The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5-9 June 2022, Oslo, Norway

Deep-HyROMnet: a deep learning-based operator approximation for model order reduction in structural mechanics

Ludovica Cicci[1,*], Stefania Fresca[1] and Andrea Manzoni[1]

[1] Politecnico di Milano, Piazza Leonardo da Vinci, 32 - 20133 Milan (Italy).
{ludovica.cicci, stefania.fresca, andrea1.manzoni}@polimi.it

Keywords: *Deep learning-based operator approximation, Projection-based model order reduction, Structural mechanics*

To speed-up the solution to parameterized differential problems with respect to high-fidelity, full order models (FOMs), e.g. the finite element method, reduced order models (ROMs) featuring smaller dimension or lower complexity have been developed over the years, such as projection-based or deep-learning based ROMs, as well as surrogate models obtained via a machine learning approach. To the former class of models belong the so-called reduced basis (RB) methods [1], which yield approximations that fulfill the physical problem at hand thanks to the use of a Galerkin projection of the FOM onto a linear low-dimensional subspace. However, when dealing with problems characterized by (high-order polynomial or nonpolynomial) nonlinearities, intrusive and expensive hyper-reduction stages are required to make the assembling of a ROM independent of the FOM dimension. To overcome this computational bottleneck, we propose a novel strategy for learning nonlinear ROM operators using deep neural networks (DNNs) [2]. The resulting hyper-reduced order model, to which we refer to as Deep-HyROMnet [3], is then a physics-based model, still relying on the RB method approach, however employing a DNN architecture to approximate reduced residual vectors and Jacobian matrices once a Galerkin projection has been performed. Numerical results dealing with fast simulations in nonlinear structural mechanics show that Deep-HyROMnets are orders of magnitude faster than POD-Galerkin ROMs equipped with standard hyper-reduction techniques, such ad the discrete empirical interpolation method, still keeping good level of accuracy.

REFERENCES

[1] A. Quarteroni, A. Manzoni and F. Negri, "Reduced basis methods for partial differential equations. An introduction", *Springer International Publishing*, 2016.

[2] S. Fresca and A. Manzoni, "POD-DL-ROM: enhancing deep learning-based reduced order models for nonlinear parametrized pdes by proper orthogonal decomposition", *Computer Methods in Applied Mechanics and Engineering*, vol. 388, p. 114181, 2022.

[3] L. Cicci, S. Fresca and A. Manzoni, "Deep-HyROMnet: A deep learning-based operator approximation for nonlinear parameterized PDEs", in preparation.