X-DMS 2015
eXtended Discretization MethodS
September 9-11, 2015, Ferrara, Italy

A medial-axis geometrical approach for crack propagation and branching

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Key words: X-FEM, Medial axis, Material failure, Crack propagation, Crack branching

ABSTRACT

We have recently proposed a continuous-discontinuous model of material failure [1]. The continuous model consists of a non-local elastic-damage model. Non-locality is introduced by working with two displacement fields: the classical field of local displacements and a non-local, gradient-enriched displacement field. This choice does regularise softening and has a number of advantages over standard non-local models based on a gradient-enriched equivalent strain (clear physical meaning of boundary conditions on the non-local variable and correct damage initiation at the crack tip, among others).

The continuous model can be used to simulate damage inception and progressive material failure. In many applications, however, an explicit representation of cracks (i.e. discontinuities) is required. This is the case, for instance, in the simulation of fracking or structural damage due to leakage of an aggressive agent, where the actual geometry of the crack plays a relevant role in the fluid-structure interaction.

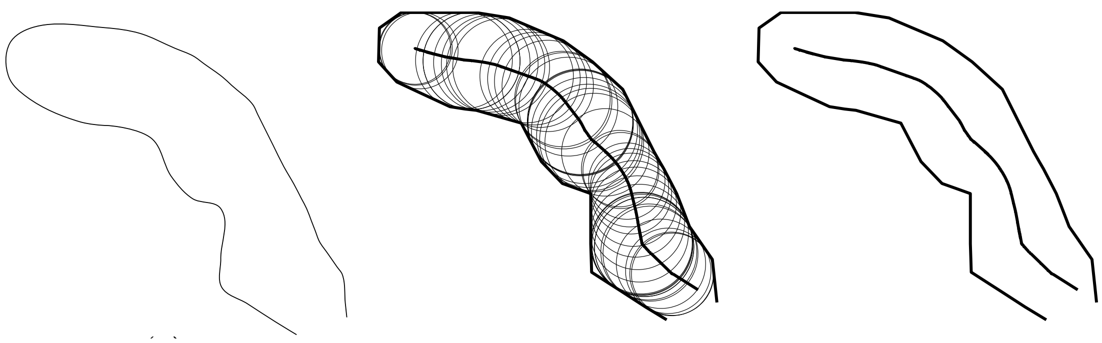

Figure 1: The medial axis is the locus of the centres of the circles bi-tangent to the contour of the damaged zone

The discontinuous model consists in introducing discontinuities in the two displacement fields (local and non-local) via X-FEM. Contrary to other continuous-discontinuous models, we advocate a *geometrical*, rather than a *mechanical*, crack tracking strategy. It is based on a very simple observation: once the damage band (i.e. the smeared representation of the crack) has evolved, it is very natural to locate the crack “through the middle of the band”. This intuitive notion has a precise geometrical definition: the medial axis (in 2D) or the medial surface (in 3D) of the damaged zone, see figure 1. These geometrical entities are widely used by the community

of computational geometry (including finite element mesh generation), and can be obtained by means of robust, open-source, user-friendly codes.

This geometrical approach to crack tracking has a number of attractive features as compared to mechanical criteria (e.g. crack perpendicular to maximum principal stress or maximum non-local strain). Since the crack path is given by the medial axis, level sets are not required. More importantly, crack tracking profits from the versatility and robustness of the geometrical notion of medial axis / surface. If the damaged zone bifurcates, for instance, this feature is captured by the medial axis (figure 2) and, with the appropriate X-FEM enrichment [2, 3], crack branching can be modelled. Note also that, in addition to isotropic damage models, the approach is applicable to any background continuous model where material degradation is represented by a scalar field, such as phase field models. The capabilities of the proposed approach to describe crack propagation and branching are illustrated by means of various two-dimensional and three-dimensional examples.

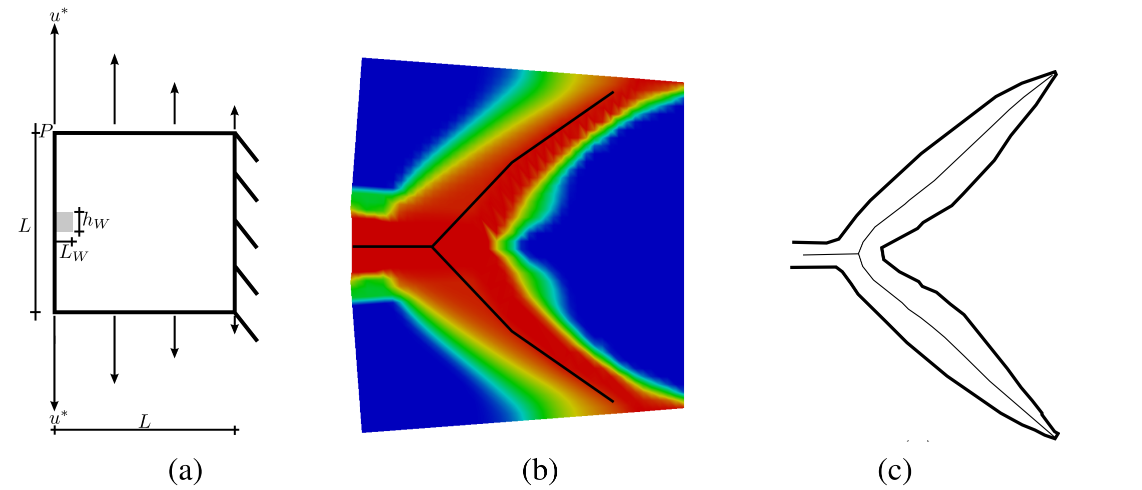

Figure 2: Crack branching: (a) problem statement; (b) damage field; (c) crack path is the medial axis of the damaged zone (defined by damage isoline $D = 0.6$)

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