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Fragment Modeling with the eXtended Finite Element Method (X-FEM)

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Problem Description

- Modeling pervasive fracture accurately is extremely challenging
- Past approaches have yielded unsatisfactory results in terms of fragment size, mass conservation, or runtime speed
- We propose the use of the eXtended Finite Element Method in conjunction with a Duplication Algorithm and an X-FEM submesh to solve these problems

Pervasive failure from blast on plate problem

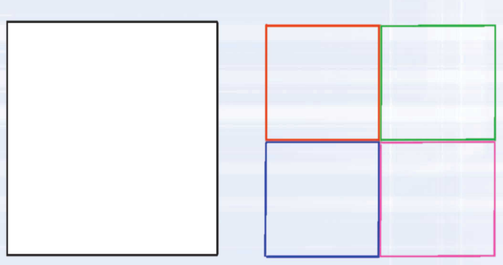
Problem Description

- Crack path is independent of the mesh unlike cohesive network approaches
- Fragments generated have correct size and exact shape
- Mass is conserved unlike element death approaches
- X-FEM can be coupled to any failure model
- Runtime is significantly decreased because substantially fewer elements are needed to produce accurate results

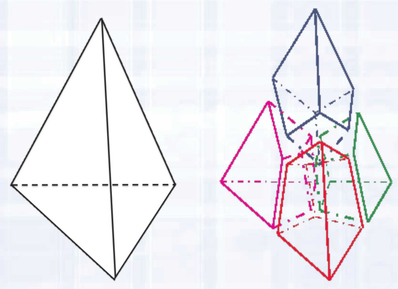
Using an X-FEM Submesh for Bookkeeping and Contact

Because of the complex nature of the cracks that form in pervasive fracture, a need has arisen to robustly keep track of the cuts in a single element. When a single element contains two or more cracks, the bookkeeping can become very complicated. With the use of the submesh, we are able to conserve the mass of the original problem even with these complex crack patterns.

In addition to the simplified bookkeeping and mass conservation, the submesh also provides an easy mechanism for creating contact surfaces on the new cut geometry. With the contact surfaces in place, we are able to model an important suite of problems where both pervasive failure and contact play significant roles such as the blast loading of structures.



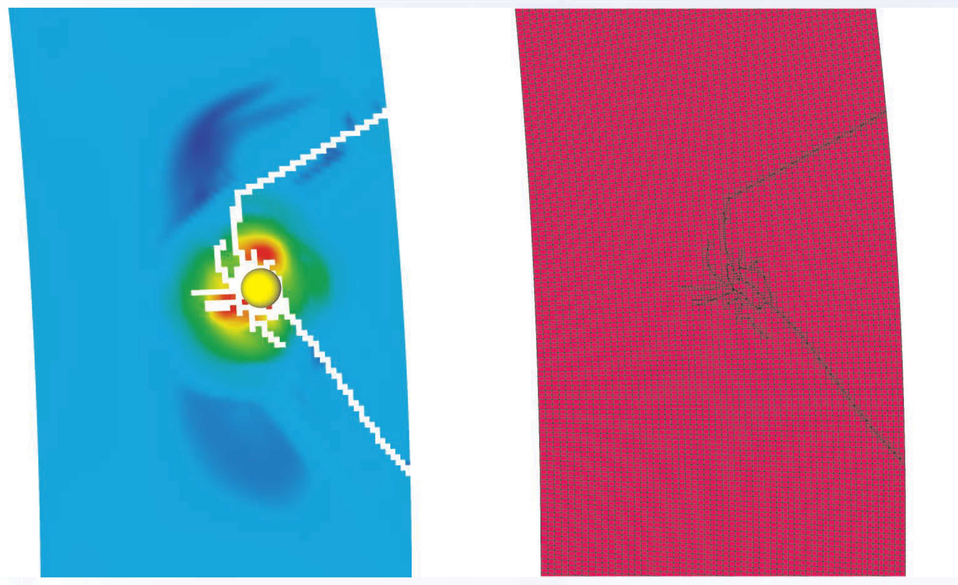
The submesh of a quadratic shell element is broken up into four sub-quads.



The submesh of a tetrahedron element is broken up into four sub-hexes.

Results

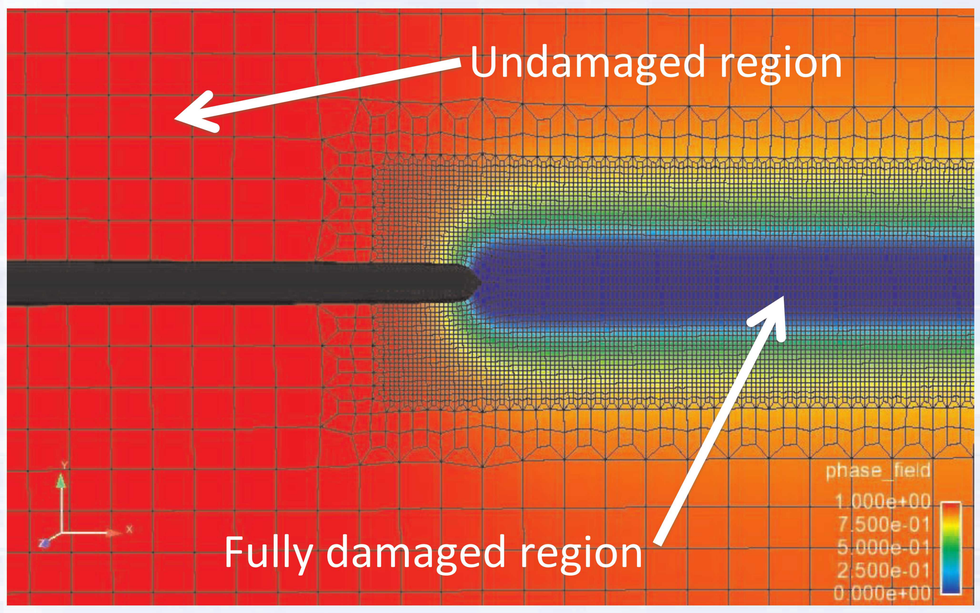
- Able to capture crack nucleation, crack propagation, crack coalescence, and crack branching
- A user can input any failure criteria of their choosing, and the X-FEM will perform the cutting based on this criterion.



Problem of baseball hitting a windshield

Future Work

- Currently developing a phase-field algorithm in order to predict crack growth more accurately
- A damage field is solved for in a reaction-diffusion solve with non-constant coefficients, and the elastic energy within en element is decomposed.
- The stress of the element is then modified, and the element fails when the damage variable goes to zero.



Phase field model of single crack propagation

Conclusions

- This approach offers the first mesh independent fracture capability in Sierra
- Able to nucleate, propagate, and branch cracks for 2-D and 3-D problems
- Offers promise for many NW applications (loss of assured safety, pressure to breach, glass to metal seals, etc.)

Exploding Sphere Problem

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