Mechanical Engineering Doctoral Defense

Reduced Order Modeling with Variable Spatial Fidelity for the Linear and Nonlinear Dynamics of Multi-Bay Structures

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abstract

This investigation focuses on the development of component-centric reduced order models (ROMs) that provide an accurate prediction of the response of part of a structure, without focusing on the rest of the structure. Three strategies to construct such ROMs are presented in the linear case, the first two of which are based on the Craig-Bampton (CB) technique and start with a set of modes for the component of interest (referred to as "β"). The response in the rest of the structure (referred to as "α") induced by these modes is then determined and optimally represented using the Singular Value Decomposition (SVD) strategy. The first CB-based approach relies on the usual fixed interface modes of β while the second one adopts SVD eigenvectors computed from a snapshot matrix composed of the α deflections. These first two methods are effectively basis reductions techniques of the CB basis. A third approach adopts as basis for the entire structure its linear modes which are dominant in the β component response. Then, the contributions of other modes in β are approximated in terms of those of the dominant modes with close natural frequencies and similar mode shapes in β. In this manner, the non-dominant modal contributions can be seen as "lumped" onto the dominant ones. This lumping permits to increase the accuracy in β at a fixed number of modes. The three approaches are critically assessed on a 9-bay panel with the modal lumping-based method leading to the most "compact" ROMs. In the nonlinear situation, the modal lumping-based approach is first recast as a rotation of the modal basis to achieve unobservable modes. In the linear case, these modes then completely disappear from the formulation owing to their orthogonality with the rest of the basis. In the nonlinear case, however, the generalized coordinates of these modes are present in the nonlinear stiffness terms of the observable modes. A closure-type algorithm is then proposed to finally eliminate the unobserved generalized coordinates. This approach, its accuracy and computational savings, is next demonstrated on a simple beam model first and then more completely on the 9-bay panel model.

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