11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

IMPLICIT LARGE EDDY SIMULATION OF TURBULENT FLOWS WITH THE HYBRIDIZED DISCONTINUOUS GALERKIN METHOD

X. Roca[1], N.C. Nguyen[1] and J. Peraire[1]

[1]Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA; xeviroca@mit.edu, cuongng@mit.edu, peraire@mit.edu

Key words: *Untructured High-Order Method, Discontinuous Galerkin, Hybridized, LES*

The direct simulation of turbulent flows is crucial for the high-fidelity estimation of the noise emissions at Mach and Reynolds numbers of engineering interest. The challenge is that turbulent flows present spatial and time features in a wide range of scales. Hence, prohibitively large 3D meshes and small time steps are required to resolve all the flow scales. To reduce the computational cost, an Implicit Large-Eddy Simulation (ILES) is considered. An ILES is well suited for noise prediction since it resolves only the large eddies, those which contribute significantly to sound radiation. On the contrary, the effect of the small unresolved eddies is accounted for by means of the numerical dissipation. To reduce numerical dissipation at larger scales, we consider a high-order numerical scheme [1], the hybridized discontinuous Galerkin method (HDG) [2, 3].

Several unique features distinguish the hybridized discontinuous Galerkin (HDG) methods from other discontinuous Galerkin methods. In this work, we exploit some of these advantages to propose a distributed and parallel HDG solver for the compressible Navier-Stokes equations [4]. First, the global degrees of freedom are reduced to the numerical trace of the solution on the element boundaries. This reduction of the global degrees of freedom increases the performance of the distributed and parallel linear solver. This reduction is more significant for higher interpolation degrees. For instance, a fifth-order approximation leads to a global linear system that corresponds to the 20% of all DOF. Second, the conserved quantities and their gradients on each element are obtained in terms of the numerical trace on the element boundary. This operation is performed element-by-element and therefore, is parallelized without communication. Since there is no communication in the second stage, the cost of the HDG solver is dominated by the solution of the global, but reduced, linear system.

REFERENCES

[1] Uranga, A., Persson, P.-O., Drela, M., and Peraire, J., Implicit Large Eddy Simulation of transition to turbulence at low Reynolds numbers using a Discontinuous Galerkin method, *International Journal of Numerical Methods in Engineering*, Vol. 86, 2011.

[2] Cockburn, B., Gopalakrishnan, J., and Lazarov, R., Unified hybridization of discontinuous Galerkin, mixed and continuous Galerkin methods for second order elliptic problems, *SIAM J. Numer. Anal.*, Vol. 47, 2009.

[3] Nguyen, N., Peraire, J., and Cockburn, B., An implicit high-order hybridizable discontinuous Galerkin method for nonlinear convection-diffusion equations, *J. Comput. Phys.*, Vol. 228, 2009, pp. 8841–8855.

[4] Roca, X., Nguyen, N.C., and Peraire, J., Scalable parallelization of the hybridized discontinuous Galerkin method for compressible flow, *21st AIAA Computational Fluid Dynamics Conference*, 2013.