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（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	創造エネルギー　　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（　理学　）
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Godunov-type method has been well-accepted as the main-stream numerical approach to solve Euler equations. The reconstruction is the core issue for the development of the new numerical schemes. For existing Godunov-type methods, the numerical dissipation and numerical oscillations brought from reconstruction errors are two critical problems in the computation of Euler equations. In this thesis, we have made following efforts to solve the above problems.

We proposed a new guideline to construct high-resolution Godunov type schemes to resolve both smooth and discontinuous solutions. The basic idea, so-called BVD (boundary variation diminishing), is to reconstruct the solution functions so that the jumps at cell boundaries are minimized, which effectively reduces the numerical dissipation in the resulting schemes. The BVD algorithm provides a reliable switching mechanism to reconstruct the solution function for both smooth profile and discontinuity. For smooth profile, we use the polynomial reconstruction, while for jump discontinuity, we use a step-like function for flux reconstruction. We have implemented the BVD algorithm with the existing schemes as the building-block schemes, i.e. 5th order WENO (Weighted Essentially Non-Oscillatory) /TENO (Targeted Essentially Non-Oscillatory) and THINC (Tangent of Hyperbola INterface Capturing) schemes. Not limited to (W/T)ENO and THINC schemes, the BVD concept as a general platform of more profound impact can be used with other candidate reconstructions to further explore high-fidelity schemes for capturing both smooth and discontinuous solutions. Excellent numerical results have been obtained for both scalar and Euler conservation laws, which show a substantial improvement in comparison with the existing methods including the high-order and less-dissipative methods. Especially, the BVD reconstruction displays superior performance in dealing with the problems including vortical flow field that is sensible to numerical dissipation.

We developed a new WENO-type limiter for MCV3 (3-point Multi-moment Constrained finite Volume) scheme under MMC-FR (Multi-Moment Constrained Flux Reconstruction) framework. The new scheme, so-called MCV-WENO4 (MCV with WENO limiter of 4th

order) scheme, distinguishes itself from the following parts. First, the WENO reconstruction is based on the sub-grid solution structures from the nodal values at the solution points within the target cell and its immediate neighbors. The stencil for reconstruction is minimized. Thus, the scheme is better suited for the local high-order reconstruction schemes where sub-grid information is available. Second, the present scheme has much less numerical dissipation, and thus doesn't use the ad hoc TVB (Total Variation Bounded) criterion needed in nearly all-existing schemes. Last but not least, the present scheme is algorithmically simple and computationally efficient. The numerical results for the widely-used benchmark tests show that our scheme can get the 4th-order uniform convergence rate as expected and high quality solutions for both discontinuities and smooth profiles.

We devised a novel WENO limiter for CIP/MM FVM (Constrained Interpolation Profile/Multi-Moment Finite Volume Method), which leads to a new scheme, so-called CIP-CSL-WENO4 (Constrained Interpolation Profile-Conservative Semi-Lagrangian scheme with WENO limiter of 4th order). The new WENO limiter uses the local DOFs (Degrees of Freedom) available in the target cell and its immediate neighboring cells, which minimizes the WENO interpolation stencil. The proposed scheme is free of the ad hoc TVB criterion that is needed in nearly all-existing schemes to control excessive numerical dissipation. The semi-Lagrangian formulation is more accurate and of better computational efficiency in comparison with the Eulerian scheme. The 4th order convergence rate has been verified for both scalar and Euler conservation laws. Furthermore, the numerical results of some widely-used benchmark tests show that the present method is able to get the high-quality solutions among the best ever reported of the numerical schemes with similar number of DOFs. The present scheme can be seen as a more consistent formulation that well balances different requirements for a high resolution scheme, such as local high-order reconstruction and limiting projection, numerical accuracy and computational efficiency.

We proposed a new version of BVD algorithm that can use the HLR (High order numerical method with Local Reconstructions) as the building-block scheme. We extended the BVD concept to the difference of the derivatives at cell interfaces, where the reconstruction minimizes the BV of both PV and derivative values, which is compatible with the reconstructions in the multi-moment method and other HLR methods. We implemented the new BVD scheme using MCV-WENO4 scheme and THINC reconstruction as the building block schemes. The resulting scheme, BVD-MCV-WENO4 scheme, shows the possibility of implementing the BVD reconstruction under the HLR formulation. The numerical results presented in this chapter demonstrate that the new BVD algorithm is capable of minimizing the numerical dissipation near the discontinuous solutions, especially for jump discontinuities, at the same time, the smooth solutions can be resolved with high accuracy.

As mentioned above, the presented numerical formulations have been verified and validated by a wide range of benchmark tests, including analysis of errors and convergence rates as well as evaluation of robustness and computational cost. We have obtained expected numerical results for all the proposed schemes.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
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