Model Order Selection for Robust-Control-Relevant Identification

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1 Background

Next-generation motion systems are envisioned to be lightweight due to increasing demands regarding throughput and precision. Typically, lightweight motion systems exhibit flexible dynamic behavior within the control bandwidth. In general, flexible dynamic behavior is not aligned with the degrees of freedom. As a result, next-generation motion systems are envisioned to be inherently multivariable. Hence, designing controllers through loop-shaping-based techniques becomes practically infeasible.

2 Problem

Model-based control effectively deals with multivariable systems. However, a model is an approximation of reality. Therefore, a model cannot encompass the complete behavior a true system. Robust control takes modeling errors explicitly into account by considering a model set that encompasses the true system. Regarding the model set, three requirements arise, the model set should (R1) encompass the true system, (R2) minimize the worst-case performance criterion and (R3) facilitate implementation: low-order models. The aim of this research is to develop an identification framework that enables R1, R2 and R3.

3 Approach

In [1], a robust-control-relevant model set is introduced by connecting the robust controller synthesis to the identification step thereby satisfying R1 and R2. However, for the proposed approach, it is unknown how to select the order of the model set. As a result, high-order models are typically selected which hampers successful implementation. The key step in this research is the development of an order selection procedure that enables R1, R2 and R3. The proposed procedure is based on a deterministic interpretation of order selection for the statistical framework [2].

4 Results

The developed approach was applied to a sixth-order mass-spring-damper system. The optimal model order is investigated for a range of bandwidth scenarios in Fig. 1. The robust-control-relevant model set with optimal model order for a bandwidth of 3.2 Hz is depicted in Fig. 2. The simulations show that in most cases a low-order model suffices for control purposes.

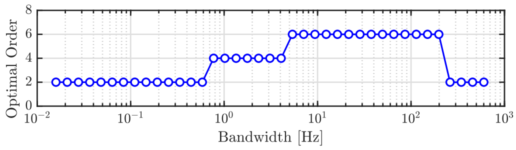

Figure 1: Optimal model order as function of the desired bandwidth.

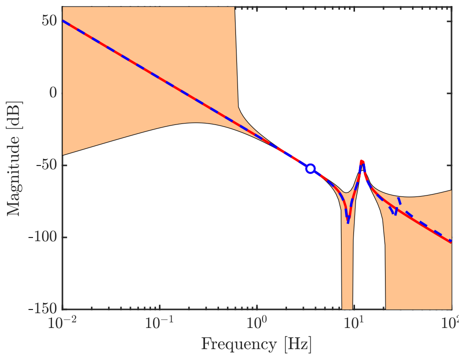

Figure 2: Bode magnitude diagram of the nominal model (——), the true system (- - -) and the robust-control-relevant model set ( ). The desired bandwidth is indicated by (○).

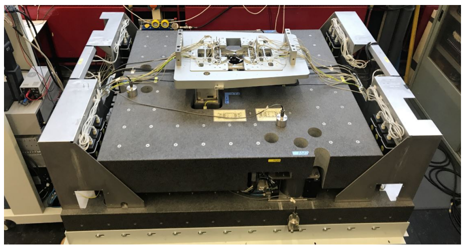

Figure 3: Reticle stage setup at the motion lab of the TU/e.

5 Outlook

Current research focuses on applying the proposed algorithm in overactuation and oversensing on the reticle stage of the TU/e, see Fig. 3.

References

[1] Oomen, T., van Herpen, R., Quist, S., van de Wal, M., Bosgra, O. and Steinbuch, M., 2013. Connecting system identification and robust control for next-generation motion control of a wafer stage. IEEE Transactions on Control Systems Technology, 22(1), pp.102-118.

[2] Stoica, P. and Selen, Y., 2004. Model-order selection: a review of information criterion rules. IEEE Signal Processing Magazine, 21(4), pp.36-37.