Reliable and efficient model reduction of parametrized aerodynamics problems: error estimation and adaptivity

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We consider goal-oriented model reduction of parametrized nonlinear PDEs, with an emphasis on aerodynamics problems that exhibit a wide range of scales, unsteadiness, and shape deformation. The key ingredients are as follows: the discontinuous Galerkin (DG) method, which provides stability for convection-dominated flows; reduced basis (RB) spaces, which provide rapidly convergent approximations of the parametric manifolds; the dual-weighted residual (DWR) method, which provides effective error estimates for quantities of interest; the empirical quadrature procedure (EQP), which provides hyperreduction of the nonlinear residual and error estimates; and an adaptive weak greedy algorithm, which (i) simultaneously adapts the DG spaces, RB spaces, and EQP to meet the user-specified output error tolerance and (ii) adaptively enriches the training set to control the training cost in high-dimensional spaces associated with shape deformation and/or unsteady problems. We demonstrate the framework for parametrized aerodynamics problems modeled by the compressible Euler and Reynolds-averaged Navier-Stokes equations. In the online stage, reduced models achieve significant computational reduction, control the discretization error, and provide the associated error estimates for quantities of interest. In the offline stage, the adaptive greedy algorithm trains reduced models for aerodynamics problems in engineering-acceptable training time.