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High Order Shock Detecting Methods and Applications

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With the increasing research and application of computational fluid dynamics (CFD) in compressible flows, it is desirable that the numerical methods of CFD have both the properties of capturing discontinuities such as the shock waves with monotone profiles and high order low dissipation in smooth regions. Weighted essentially non-oscillatory (WENO) schemes have uniform higher order accuracy in smooth region and keep the essentially non-oscillatory properties near shock waves, and hence are widely used in computational fluid dynamics. However, numerical studies show that the resolution of short waves of WENO schemes is not ideal, and their excessive numerical dissipation for the compressible flows in which shock waves and turbulence are present and interact dynamically overwhelm the physical dissipation. Meanwhile, the cost of computation of nonlinear weights of the WENO schemes is more expensive than the linear difference schemes.

In order to develop high performance numerical method for compressible flows, researchers proposed the hybrid schemes combining shock-capturing schemes and high-order accuracy low dissipation schemes, i.e. near shock wave regions, the shock-capturing schemes are used, while in smooth regions, the high-order low dissipation schemes are used. An important and challenge issue is: how to detect a shock accurately and efficiently.

In this paper, several high-order smoothness indicators for a whole stencil used to construct a scheme are suggested. Based on the relationship between these whole smoothness indicator and the individual smoothness indicator of each candidate stencil for ENO/WENO scheme, several shock-detecting methods, including the second-order method on a three points stencil, the third-order and fourth-order methods on a five points stencil, are proposed. No any artificial problem-dependent parameter is introduced in these shock-detecting methods. Then, the hybrid schemes combining the high-order WENO scheme and high-order compact scheme are constructed by using these shock-detecting methods. Numerical results demonstrate the effectiveness and accuracy of these detecting methods, and also the high performance of the hybrid schemes.

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