Identification for Control of High-Tech Motion Systems

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1 Background

In the near future the requirements for motion control will become much tighter. To meet these future demands, it is envisaged that active control of flexible dynamics is required, including the use of additional actuators and sensors. This implies that the number of inputs and outputs is likely to increase, as well as the order of the relevant flexible dynamics. As a result, a model-based approach based on parametric models is a natural approach for a systematic design of controllers for such complex systems.

Although the theory and design of model-based controllers for motion systems is well-developed, the modeling task still poses a major challenge in practice. System identification is the natural approach for the modeling of such systems, since it is inexpensive, fast, and accurate. However, the identification of parametric models, as is typically required for model-based control, remains rather challenging for these high-precision motion systems.

One of the challenging aspects is the numerical reliability of the identification algorithms. This is evidenced by the fact that a significant number of approaches to address numerical implementation have been developed, including frequency scaling, amplitude scaling and the use of orthonormal basis functions. More recently, a numerically reliable identification approach was proposed based on the use of orthonormal basis functions with respect to a discrete, data-dependent inner product [1]. In this work, an extension of this approach is investigated and showcased on a high quality dataset of a vibration isolation system.

2 Approach

A recently introduced algorithm for frequency domain parametric system identification is the IV-algorithm [2]. Essentially, the computational aspect of this algorithm involves solving linear equations of the form $C^H A\theta = C^H b$. The matrices C and A, and their conditioning, depend on the choice of basis functions used to parameterize the model. Recently the use of a bi-orthonormal basis has been introduced [3], which is bi-orthonormal with respect to the bi-linear form

$$\left\langle \psi_i(\xi),\, \phi_j(\xi) \right\rangle := \sum_{k=1}^{m} \psi_j^H(\xi_k) w_{2k}^H w_{1k} \phi_i(\xi_k), \qquad (1)$$

where the weights w_{1k} and w_{2k} are the weights in C and A. Theoretically, this basis leads to optimal numerical conditioning of the system of equations, i.e., $\kappa(C^H A) = 1$. In this work we implemented and experimentally investigated this technique as well several pre-existing solutions for the identification of a high tech motion system.

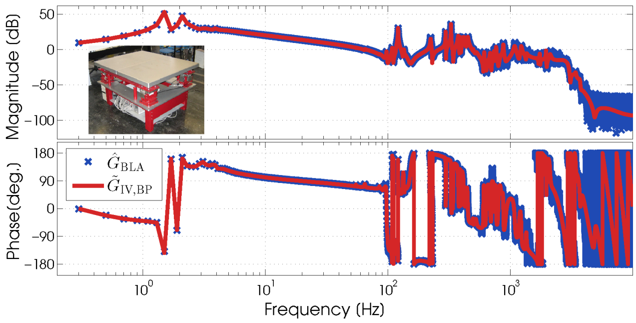

Figure 1: Non-parametric estimate of $G_{\mathrm{BLA}\,1,1}$ (blue) and the fitted model (red)

3 Results

An extensive MIMO dataset has been measured on an active vibration isolation system using full random orthogonal multisines to measure the best linear approximation [4].

Figure 1 shows the non-parametric estimate of $G_{\mathrm{BLA}\,1,1}$ as well as a 100^{th} order model, identified using the approach described in section 2. As can be seen in this Figure, the identified model is in good agreement with the non-parametric data. The geometric mean condition number during iterations, using the bi-orthonormal basis, was $\overline{\kappa} = 2$, indicating good numerical reliability. For reference, the IV algorithm using a monomial basis yields $\overline{\kappa} = 1 \cdot 10^{154}$, or $\overline{\kappa} = 2 \cdot 10^{18}$ for a scaled monomial basis. For these reference solutions, the algorithm did not converge and suboptimal results were obtained. That these numerical issues are already present in the SISO case, shows the relevance and challenge of numerically reliable identification.

4 Ongoing work

Related to the work presented here, further research is currently being done on the following topics:

- position dependent modal modeling,
- control relevant modeling, and
- further extensions of the bi-orthormal basis function implementation (MIMO) and theory.

References

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