Quasi-static Crack Propagation using Non-ordinary State-based Peridynamics

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A majority of the efforts to date in modeling crack propagation have used continuum models built upon using partial derivatives with respect to the spatial coordinates in the force and displacement relationship between adjacent particles. However, these methods are inherently ill-suited for modeling cracks because the partial derivatives are undefined along the crack faces where the displacement field is discontinuous. Consequently, in order for these methods to model crack propagation, they have to continuously remove the discontinuous displacement field as the crack propagates. In order to handle the discontinuous displacement fields around cracks, current popular finite element methods resort to global/local domain remeshing, adaptive meshing such that the newly formed crack is always along an element's edge, or by adding additional degrees of freedom and enhancing the shape functions near the crack planes. Additionally, these methods require a supplementary fracture law in order to predict crack trajectories. Popular methods used to predict the crack direction and the amount of crack extension are the use of a cohesive zone and a traction separation law, or by predicting a failed element, usually based on a maximum principle stress criterion, and then extending the crack in the direction normal to the maximum principle stress. However, these methods fall short on robustness and computational complexity under the following circumstances: when used to handle non-homogeneous materials, when cracks start to coalesce and branch, when cracks initiate, and when the simulation is in three dimensions.

In contrast, peridynamics is a continuum model for efficiently handling the spontaneous formation, propagation, branching and coalescing of cracks by using integration rather than differentiation to compute the force at a material point, resulting in valid equations everywhere in the body. In particular, this talk will focus on the extension of the non-ordinary state-based peridynamics formulation for the study of quasi-static crack propagation using implicit methods. One asset of the non-ordinary state-based formulation is the fact that the bond force between particles is characterized in terms of strain and stress tensors and, therefore, allows for classical continuum mechanics definitions such as deformation gradients and stress tensors for use in constitutive models. Additionally, these classical continuum quantities can be used to predict bond rupture based on critical stress/strain invariants or in an energy based criteria. A comprehensive study on quasi-static crack propagation and the effects of the bond rupture criteria, mesh size, mesh orientation, horizon size, influence function and other peridynamics parameters will be covered. Lastly, established and prevalent analytical and experimental results for quasi-static crack propagation will be validated using the non-ordinary state-based formulation.