High-fidelity surrogate models for flow problems in parameterized geometries

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ABSTRACT

Design and optimization cycles in an industrial production environment require multiple queries of a parametric model. In the automotive and aerospace industry, this is usually represented by a set of partial differential equations, e.g. Stokes and Navier-Stokes equations modelling incompressible flows, in which boundary conditions, physical properties of the fluid and geometry of the domain may vary within a range of values of interest. In this context, the parameters under analysis act as extra coordinates of a higher-dimensional partial differential equation. A high-fidelity surrogate model is proposed coupling the separable approximation of the proper generalized decomposition (PGD) [1, 2] and the high-order spatial discretization of the hybridizable discontinuous Galerkin (HDG) method [3, 4, 5]. The PGD rationale is exploited to construct a computational vademecum describing the features of the flow under analysis in parameterized geometries. Hence, the resulting generalized solution explicitly depends on the parameters controlling the shape of the domain. The proposed reduced order model inherits the good approximation properties of HDG, including its flexibility to devise accurate high-order, nonuniform and polynomial degree adaptive discretizations. Such advantages are exploited in the offline phase of the proper generalized decomposition to construct an accurate reduced basis with no a priori knowledge of the solution. Numerical examples will be presented to show the capabilities of the proposed surrogate model to compute fast and accurate approximations of flow problems during an online phase, for different geometrical configurations of interest.

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