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Partitioned Polytopal Finite-Element Methods for Nonlinear Solid Mechanics

Abstract

This work presents a novel polytopal finite-element framework that addresses the collective issues of discretization sensitivity and mesh generation for computational solid mechanics problems. The use of arbitrary polygonal and polyhedral shapes in place of canonical isoparametric elements seeks to remediate issues pertaining to meshing and mesh quality (particularly for irregularly shaped elements), while maintaining many of the desirable features of a traditional finite element method.

A general class of *partitioned element methods* (PEM) is proposed and analyzed, constituting a family of approaches for constructing piecewise polynomial approximations to harmonic shape functions on arbitrary polytopes. Such methods require a geometric partition of each element, and under certain conditions will directly yield integration consistency. Two partitioned element methods are explored in detail, including a novel approach herein referred to as the *discontinuous Galerkin partitioned-element method* (DG-PEM). An implementational framework for the DG-PEM is presented, along with a discussion of its associated numerical challenges.

The numerical precision of the PEM is explored via classical patch tests and single element tests for a representative sampling of polygonal element shapes. Solution sensitivity with respect to element shape is examined for a handful of problems, including a mesh convergence study in the nearly incompressible regime. Finally, the efficacy of the DG-PEM is assessed for a number of benchmark problems involving large deformations and nonlinear material behavior.