Simulations of Crack Propagation using Isogeometric Enrichments and Algebraic Level Sets

K. Upreti*, A. Tambat and G. Subbarayan

Purdue University, West Lafayette, IN, USA
* corresponding author: ganeshs@purdue.edu

Abstract:

Boundaries with specified behavior, phase boundaries, crack surfaces or singular points are, geometrically speaking, lower-dimensional features relative to two- or three-dimensional geometrical domains. Often, the distinguishing characteristics of the behavior at these features are known a priori and may be exploited to enrich isogeometric models. Explicit geometrical representations possess parametrically computable tangents, normals and curvature, while in implicit strategies the geometric ‘‘exactness’’ of enriching lower-dimensional features is not exploited or retrieved only in the limit of mesh refinement.

In author’s previous work, CAD-inspired hierarchical partition of unity field compositions were generalized to modeling explicitly defined enrichments within the isogeometric framework[1]. The base approximations were ‘‘enriched’’ isogeometrically on parametrically defined lower-dimensional geometrical features of the base entity and by constructing distance fields from them. In the present work, isogeometric enriched field approximations are used to carry out three-dimensional fracture simulations.

Geometrically explicit/behaviorally implicit three-dimensional fracture simulations pose two main challenges. The first challenge pertains to the evaluation of three-dimensional distance fields in a computationally efficient and robust manner. To this end, we demonstrate recently developed semi-analytic/algebraic procedure for distance field evaluation from quadratic/cubic NURBS surfaces[2, 3]. The second challenge relates to the propagation of a parametrically defined crack surface. We develop a new procedure for evolution of NURBS surfaces, where the parametric domain is altered to accommodate new control points of the evolving surface.

The proposed fracture modeling strategy allows both discontinuous enrichment of the displacement field as well as a material damage description associated with the fracture surface. Both of these approaches are demonstrated. Benchmark crack propagation examples are solved to demonstrate the accuracy and robustness of the technique.

Keywords: Isogeometric enrichments, fracture, distance fields, algebraic geometry

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