Development of a family of cost-optimized prefactored high-order compact schemes for low-speed aeroacoustics

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Abstract

A new class of cost-optimized prefactored high-order compact schemes, developed for shock-free error-bounded aeroacoustic applications, is presented. The cost-optimization theory of Pirozzoli (2007), based on the minimization of the computational cost for a given level of numerical error, is applied to obtain a new class of time-explicit prefactored compact schemes. Suitable high-order prefactored boundary closures, which are accurate and stable within a selected Fourier space envelope, are coupled with the new interior schemes. More conventional non-reflecting boundary conditions are shown to display an impedance mismatch, thus reducing the order of accuracy of the overall scheme. An eigenvalue analysis is performed, to verify the stability of the prefactored cost-optimized schemes coupled with the boundary closures. A parallelization strategy, based on a finite-sized overlapping interface, is presented, and weak scalability tests results are shown. Good agreement is recovered between the predicted percentage cost-saving of the one-dimensional cost function and the measured savings in computational time for a one-dimensional monochromatic wave propagation test. Sample applications to broadband and two-dimensional space benchmark problems clearly bring out the favourable properties of the baseline scheme for large-scale aeroacoustic applications.

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