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INPUT-OUTPUT BASED MODEL REDUCTION FOR INTERCONNECTED SYSTEMS

Philip Holzwarth* **and Peter Eberhard**

Institute of Engineering and Computational Mechanics, University of Stuttgart
Pfaffenwaldring 9, 70569 Stuttgart, Germany
{philip.holzwarth,peter.eberhard}@itm.uni-stuttgart.de, www.itm.uni-stuttgart.de

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Elastic Multibody Systems (EMBS) are widely used as description for mechanical systems considering motions and deformations. Many problems require the consideration of deformable bodies, which can be accounted for with the floating frame of reference approach. The elasticity of single bodies can be modeled with a linear Finite Element approach. In order to achieve acceptable computation times, the resulting high-dimensional equations must be reduced. Classic, industrially established methods in this field, such as the Craig-Bampton method [2], rely on the use of eigenmodes of the system, combined with various types of component modes, e.g. static deflections of the component due to applied forces. The equations of motion resulting from a linear Finite Element model can be interpreted as a second order linear time-invariant system

$$\begin{aligned} \boldsymbol{M}\ddot{\boldsymbol{q}}(t) + \boldsymbol{K}\boldsymbol{q}(t) &= \boldsymbol{B}\boldsymbol{u}(t), \\ \boldsymbol{y}(t) &= \boldsymbol{C}\boldsymbol{q}(t), \end{aligned} \tag{1}$$

with mass matrix $\boldsymbol{M}$ and stiffness matrix $\boldsymbol{K}$. Forces acting on the model are considered as inputs $\boldsymbol{u}(t)$ and deformations of interest are collected in the outputs $\boldsymbol{y}(t)$. In various publications, e.g. [1, 3], the advantages of input-output based model order reduction, especially in comparison to global eigenmode approaches, have been illustrated. The focus on the input-output behavior enables a targeted and possibly automated selection of ansatz functions. In Balanced Truncation and frequency weighted Gramian-matrix based schemes, only the deformations that are most easily excited and observed are used to describe the dynamic behavior.

The definition of inputs in the context of mechanical systems is, however, not always straightforward. One major advantage of EMBS is the modularity of the setup, closely related to sub-structuring techniques. Single flexible components can be exchanged while others remain. Therefore, not all components of the system have to be re-modeled and re-calculated for every modification. This helps to avoid unnecessary computations and enables the use of databases. In the case of components being exchanged, obviously, the overall dynamics of the system will also change. If a given flexible body is part of a system which may not be fully know at the time of the model reduction, the choice of inputs is difficult. The stiffness at the interaction nodes and thus the forces acting on the bodies may drastically change.

In this contribution, it is shown that the advantages of both sub-structuring ideas and input-output based model order reduction can be combined, leading to a new reduction scheme. The presented method achieves good results, even if the type, respectively the stiffness, of the interconnection is not known a-priori. Thus, applying input-output based model order reduction with possibly varying interactions becomes feasible. The advantages over established methods, such as the Craig-Bampton scheme, will be illustrated for an industrially used model, as shown in Figure 1.

Figure 1: Industrially used, densely meshed Finite Element model.

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