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Bayesian Optimization on Fifth-Order Targeted ENO Scheme for Compressible Flows

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Targeted ENO (TENO) has originally been proposed by Fu et al. [1] in order to overcome the shortcomings of WENO schemes which are excessive dissipation, and limited robustness for lower order upwind-biased, and central-biased schemes, respectively [2]. TENO offers a set of free parameters to alter the inherent effective local dissipation and dispersion. In the original formulation of [1], these free parameters have been adjusting by means of the approximate dissipation-dispersion relation [3].

Data-driven methods enable optimizing these free parameters instead of adjusting these. In this work, we demonstrate the application of an iterative Bayesian optimization approach on designing fifth-order TENO (TENO5) schemes. Exploiting that Bayesian optimization efficiently and robustly finds an optimum of an expensive function with a low number of trials, we construct specific TENO5-schemes for compressible flows with gasdynamic discontinuities, and implicit large eddy simulation (ILES) of turbulent flows. For the former, we measure the error between under-resolved simulations of the Sod shock tube and its analytical solution for automatically generated TENO5 formulations. For the latter, under-resolved inviscid Taylor-Green vortex flows are evolved to their turbulent state, in which their kinetic energy spectrum in the inertial subrange is compared to the theoretical Kolmogorov-scaling solution.

We show that these two TENO5 formulations perform superior to the original formulation of [1] for the wave-number ranges in dissipation-dispersion relation relevant to the specific types of flows. Also, a variety of benchmark test flows show that both TENO5 formulations perform better than the original one in terms of phase speed, shock resolution and physical consistency of turbulent flows, i.e. in practical applications.

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