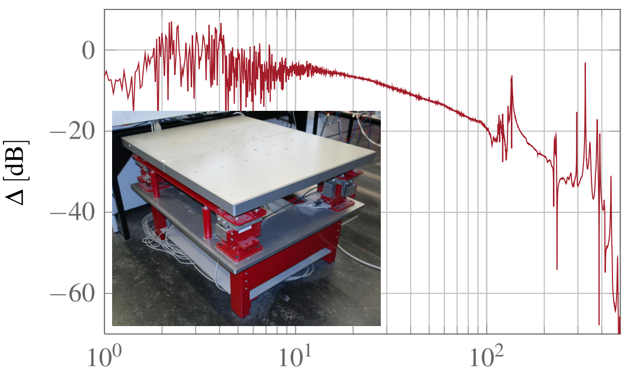

Figure 1: Measured Δ of an AVIS

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