Accelerated Simulation via Combination of Model Reduction, Surrogate Modeling and Reuse of Simulation Data – ADMOS 2023

A. Strauß*, J. Kneifl†, J. Fehr† and M. Bischoff*

* Institute for Structural Mechanics
University of Stuttgart
Pfaffenwaldring 7, 70550 Stuttgart, Germany
e-mail: [strauss, bischoff]@ibb.uni-stuttgart.de, web page: www.ibb.uni-stuttgart.de

† Institute of Engineering and Computational Mechanics
University of Stuttgart
Pfaffenwaldring 7, 70550 Stuttgart, Germany
e-mail: [jonas.kneifl, joerg.fehr]@itm.uni-stuttgart.de, web page: www.itm.uni-stuttgart.de

ABSTRACT

In many applications in Computer Aided Engineering, like parametric studies, structural optimization or virtual material design, a large number of almost similar models have to be simulated. Although the individual scenarios may differ only marginally in both space and time, the same effort is invested for every single new simulation with no account for experience and knowledge from previous simulations. Therefore, we have developed a method that combines Model Order Reduction (MOR), surrogate modeling and the reuse of simulation data, thus exploiting knowledge from previous simulation runs to accelerate computations in multi-query contexts. MOR allows reducing model fidelity in space and time without significantly deteriorating accuracy. By reusing simulation data, a predictor or preconditioner can be obtained from a learned surrogate model to be used in subsequent simulations.

The efficiency of the method is showcased by the exact computation of critical points encountered in nonlinear structural analysis, such as limit and bifurcation points, by the method of extended systems [1] for systems that depend on a set of design parameters, like material or geometric properties. Such critical points are of utmost engineering significance due to the special characteristics of the structural behavior in their vicinity. Using classical reanalysis methods, like the fold line analysis [2], the computation of critical points of almost similar systems can be accelerated. This technology is limited, however, by the fact that only small parameter variations are possible. Otherwise, the algorithm may not converge to the correct solution or fail to converge. The newly developed data-based "reduced model reanalysis" method overcomes this limitation. Thus, a larger parameter space can be covered. The efficiency of this method is demonstrated for a couple of numerical examples, including standard and isogeometric finite element models. In addition, an adaptive time-stepping method has been developed that allows more efficient data generation for the surrogate model during the offline phase.

REFERENCES

[1] P. Wriggers , W. Wagner and C. Miehe. A quadratically convergent procedure for the calculation of stability points in finite element analysis. *Computer Methods in Applied Mechanics and Engineering* 1988; 70(3): 329-347.

[2] A. Eriksson. Fold lines for sensitivity analyses in structural instability. *Computer Methods in Applied Mechanics and Engineering* 1994; 114(1): 77-101.