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A Hybrid Asynchronous Variational Integrator for the Phase Field Approach to Dynamic Fracture

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ABSTRACT

The phase field approach has powerful abilities to simulate complicated fracture behaviors. However, the requirement of fine mesh near cracks leads to high computational cost, especially for dynamic cases in which the critical time step is restricted by the smallest element size according to the CFL stability condition. In this work, the asynchronous variational integrator (AVI) is used to alleviate the high computational cost in the case of dynamic brittle fracture. The AVI is derived from the discrete Hamilton's principle with asynchronous temporal discretization, which allows each element in the mesh to have its own local time step that is independent of other elements. The asynchrony allows the elements with smaller time steps to be more frequently updated. A hybrid explicit-implicit staggered scheme is used to solve the coupled multi-field system, in which the displacement and velocity fields are integrated with an explicit scheme while the phase field is the solution to an inequality-constrained optimization problem. In essence, the phase field of only one element is solved implicitly at a time based on elemental patches, it is very convenient to enforce the upper and lower bounds strictly through the reduced-space active set strategy. In addition, two important variants of the phase field approach are equally easily implemented. The results of several benchmark problems show that AVI for the phase field approach captures the complicated dynamic fracture behavior successfully and speeds up the computational efficiency significantly.

KEYWORDS

Asynchronous variational integrators; phase field approach; dynamic brittle fracture; hybrid scheme

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