DEEP LEARNING-BASED REDUCED ORDER MODELS FOR NONLINEAR PARAMETRIZED PDES: APPLICATION TO CARDIAC ELECTROPHYSIOLOGY

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Conventional reduced order models (ROMs) anchored to the assumption of modal linear superimposition, such as proper orthogonal decomposition (POD), may reveal inefficient when dealing with nonlinear time-dependent parametrized PDEs, especially for problems featuring coherent structures propagating over time, such as cardiac electrophysiology (EP). To enhance ROM efficiency, we propose a nonlinear approach to set ROMs by exploiting deep learning (DL) algorithms as convolutional neural networks. In the resulting DL-ROM, both the nonlinear trial manifold and the nonlinear reduced dynamics are learned in a non-intrusive way by relying on DL algorithms trained on a set of full order model (FOM) snapshots, obtained for different parameter values. Performing then a former dimensionality reduction on FOM snapshots through POD and using a suitable multi-fidelity pretraining enable, when dealing with large-scale FOMs, to speed-up training times, and decrease the network complexity, substantially. Accuracy and efficiency of the DL-ROM technique are assessed on different parametrized PDE problems in cardiac EP, representing both physiological and pathological scenarios, computational mechanics and fluid dynamics, where new queries to the DL-ROM can be computed in real-time. In particular, DL-ROMs are shown to be able to solve, after the training stage, cardiac EP problems on realistic geometries, for any new scenario in real-time, even in extremely challenging contexts such as re-entry and re-entry break-up problems, modeling the triggering phenomena related with cardiac arrhythmias.

References

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