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Hybrid High-Order Finite Volume/Discontinuous Galerkin Methods for Turbulent Flows

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The development of high order numerical methods is a highly active and important field for the advancement of computational fluid dynamics (CFD). Currently, second-order finite volume (FV) methods are standard for commercial CFD codes. However, higher orders of accuracy are beneficial for high-fidelity turbulence modelling techniques, where a wide range of spatio-temporal scales need to be resolved. In addition, high-order methods are more computationally efficient.

Two particularly promising directions on the path towards the development of a high order scheme are finite volume schemes with a nonlinear reconstruction method, such as the Weighted Essentially Non-Oscillatory (WENO) method, and the discontinuous Galerkin (DG) method. WENO allows for arbitrarily high order methods through extension of the reconstruction stencil. In addition, as the name suggests, the method is able to resolve strong discontinuities without spurious oscillations. However, enlarging the stencil increases the computational cost, and creates complications for parallelization. DG methods have recently gained popularity due to their compactness, accuracy, and adaptability. However, they have a few weaknesses including the large memory and computational cost required and spurious oscillations in the vicinity of strong discontinuities.

A logical conclusion is to combine the two approaches in order to preserve the advantages of both methods while eliminating some disadvantages. Due to their compact size, the CWENO/CWENOZ schemes [1] are more suitable to be used in conjunction with the DG framework. However, in order to preserve the accuracy and compactness properties of the original DG method, the limiting procedure should be applied only where necessary. For this reason, the limiting strategy usually consists of two steps: first, the so-called troubled cells, where a limiting procedure is required, are determined through a troubled cell detector [2]; then, the higher modes of the unlimited DG solution are replaced with the WENO solution.

We present the results of our implementation of a hybrid FV-DG method into the open-source unstructured CFD code UCNS3D.

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