# ReALE - Reconnection-based Multimaterial Arbitrary Lagrangian-Eulerian Method

Mimetic Methods for Partial Differential Equations

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*Abstract*

The need of the office of science programs to approximate the solutions of strongly nonlinear, coupled partial differential equations in complex domains has been a continuous driver for the dual development of supercomputing platforms and for more accurate and efficient numerical algorithms. Despite the years and magnitude of the effort that has been put into computational science, in many ways the construction of new algorithms for complex problems remains as much of an art than a science. While the accuracy and efficiency of an algorithms for idealized problems can be studied with mathematical tools of numerical analysis, increased predictiveness of realistic simulations more typically requires the incorporation of physical principles into the algorithm. The goal of "Mimetic Methods for Partial Differential Equations" project at LANL (M. Shashkov, PI) is to develop methods that are constructed to embed physical principles.The physical principles that might be incorporated include causality, coordinate invariance, conservation laws, symmetries, asymptotics, and well-posedness. In first part of the talk I will give brief overview of the project and describe main recent achievements. It includes discretization of diffusion and Maxwell's equations on 3D generalized polyhedral meshes with non-flat faces; enforcement discrete maximum principle for diffusion and advection-diffusion equations mimetic discretization of equations of linear elasticity, high-order discretizations for diffusion problem, remapping and closure models for multi-material arbitrary Lagrangian-Eulerian (ALE) methods.

In second part of my talk I will describe new reconnection-based arbitrary Lagrangian-Eulerian (ReALE) method for high-speed compressible multi-material flows. This work done in collaboration with R. Loubere, P.-H. Maire, J. Breil, S. Galera. ReALE method for can be viewed as an extended ALE methodology that allows changes of topology at rezone stage [1,2]. Another important difference compared to classical ALE lies in the way rezoning is performed. Indeed, by adding cell-based moving generators, one constructs a Voronoi tessellation at each time step (rezoned mesh). A quasi-Lagrangian motion of generators allows the preservation of the accuracy of the Lagrangian scheme. On the other hand, a quasi-centroidal motion allows to build a smooth rezoned mesh. We developed an intermediate Lagrangian/centroidal motion based on a weight function derived from eigenvalues of the one time step deformation tensor. The ability for generators to dynamically change neighborhood enables reconnection; when vorticity occurs this is a particularly attractive feature. An exact intersection-based remapper is then used to conservatively project physical quantities from the Lagrangian mesh onto the new rezoned one (the reconnected Voronoi mesh obtained after generators motion). We will present numerical evidence (which includes several problems involving vorticity formation and presence of strong shear deformation, for example, bubble/shock interaction, Rayleigh-Taylor instability) that this reconnection friendly framework drastically extends the capability of any classical ALE code.

References

[1] R. Loubere,et al., ReALE: A Reconnection-based Arbitrary-Lagrangian-Eulerian Method, J. of Comput. Phys., 229 (2010), 4724-4761.

[2] R. Loubere, P.H. Maire and M.J. Shashkov, ReALE: A Reconnection Arbitrary Lagrangian-Eulerian method in cylindrical geometry, Computers & Fluids, 46 (2011), 56-69.