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Using Geometrically, Topologically and Materially Unstructured Methods to Reduce Mesh Dependency in Dynamic Cohesive Fracture Simulations

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We present a method to reduce mesh bias in dynamic fracture simulations using the finite element method with adaptive insertion of extrinsic cohesive zone elements along element boundaries. The geometry of the domain discretization is important in this setting since cracks are only allowed to propagate along element facets and can potentially bias the crack paths. To reduce mesh bias, we consider geometrically unstructured polygonal finite elements in this work. To overcome the problem of limited crack paths, and to significantly improve crack patterns, we propose adaptive refinement [1] and adaptive element splitting [2], increasing the number of potential crack directions at each crack tip, as illustrated in Figure 1.

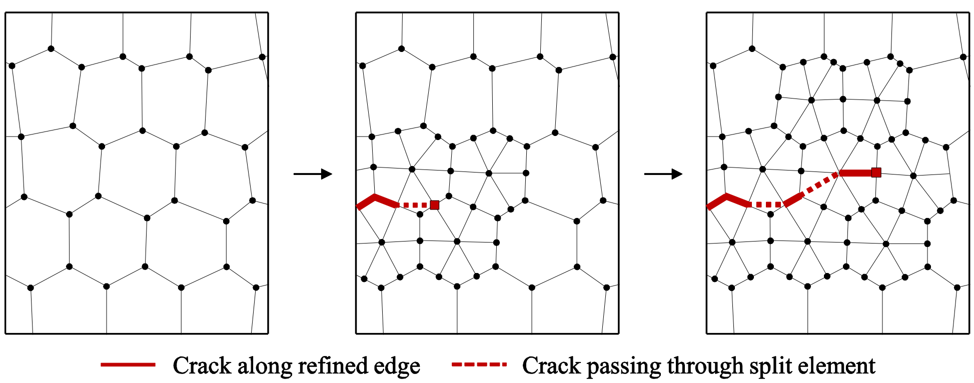

Figure 1. Schematic illustrating the adaptive refinement scheme and a possible crack path along both refined edges and split edges.

As an additional means of reducing mesh dependency, microstructural randomness is incorporated into the method by means of a Weibull distribution of cohesive material properties, α [3]:

$$\alpha = \frac{L_s^{1/m}}{L_f^{1/m}} \alpha_o \left(-\ln\left(1-\rho\right)^{1/m} \right) \tag{1}$$

where α_o is the average cohesive property (in this work, α_o is either the cohesive strength or the cohesive fracture energy), L_f is the length of the cohesive element, L_s is a scaling parameter and m is the Weibull modulus. To illustrate the effect of the Weibull modulus of the material distribution, a sample mesh with 16,000 randomly number facets was generated, and cohesive properties were randomly assigned to the facets. For example, when a mesh with an average cohesive stress of 1.733GPa was modeled, the resulting variation of stress for m = 50, 30, and 10 is illustrated in Figure 2.

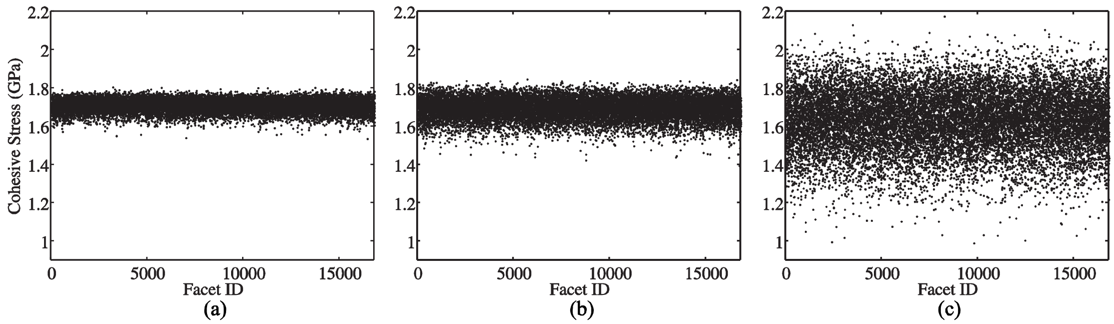

Figure 2. Example statistical distribution for a modulus of (a) $m = 50$, (b) $m = 30$, and (c) $m = 10$

Geometric studies are conducted to quantify reduction in mesh bias. First, we investigate the path length, by comparing the length of the path, along finite element edges, between two points, to the Euclidian distance between the same points, as illustrated in Figure 3(a). Second, we quantify the deviation from the straight line path between the two points using the Hausdorff Distance [4], as illustrated in Figure 3(b).

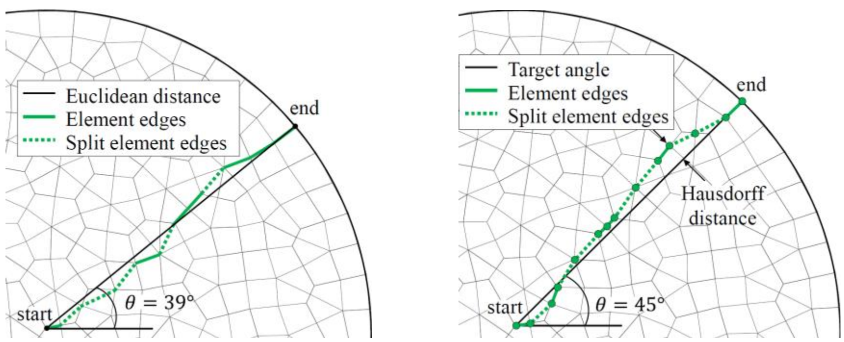

Figure 3: Geometric studies to quantify (a) path length, and (b) path deviation.

Numerical examples are presented which demonstrate improved agreement with experimental results in the literature.

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