Reduced Order Modeling of dynamical systems   
through deep learning techniques   
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ABSTRACT

Developing efficient and reliable reduced order models (ROMs) for nonlinear dynamical systems is of paramount importance to enhance the use of numerical simulations in several contexts from applied sciences and engineering. Noteworthy examples include uncertainty quantification, inverse problems, data assimilation, and the design of high-fidelity digital twins. In all these cases, full-order models obtained, e.g., through the finite element method, would make the repeated simulations of complex systems in different virtual scenarios computationally unaffordable, because of the need of fine spatial and/or time discretizations.

Several efforts have been made recently to build ROMs exploiting deep learning (DL) techniques, such as convolutional architectures, deep autoencoders, and graph networks, and to overcome common limitations shared by classical conventional ROMs – built, e.g., through proper orthogonal decomposition – when applied to nonlinear dynamical systems. These might be related to (i) the need to deal with projections onto high-dimensional linear approximating trial manifolds, (ii) expensive hyper-reduction strategies, or (iii) the intrinsic difficulty to handle physical complexity with a linear superimposition of modes. In this respect, neural networks and deep learning algorithms represent a key ingredient of a wide range of new techniques, including ways to enhance projection-based ROMs, to build non-intrusive ROMs, to exploit physics-informed neural networks, to develop deep operator networks for the approximation of operators in parametrized PDEs, just to mention a few options.

This mini symposium will gather a broad spectrum of contributions in this very recent research field, emphasizing the theoretical aspects, computational performances, and practical use of DL-based algorithmic methods to enhance ROMs in various contexts from applied sciences and engineering.