Model order reduction in computational mechanics using Gaussian process regression

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ABSTRACT

In this work, a data-driven non-intrusive reduced basis (RB) method [1,2] is proposed for parametrized nonlinear problems in computational mechanics. This method requires the offline preparation of a database comprising full-order solutions at different time/parameter locations. A set of RB is extracted from the snapshot solutions in the database by the proper orthogonal decomposition (POD), and the maps between the time/parameter values and the expansion coefficients of the POD basis are approximated as Gaussian process regression (GPR) models. For time-dependent problems, the singular-value decomposition (SVD) is utilized to extract the principal components in the data of the expansion coefficients and decompose the regression functions into several time- and parameter- modes. During the online stage, the solution at a new time/parameter location can be recovered rapidly as a linear combination of the RB vectors with the outputs from the regression models as the coefficients, which enables an efficient and reliable online evaluation for multi-query, real-time simulations. The effectiveness of this method is illustrated by some non-trivial examples in computational mechanics.

Furthermore, this data-driven method is applied to the analysis of large-scale engineering structures with local nonlinearities. A computationally efficient approach [3] is proposed under the assumption of a prescribed linear-nonlinear domain decomposition. The global sensitivity analysis is utilized to reduce the high dimensionality of the parameter space and the data-driven RB scheme is used for the non-intrusive offline-online decoupling. For the linear subproblem, the conventional RB method is used with a combination with static condensation and port reduction, and the GPR facilitates the treatment of the nonlinear subproblem. This approach has been shown to be an effective tool for large-scale simulations with local nonlinearities and high-dimensional parameter domains.

REFERENCES

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