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Robust a posteriori stress analysis for quadrature collocation approximations of nonlocal models via nonlocal gradients

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Abstract

As alternatives to partial differential equations (PDEs), nonlocal continuum models given in integral forms avoid the explicit use of conventional spatial derivatives and allow solutions to exhibit desired singular behavior. It is of practical interest to develop robust numerical schemes not only for the numerical solution of nonlocal models but also for the evaluation of suitably defined derivatives of solutions. The latter motivates the development of a nonlocal analog of gradient recovery for numerical solution of PDEs. For structure mechanical models, this leads to a posteriori nonlocal stress analysis. We illustrate that when smooth solutions are found in nonlocal models, one may compute local gradients of nonlocal solutions using conventional techniques like that for PDEs. More generically however, we present a framework for stress analysis of nonlocal solutions based on nonlocal gradient operators and their asymptotically compatible discretization. We demonstrate that the nonlocal gradient recovery is consistent in the local limit and is more advantageous than using local gradients of nonlocal solutions. Superconvergence properties of some special nonlocal gradient operators are identified for nonlocal continuum models. Moreover, methods are presented to preserve such features in the numerical discretization. Both computational observations and theoretical insights are provided to substantiate our findings.

Keywords: Nonlocal gradient, nonlocal stress, nonlocal models, peridynamics, asymptotic compatibility, quadrature collocation approximations, order of convergence, superconvergence

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