Computing Fracture Surface Patterns

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We aim to simulate highly detailed geometry resulting from brittle fractures. Typical approaches to simulating brittle fracture rely on finite elements, and detailed crack surface geometry typically requires extremely large numbers of elements, small simulation time steps, and frequent re-meshing. With the goal of alleviating this computational burden, we introduce a few additional degrees of freedom (spatially varying material toughness, material strength independent from toughness) and a few careful assumptions (small deformations, quasi-static elasticity, and homogeneous stiffness). We can then formulate a coarse boundary element method (BEM) coupled to a very high resolution Lagrangian crack propagation algorithm. This combination allows us to efficiently compute highly detailed fracture surface geometry which reproduces (perhaps for the first time) large-scale qualitative phenomena like chevrons, tongues, and roughness correlations that are used by geologists to catalog natural fracture patterns. With an additional unphysical assumption (that cracks do not interact with each other), we can simulate qualitatively indistinguishable fracture patterns at asymptotically optimal computational complexity.