Matrix-free nonconforming discontinuous Galerkin methods on GPU architectures with MFEM

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ABSTRACT

MFEM [1] is an open-source, lightweight, flexible and scalable C++ high-order finite element methods library targeting portability, scalability and high-performance computing. Application codes based on MFEM, such as the high-order finite element ALE hydrodynamics research and development code BLAST [2], or the Lagrangian high-order finite-element code LAGHOS [3], heavily rely on the ability of discontinuous Galerkin (DG) methods to handle arbitrary unstructured nonconforming geometries without compromising simulation stability.

Modern and incoming HPC architectures have redefined the hardware landscape by the massive utilization of GPUs. In the continuity of the U.S. Department of Energy Exascale Computing Project co-design Center for Efficient Exascale Discretization, recent developments in the MFEM library have extended matrix-free finite element operators to DG methods. Matrix-free operators offer much reduced data movement at the cost of increased arithmetic intensity when compared to the utilization of a sparse matrix, making matrix-free algorithms particularly well suited for GPU architectures.

In this talk, we will motivate the use of matrix-free high-order methods to target high-performance on GPU architectures, we will introduce the matrix-free decomposition for nonconforming DG methods used in MFEM, and finally we will be presenting performance results on HPC architectures.

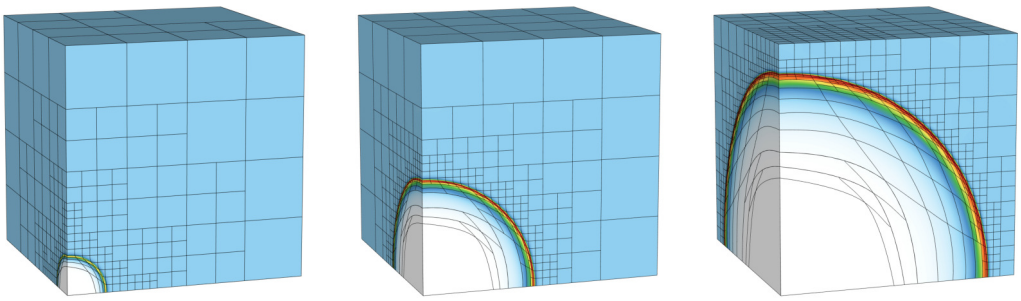

Figure 1: Dynamic adaptive mesh refinement for the high-order finite element discretization of the Sedov problem in the Laghos miniapp.

References

[1] R. Anderson, J. Andrej, A. Barker, J. Bramwell, J.-S. Camier, J. Cerveny, V. Dobrev, Y. Dudouit, A. Fisher, Tz. Kolev, W. Pazner, M. Stowell, V. Tomov, I. Akkerman, J. Dahm, D. Medina, and S. Zampini, "MFEM: A Modular Finite Element Methods Library", Computers & Mathematics with Applications, 10.1016/j.camwa.2020.06.009

[2] R. A. Anderson, V. A. Dobrev, Tz. V. Kolev, R. N. Rieben and V. Z. Tomov, "High-Order Multi-Material ALE Hydrodynamics", *SIAM Journal on Scientific Computing*, (40) 2018, pp. B32-B58.

[3] Laghos: Lagrangian high-order solver miniapp, https://github.com/CEED/Laghos.