A MONOLITHIC SPACETIME DISCONTINUOUS GALERKIN METHOD FOR FLUID-STRUCTURE INTERACTION PROBLEMS

Jayandran Palaniappan[†*] **Reza Abedi**[†*] **Shripad Thite**[†◇] **Robert Haber**[†*]

[†]Center for Process Simulation and Design
[*]Department of Theoretical & Applied Mechanics
[◇]Department of Computer Science
University of Illinois at Urbana-Champaign, Urbana, IL 61801 USA
{palanppn, rabedi, r-haber}@uiuc.edu

Fluid-structure interaction (FSI) problems occur in a variety of engineering and scientific applications, ranging from aeroelasticity to combustion in solid fuel rocket engines to cardiovascular flows. A central concern is the accurate representation of balance of mass, momentum and energy, especially in problems with shocks where localized phenomena dominate. The landscape of numerical methods for FSI problems is dominated by *partitioned methods* which use distinct discretization paradigms in the solid and fluid subdomains and employ loose forms of asynchronous coupling at the interface. The ability to couple existing numerical codes for the individual phases is the primary reason for the popularity of partitioned methods. However, partitioned methods do not easily satisfy the fundamental balance laws for the heterogeneous continuum system. *Monolithic methods* rely on a single discretization paradigm and synchronous treatment of the jump conditions at the solid–fluid interface to provide tight coupling between fluid and structure subdomains and a more careful treatment of the balance laws. Of course, the monolithic approach usually precludes the reuse of existing softwares that often represent a substantial resource investment.

We present a new monolithic spacetime discontinuous Galerkin (SDG) method for modeling interactions between an elastic solid and an inviscid fluid. In the solid subdomain, we use the SDG method for elastodynamics introduced in [1]. For the fluid subdomain, we use an extension of the SDG method for scalar nonlinear conservation laws [2] to systems of conservation laws. A Galerkin weighted residual statement enforces integral forms of the appropriate conservation or balance law over every element to within machine precision. The Rankine-Hugoniot conditions arise naturally as the spacetime jump conditions that couple the solutions in adjacent elements, and our method weakly enforces the appropriate continuum jump conditions for mass, momentum and energy balance across the solid-fluid interface.

The direct patch-by-patch solution procedure used in previous SDG methods [1, 2] for single–phase problems modeled on causal spacetime meshes is also applicable to our monolithic method for FSI problems. We use a front–tracking extension of the Tent Pitcher algorithm [3] to construct patch–wise causal meshes in 2D×time that align spacetime element faces with the trajectories of propagating or stationary interphase boundaries. We demonstrate the performance of the SDG method for FSI problems in applications involving both material and nonmaterial interfaces.

References

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