High-Order Multi-Material ALE Hydrodynamics

Robert W. Anderson*, Veselin A. Dobrev*, Tzanio V. Kolev*, Robert N. Rieben† and Vladimir Z. Tomov*

*Center for Applied Scientific Computing, Lawrence Livermore National Laboratory, anderson110@llnl.gov, dobrev1@llnl.gov, tzanio@llnl.gov, tomov2@llnl.gov

† Weapons and Complex Integration, Design Physics Division, Lawrence Livermore National Laboratory, rieben1@llnl.gov

ABSTRACT

We present a new approach for multi-material Arbitrary Lagrangian-Eulerian (ALE) hydrodynamics simulations based on high-order finite elements posed on high-order curvilinear meshes. The method builds on and extends our previous work in the Lagrangian [1] and remap [2] phases of ALE, and depends critically on a functional perspective that enables sub-zonal physics and material modeling [3]. Curvilinear mesh relaxation is based on node movement, which is defined through the solution of an elliptic equation. The remap phase is posed in terms of advecting state variables between two meshes over a fictitious time interval. The resulting advection equation is solved by a Discontinuous Galerkin (DG) formulation, combined with a customized Flux Corrected Transport (FCT) type algorithm. Because conservative fields are remapped, additional synchronization steps are introduced to preserve bounds with respect to primal fields. These steps include modification of the low-order FCT solutions, definition of conservative FCT fluxes based on primal field bounds, and monotone transitions between primal and conservative fields. This paper describes the mathematical formulation and properties of our approach and reports a number of numerical results from its implementation in the BLAST code [4].

REFERENCES

[1] V. A. Dobrev, T. V. Kolev, and R. N. Rieben, High-order curvilinear finite element methods for Lagrangian hydrodynamics, SIAM J. Sci. Comp., 34 (2012), pp. B606–B641.

[2] R. W. Anderson, V. A. Dobrev, T. V. Kolev, and R. N. Rieben, Monotonicity in high- order curvilinear finite element arbitrary Lagrangian–Eulerian remap, Internat. J. Numer. Methods Fluids, 77 (2015), pp. 249–273.

[3] V. A. Dobrev, T. V. Kolev, R. N. Rieben, and V. Z. Tomov, Multi-material closure model for high-order finite element Lagrangian hydrodynamics, Internat. J. Numer. Methods Fluids, (2016), pp. n/a–n/a.

[4] BLAST: High-order finite element Lagrangian hydrocode. http://www.llnl.gov/CASC/blast.

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, LLNL-ABS-707600.