The Abstracted Reduction Framework

The Abstracted Reduction Framework: Efficient and Systematic Reduction of Coupled Systems

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1 Introduction

With increasingly demanding requirements on the accuracy of reduced-order models, reduction methods should consider not only the system itself, but also its environment. To do so, however, such methods need to evaluate their coupled dynamics, which may become computationally intractable. A solution is to model environments with highly abstracted models, containing only its essential dynamics, and use the resulting approximate coupled dynamics to reduce our system. However, the question arises: "How much of the dynamics do we need to retain in this abstracted environment model?". In this work, we present the abstracted reduction framework: a systematic approach to determine sufficient environment abstraction and system reduction, to meet predefined accuracy specifications on the coupled dynamics.

2 Abstracted reduction approach

To improve tractability, the abstract model of the system's environment is first determined by computationally cheap open-loop reduction, before using a closed-loop method to reduce the system in connection with this abstract environment model. As the closed-loop reduction evaluates relatively low-order coupled dynamics, its computational cost is reduced significantly. To determine appropriate reductions, we introduce a systematic approach to relate prescribed specifications on the accuracy of the coupled dynamics to required error bounds on the reductions [1]. By selecting the minimum orders for which the reduction errors meet these error bounds, we can guarantee that the reduced-order, coupled dynamics will meet initial accuracy specifications.

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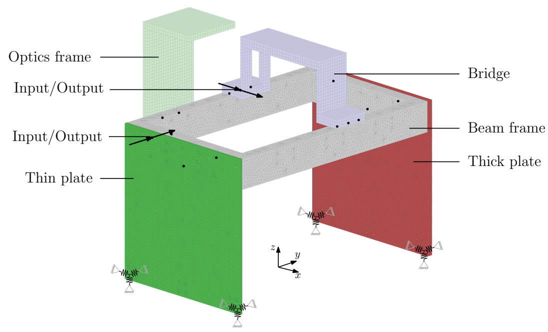

Figure 1: Schematic drawing of the structural system.

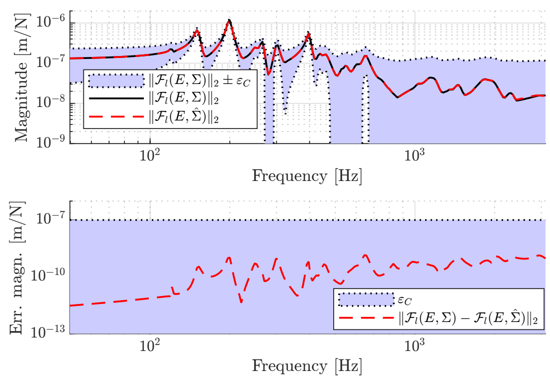

Figure 2: Prescribed bound ε_C, spectral norms of the original and reduced coupled dynamics, $\mathcal{F}_l(E,\Sigma)$ and $\mathcal{F}_l(E,\hat{\Sigma})$, resp., and the resulting error.

3 Numerical example

Observe the structural dynamics model, consisting of 5 components in Figure 1. We impose a coupled error bound ε_C of 10^{-7} m/N and reduce the thin plate model Σ to $\hat{\Sigma}$ accordingly, while the remaining components compose the environment E. This results in 89% reduction of E (from 1756 to 194 states) and 83% reduction of Σ (from 380 to 65 states). The frequency responses and bound ε_C are shown in Figure 2.

References

[1] L. A. Janssen, B. Besselink, R. H. Fey, and N. van de Wouw, "Modular Model Reduction of Interconnected Systems: A Top-Down Approach," *IFAC-PapersOnLine*, vol. 56, no. 2, pp. 4246–4251, 2023.