NONLINEAR MANIFOLD TO COMPONENT-WISE REDUCED ORDER MODELS TOWARDS MULTI-SCALE PROBLEMS

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ABSTRACT

Traditional linear subspace reduced order models (LS-ROMs) can accelerate physical simulations in which the intrinsic solution space falls into a subspace with a small dimension, i.e., the solution space has a small Kolmogorov n-width with a small n. However, for physical phenomena not of this type, e.g., any advection-dominated flow phenomena such as in traffic flow, atmospheric flows, and air flow over vehicles, there is no linear subspace that approximates the solution well with a small dimension. Furthermore, high-dimensional parameter space poses a serious issue of computationally expensive training cost due to the number of training data increasing exponentially with the parameter space dimension. To address cases such as these, I will present two different reduced order model techniques.

The first one is a fast and accurate nonlinear manifold ROM (NM-ROM) [1] that can better approximate high-fidelity model solutions with a smaller latent space dimension than the LS-ROMs. Numerical results show that neural networks can learn a more efficient latent space representation on advection-dominated data from 1D and 2D Burgers' equations. Speedup of 10x and relative error of less than 1% are achieved with an appropriate treatment of the nonlinear terms through a hyper-reduction technique.

The second one is a component-wise reduced order model (CW-ROM) [2] that resolves the challenge posed by a high-dimensional parameter space. The CW-ROM enables a smaller size and parameter set of training, resulting in an efficient training procedure. Furthermore, the accuracy can be tuned, so an arbitrarily accurate solution can be achieved with a considerable speedup. It is applied to a multi-scale topology optimization problem, i.e., lattice-type structure design optimization, achieving a speed-up of 1000x with a relative error less than 1%.

REFERENCES

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[2] S. McBane and Y. Choi (2021) "Component-wise reduced order model lattice-type structure design." *Computer Methods in Applied Mechanics and Engineering*, 381, p113813.

+ This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.