A hybrid computational method for multiphysics, multidomain problems: A demonstration

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Large-scale, high-fidelity engineering simulations in many application domains require the integration of physics, solvers, and discretizations on complex geometries; however, there does not exist a mathematical foundation for addressing these complex multidomain, multiphysics applications. Traditional numerical approaches, such as finite difference and finite volume methods, are not generally amenable to geometrically complex hybrid meshes or to problems with disparate spatial and temporal scales. As a result, model and numerical accuracy are often sacrificed for ease of implementation. This often results in the violation of fundamental physical principles such as conservation laws. We will demonstrate a hybrid continuous/discontinuous Galerkin formulation that provides a unique self-consistent approach capable of addressing these challenges.

Continuous Galerkin and discontinuous Galerkin (DG) finite element (FE) methods are well-understood numerical methodologies; however, each method has inherent disadvantages. For example, the traditional Galerkin FE method is well-suited for solving highly diffusive problems, but requires significant stabilization to accurately characterize highly convective regimes. Conversely, DG methods are often chosen when problems are highly convective, but fail in non-isotropic diffusive applications.

In this work, we will exploit the capabilities of each method to solve a demonstration, two-dimensional multiphysics, multidomain problem involving the thermal cooling of a metal plate in parallel flow. We will illustrate how to properly choose the interfacial boundary conditions between the physical domains. This proof-of-concept problem demonstrates the efficacy of the hybrid method and this approach is promising for other problems with significantly more complex geometries and physics spanning multiple domains and a larger spectrum of temporal and spatial scales.

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