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

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23 **Abstract**

24
25 As alternatives to partial differential equations (PDEs), nonlocal continuum
26 models given in integral forms avoid the explicit use of conventional spatial
27 derivatives and allow solutions to exhibit desired singular behavior. It is of
28 practical interest to develop robust numerical schemes not only for the numerical
29 solution of nonlocal models but also for the evaluation of suitably defined
30 derivatives of solutions. The latter motivates the development of a nonlocal
31 analog of gradient recovery for numerical solution of PDEs. For structure
32 mechanical models, this leads to a posteriori nonlocal stress analysis. We illustrate
33 that when smooth solutions are found in nonlocal models, one may compute
34 local gradients of nonlocal solutions using conventional techniques like that for
35 PDEs. More generically however, we present a framework for stress analysis
36 of nonlocal solutions based on nonlocal gradient operators and their asymptotically
37 compatible discretization. We demonstrate that the nonlocal gradient
38 recovery is consistent in the local limit and is more advantageous than using
39 local gradients of nonlocal solutions. Superconvergence properties of some special
40 nonlocal gradient operators are identified for nonlocal continuum models.
41 Moreover, methods are presented to preserve such features in the numerical
42 discretization. Both computational observations and theoretical insights are
43 provided to substantiate our findings.
44

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