GPU Acceleration of a High-Order ALE Remap Algorithm for Hydrodynamics

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ABSTRACT

For simulations of hydrodynamics, the arbitrary Lagrangian-Eulerian (ALE) framework is a commonly adopted approach for developing multi-material hydrodynamics codes. ALE methods combine the favorable features of the Lagrangian method, such as the ability to accurately resolve material interfaces, and the numerical robustness of an Eulerian method. One approach to construct an ALE method is to split the computation into three phases. The first phase evolves the simulation in Lagrangian frame of reference until the mesh reaches a level of distortion, a new mesh is then generated, and finally simulation variables are remapped on to the new mesh.

With the introduction of advanced architectures such as GPUs, a major effort has been set forth to develop algorithms and implementations of hydrodynamics codes which can realize performance on these architectures. In this work, we focus on the remap algorithm from the Blast code developed at LLNL [3]. The remap algorithm is based on the work of Anderson and co-authors [1, 2] which introduce a high-order approach based on concepts from flux corrected transport (FCT) and a discontinuous Galerkin discretization for the advection equation. The resulting method guarantees monotonicity, conservation of physical properties, and a high-order solution for sufficiently smooth fields.

To target advanced architectures, our implementation builds on the RAJA programming model and Umpire resource manager developed at LLNL [4]. Together RAJA and Umpire enable maintaining a single source code which can target multiple programming model backends and a memory resource manager for heterogenous computing systems. Starting from a sequential implementation, we present techniques to tailor the FCT remap algorithm to take advantage of the single instruction multiple thread (SIMT) architecture of the graphics processing unit and its performance under the Blast hydrodynamics code.

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REFERENCES

[1] Anderson, Robert W., et al. *Monotonicity in high-order curvilinear finite element arbitrary Lagrangian-Eulerian remap*. International Journal for Numerical Methods in Fluids 77.5 (2015): 249-273.

[2] Anderson, Robert W., et al. *High-order multi-material ALE hydrodynamics*. SIAM Journal on Scientific Computing 40.1 (2018): B32-B58.

[3] Dobrev, Veselin A., Tzanio V. Kolev, and Robert N. Rieben. *High-order curvilinear finite element methods for Lagrangian hydrodynamics*. SIAM Journal on Scientific Computing 34.5 (2012): B606-B641.

[4] http://github.com/LLNL/RAJA

[5] http://github.com/LLNL/Umpire