On a class of two-dimensional incomplete Riemann solvers

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Abstract

We propose a general class of genuinely two-dimensional incomplete Riemann solvers for systems of conservation laws. In particular, extensions of Balsara's multidimensional HLL scheme [1] to two-dimensional PVM/RVM (Polynomial/Rational Viscosity Matrix) finite volume methods [2, 3] are considered. The numerical flux is constructed by assembling, at each edge of the computational mesh, a one-dimensional PVM/RVM flux with two purely two-dimensional PVM/RVM fluxes at vertices, which take into account transversal features of the flow.

The proposed methods are applicable to general hyperbolic systems, although in this work we focus on applications to magnetohydrodynamics. In particular, we propose an efficient technique for divergence cleaning of the magnetic field that provides good results when combined with our two-dimensional solvers. The nonconservative form of ideal MHD equations [5] allows to impose the divergence-free condition automatically in the framework of path-conservative schemes [4]. Several numerical tests including genuinely two-dimensional effects are presented to test the performances of the proposed schemes.

References

[1] D.S. Balsara, A two-dimensional HLLC Riemann solver for conservation laws: application to Euler and magnetohydrodynamic flows, J. Comput. Phys. 231 (2012) 747–7503.

[2] M.J. Castro, E.D. Fernández-Nieto, A class of computationally fast first order finite volume solvers: PVM methods, SIAM J. Sci. Comput. 34 (2012) A2173–A2196.

[3] M.J. Castro, J.M. Gallardo, A. Marquina, A class of incomplete Riemann solvers based on uniform rational approximations to the absolute value function, J. Sci. Comput. 60 (2014) 363–389.

[4] C. Parés, Numerical methods for nonconservative hyperbolic systems: a theoretical framework, SIAM J. Num. Anal. 44 (2006) 300–321.

[5] K.G. Powell, An approximate Riemann solver for magnetohydrodynamics (that works in more than one space dimension), Technical Report, vol. 94 – 24, ICASE, Langley, VA, 1994.