Accelerating model order reduction by multi-fidelity error estimation

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ABSTRACT

Model order reduction (MOR) is usually equipped with two stages: the offline stage and the online stage. For many intrusive MOR methods that are based on projection, the offline stage is usually realized via a greedy algorithm. The greedy algorithm is used to properly select *important* parameter samples that contribute most to the solution space. The offline computational time is basically the runtime of the greedy algorithm. For large-scale systems, the offline computation is expensive and the runtime is longer than several hours even if it is run on a high-performance server. Sometimes, the system is not very large, for example, the number of degrees of freedom is only $O(10^5)$, but the system structure is complicated such that the greedy algorithm still takes long time to converge. Once the reduced-order model is obtained, the online stage of querying the reduced-order model for simulation is very fast and in real-time.

This work concerns a strategy of significantly accelerating the greedy algorithm. We propose multi-fidelity error estimators and replace the high-fidelity error estimator in the greedy algorithm. In fact, a bi-fidelity error estimation has been used in the adaptive greedy algorithm proposed in [1] without being formally defined. To further improve the convergence speed of the greedy algorithm, we propose multi-fidelity error estimation built upon the bi-fidelity error estimation. Here, we use a more efficient high-fidelity error estimator than the two different high-fidelity error estimators used in [1]. Although the proposed multi-fidelity error estimation is dependent on the original high-fidelity error estimator, the concept of using multi-fidelity error estimation is generic and can be extended to develop multi-fidelity error estimation associated with other high-fidelity error estimators.

The multi-fidelity error estimator is then used to adaptively update the training set of the greedy algorithm, keeping the offline computational costs on a possibly lowest level. Consequently, the computational complexity at each iteration of the greedy algorithm is reduced and the algorithm converges more than 3 times faster without incurring noticeable accuracy loss.

REFERENCES

[1] S. Chellappa, L. Feng, and P. Benner. An adaptive sampling approach for the reduced basis method. In *Realization and Model Reduction of Dynamical Systems - A Festschrift in Honor of the 70th Birthday of Thanos Antoulas*, pages 137–155. Springer, Cham, 2022.