Certified Model Order Reduction for Coupled Mechanical Systems

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ABSTRACT

Utilizing simulation results for questions relevant to safety and costs requires a certified and validated simulation process. For the simulation of mechanical subsystems in a multiphysics environment, the method of elastic multibody systems (EMBS) with its integrated modular fashion is an appropriate choice very frequently. Here we focus on the floating frame of reference formulation. One single elastic body is described with a nonlinear second order differential equation (ODE) which can be split into two parts, the part belonging to the motion of the floating frame and the high-dimensional elastic part belonging to the linear elastic motion with respect to the reference frame, see e.g. [1]. For efficient transient simulations, the elastic degrees of freedom need to be reduced by considering only the elastic part of the nonlinear ODE as a linear time invariant multiple input multiple output (MIMO) system. Afterward, projection spaces for the linear second-order MIMO system are calculated with various approaches [1] and theses projection spaces are used to create a reduced nonlinear ODE of a single body. Next, the reduced bodies are assembled into the global EMBS and solved forward in time, see e.g. [2].

Withing this simulation process, multiple approximations are made and every approximation introduces an error. But without information about the approximation error, the simulation results cannot be trusted anymore. Therefore, error bounds will be developed in a hierarchical approach. The first source of error is the reduction of the linear MIMO system. Efficient error bounds for linear second order mechanical systems are addressed in [3]. Also, various error estimators exist if linear reduced models are linearly coupled to each other and the surrounding. In this work, we evaluate the performance of these error estimators for various typical mechanical systems in time as well as in the frequency domain. Also, we give an outlook how to pursue the next steps for a certified and validated simulation process and how to develop error bounds for the error which is based on the nonlinearity introduced by the reference frame movement. Afterward, rigorous error statements for the error introduced by coupling different reduced models into one global EMBS need to be derived by making use of global or local Lipschitz constants.

REFERENCES

[1] J. Fehr. *Automated and Error-Controlled Model Reduction in Elastic Multibody Systems.* Dissertation, Schriften aus dem Institut für Technische und Numerische Mechanik der Universität Stuttgart, Vol. 21. Shaker, Aachen, 2011.

[2] P. Holzwarth and P. Eberhard. Interpolation and truncation model reduction techniques in coupled elastic multibody systems. In *Proceedings of the ECCOMAS Thematic Conference on Multibody Dynamics*, Barcelona, Spain, June 29—July 3 2015.

[3] T. Ruiner, J. Fehr, B. Haasdonk, and P. Eberhard. A-posteriori error estimation for second order mechanical systems. *Acta Mechanica Sinica*, 28(3):854–862, 2012.