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Non-intrusive reduced order modeling of natural convection in porous media

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A simulation tool capable of speeding up the calculation for natural convection in porous media is of sizeable practical interest for engineers, in particular, to effectively perform sensitivity analyses, uncertainty quantification, and optimization of CO_2 sequestration and geothermal harvesting. We present a non-intrusive reduced order model (ROM) using the nested proper orthogonal decomposition (POD) and artificial neural networks (ANN). In this study, the nested POD refers to a compression strategy in which time and uncertain parameter domains are compressed consecutively (in contrast to the classical POD method in which all domains are compressed simultaneously). We utilize the two-field mixed finite element method and interior penalty discontinuous Galerkin approximation for spatial discretization and the 4th-order backward differentiation formula for time-stepping as our full order model (FOM). This combination is selected to avoid spurious oscillations resulting from the lack of local mass conservation and accurately capture the gravity-driven flow in advection-dominated problems. The proposed framework is divided into an offline phase for the ROM construction, which we will present through five consecutive steps and (single-step) online stage for the ROM evaluation. The \textbf{offline phase} includes the following steps: (1) initialize a training set (uncertain parameters), which could correspond to material properties, boundary conditions, or geometric characteristics, (2) query the FOM for each value in the training set, (3) compress the FOM results using the nested POD, (4) obtain the optimal representation of the FOM results employing an L^2 projection, and (5) train the ANN to map the set of uncertain parameters (input) to the collection of coefficients calculated from an L^2 projection over the reduced basis (output). During the \textbf{online phase}, for given values of uncertain parameters, we aim to recover the online approximation of our primary variables by querying the ANN evaluation of the collection of coefficients and reconstructing the resulting finite element representation through the reduced basis functions. We conclude the presentation using a series of validations through the method of manufactured solutions used in and benchmark problems of the Horton–Rogers–Lapwood and Elder problems.

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Time Block Preference

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References

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