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The hp-d adaptive Finite Cell Method for geometrically nonlinear problems of solid mechanics

Abstract:
The Finite Cell Method (FCM) combines the fictitious domain approach with the p-version of the finite element method and adaptive integration. For problems of linear elasticity, it offers high convergence rates and simple mesh generation irrespective of the geometric complexity involved. The present article presents the integration of the Finite Cell Method into the framework of nonlinear finite element technology. However, the penalty parameter of the fictitious domain is restricted to few orders of magnitude in order to maintain local stability of the deformation gradient. As a consequence of the weak penalization, nonlinear strain measures provoke excessive stress oscillations in the cells cut by geometric boundaries, leading to a low algebraic rate of convergence. Therefore, the FCM approach is complemented by a local overlay of linear hierarchical basis functions in the sense of the hp-d method, which synergetically use the h-adaptivity of the integration scheme. Numerical experiments show that the hp-d overlay effectively reduces oscillations and permits stronger penalization of the fictitious domain by stabilizing the deformation gradient. The hp-d adaptive Finite Cell Method is thus able to restore high convergence rates for the geometrically nonlinear case, while preserving the easy meshing property of the original FCM. Accuracy and performance of the present scheme are demonstrated by several benchmark problems in 1, 2 and 3 dimensions, and the nonlinear simulation of a complex foam sample.