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DYNAMIC CRACK BRANCHING AND ADAPTIVE REFINEMENT IN PERIDYNAMICS

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ABSTRACT

Under fast loading, cracks branch. Modeling of this phenomenon has been challenging and a fully satisfactory solution is still needed [1]. The peridynamic theory [2] is a new non-local method that differs from other non-local methods because it avoids using spatial derivatives in the formulation of the equations of motion. Modeling of dynamic fracture is a prominent advantage of the peridynamic theory compared to other methods. In peridynamics, the same equations apply everywhere regardless of discontinuities. Cracks initiate, grow spontaneously and unguided. Transition between fracture modes happens spontaneously without any need for ad-hoc criteria [3].

A similar integral to the J-integral can be formulated for the nonlocal method peridynamics. We use this conservation integral to compute the stress intensity factor for mode I fracture. We perform convergence tests for the stress intensity factor and show convergence. In peridynamics, cracks are part of the solution, not part of the problem. We show that with peridynamics, branching happens even on coarse grids [4]. The convergence of the crack path in terms of the horizon going to zero is discussed.

To improve efficiency for single-scale problems and to treat multi-scale problems, adaptive refinement is essential. We present the scaling required in the bond-based peridynamics which allows for adaptive refinement [5]. In certain problems, such as those at the nanoscale, the horizon is determined by the physics of interactions between particles. However, at the macroscale level, the horizon may be chosen according to convenience, since for any value of δ, the parameters in the peridynamic material model can be chosen to match the strain energy of a classical elastic material. To allow large variations in grid spacing within a discretized region, needed in grid refinement and multiscale modeling, one has to allow the horizon to vary with position. Examples of automatic adaptive refinement and coarsening for crack propagation and branching are shown [4] (see Fig. 1). The horizon used in peridynamics can be conveniently adjusted to correlate to an actual material length-scale when needed.

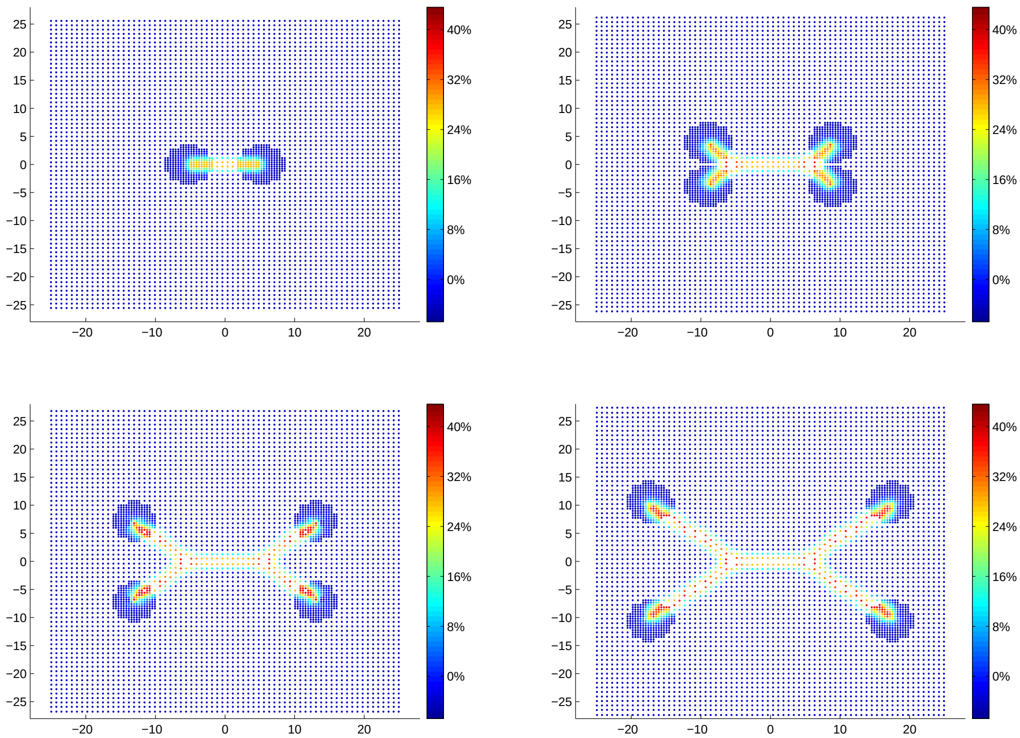

Figure 1: Branching of a straight crack under fast dynamic loading. Adaptive refinement (coarsening) is used in regions where the strain energy is high (low). The colors represent bond damage levels.

Multiscale modeling and grid adaptivity are closely related in peridynamics. The peridynamic method offers the promise for a seamless implementation of multiscale models, since it can represent, without changes in the form of its equations, different scales.

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REFERENCES

[1] J.-H. Song, P.M.A. Areias, and T. Belytschko. "A method for dynamic crack and shear band propagation with phantom nodes". *International Journal for Numerical Methods in Engineering*, **67**, 868-893, 2006.

[2] S.A. Silling. "Reformulation of elasticity theory for discontinuities and long-range forces". *Journal of the Mechanics and Physics of Solids*, **48**, 175–209, 2000.

[3] S.A. Silling and F. Bobaru. "Peridynamic modeling of membranes and fibers". *International Journal of Non-Linear Mechanics*, **40**, 395–409, 2005.

[4] F. Bobaru, M. Yang, L.F. Alves, S.A. Silling, and E. Askari. "Adaptive Refinement in 2D Peridynamics and dynamic crack propagation". *To be submitted*, 2008.

[5] F. Bobaru, M. Yang, L.F. Alves, S.A. Silling, E. Askari, and J. Xu. "Convergence, Adaptive Refinement, and Scaling in 1D Peridynamics". *Submitted*, 2007.