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Output-Based Discretization Error Control in Turbulent Flow Simulations

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Advances in computational power have enabled scale-resolving simulations of turbulent flow, yet the high cost of these simulations prohibits their use in a multi-query setting, such as design optimization. In addition, discretization errors resulting from under-resolved spatial and temporal domains often go unchecked, as a posteriori error estimates do not easily extend to such simulations due to their chaotic nature. As evidenced by recent workshops on high-fidelity discretizations, these errors can significantly impact numerical solutions and prevent the use of such simulations for predictive analysis. We discuss two solutions to this challenge of robust turbulent-flow computation. The first is a mesh adaptation procedure based on the entropy adjoint, which is stable and inexpensive to compute, and which minimizes spurious entropy production in unsteady simulations. The second is a data-driven approach for calculating adjoints by correcting a lower-fidelity model, such as Reynolds-averaged Navier-Stokes (RANS). The corrected RANS equations yield a steady adjoint solution that can be used with unsteady residuals to define an output-based indicator for adaptation. Results for several prototypical aerodynamic problems demonstrate the utility of the proposed methods for estimating and reducing discretization errors.