Development of an efficient Navier-Stokes/LES solver on unstructured grids for high-order accurate schemes

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Abstract

The main goal of this thesis is to develop an efficient Navier-Stokes/LES solver on unstructured grids for high-order accurate spatial discretizations, and build up the necessary know-how to make a high-order accurate solver for industrial purposes. In the field of the computational fluid dynamics, the expectation is that an efficient higher-order discretization may provide an alternate path for achieving high accuracy in a flow with a wide disparity of length scales at reduced cost, by avoiding the use of excessive grid resolution. However, the development of optimal, or near optimal solution strategies for higher-order discretizations and implicit time integration strategies, remains then one of the key determining factors in devising higher-order methods. In addition, although spatially high-order accurate numerical schemes guarantee the accurate resolution of small scales, their application to the simulation of general turbulent flows implies that particular attention has still to be paid to subgrid models. In this framework, two spatially high-order accurate methods for unstructured grids are considered, namely the spectral volume and the spectral difference methods. To fully exploit the potential benefits of such high-order operators, an efficient non-linear algebraic solver, denoted as non-linear LU-SGS algorithm, is investigated. This solver is used to invert the non-linear algebraic systems arising from implicit time discretizations with the backward Euler scheme and the second-order backward difference formula. Several test cases are used to demonstrate the potential benefits of the implicit time integration/algebraic solver technique. In addition, the need for paying particular attention to subgrid models for the simulation of general turbulent is recognized. A high-order spectral difference scheme is coupled with a subgrid model to perform LES. A new procedure to calculate the filter width is proposed. The accuracy and the reliability of the method are tested by solving 2D and 3D turbulent test cases. A good agreement between the present numerical results and reference solutions is observed, showing the capability and the quality of the new coupling approach.