HYPER REDUCTION OF NONLINEAR FINITE ELEMENT STRUCTURAL MODELS WITH CONTACT AND FAILURE

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ABSTRACT

The computational efficiency of nonlinear, projection-based, model reduction methods depends on the fast and stable approximation of residual vectors and associated Jacobian matrices. Such approximations are often referred to as hyper reduction, and their outcome is often referred to as a Hyper Reduced Order Model (HROM). Large classes of problems arise in engineering practice for which HROMs deliver massive speed-ups and enable real-time computations. When hyper reducing a problem subject to constraints — for example, a problem with contact constraints — attention must be focused on maintaining the satisfaction of the Ladyzenskaja-Babuska-Brezzi (LBB) condition in order to obtain a stable, robust, and computationally efficient HROM.

Building on the work presented in [1] featuring the usage of a non-negative matrix factorization algorithm for constructing a Reduced-Order Basis (ROB) for contact forces, a complete framework for constructing stable, robust, and accurate HROMs for comprehensive nonlinear contact problems is described in this presentation. This framework incorporates the local ROB approach [2] for both displacement and Lagrange multiplier degrees of freedom, when the latter ones are used for enforcing contact constraints; and the Energy Conserving Sampling and Weighting (ECSW) method [3, 4] for the hyper reduction of internal, external, and contact forces. In particular, necessary conditions are derived for ensuring that ECSW always preserves the LBB condition. The performance of this nonlinear Model Order Reduction (MOR) framework is assessed for several contact and failure analysis problems and contrasted with that of a counterpart where hyper reduction is performed using the Discrete Empirical Interpolation Method (DEIM). In particular, the robustness and accuracy of the proposed nonlinear HROM away from the configurations where it is trained are demonstrated for the collapse analysis of a family of aluminum cylinders under a prescribed pressure load.

References