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Adaptive Remeshing Technique in Discrete Models of Random Geometry

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Abstract: The adaptive discretization technique for static discrete models of random geometry based on Voronoi cells is developed here. It is based on adding randomly located nodes into the highly stressed regions and updating the discretization based on those nodes before the crack may initiate in or propagate through the regions.

Introduction

Discrete representation of materials is a natural alternative to continuous approaches. A collection of springs and rigid cells organized into a net structure is often called a discrete or lattice model. The first attempts to model crack propagation through such discrete assemblies were made by physicists in '80s. Since that time, many types of discrete models have been developed [1, 2, 3, 4].

The extremely fine discretization of lattice models leads to extreme computational demands, however it is often necessary. Especially when the discretization is related to meso-scale structure of the simulated material. The paper introduces a technique to adaptively refine model discretization during the simulation run in the area where the crack initiates and propagates.

Without this tool, it is necessary to densely discretize the whole domain and therefore to create computationally demanding model. Some computational time can be saved by selecting a-priory areas where the crack shall not occur and use e.g. linear elastic finite elements there instead of the finely discretized discrete model [5, 3]. However even with such remedy, the area with fine discretization might be still unreasonable large because the location of crack is not known in advance.

Availability of adaptive remeshing will allow to start simulation with rough discretization and refine it adaptively as the crack initiates and propagates. Some attempts to introduce this important feature exists [6, 7]. They are based on adaptive replacement of some continuous model with the discrete one, but problematic interface between continuum and discrete model is involved and the discrete model has to have regular geometry (that produces directional bias).

Description of the algorithm

Another approach is proposed here. The adaptive remeshing is performed within the the discrete lattice model only and allows to use irregular geometry based on Voronoi tessellation. The algorithm works as follows. Initially, the whole domain is roughly discretized. Whenever any bond of the rough model exceeds some chosen limit (of equivalent strain), discretization in its vicinity is replaced by finer one and some transitional area connecting the rough and fine discretization is added as well.

The discrete model use here is a modified version of [3] from which the constitutive relations were adopted. Model geometry and connectivity is generated by Voronoi tessellation on randomly located nuclei with restricted minimal mutual distance, $l_{\min}$. The value of $l_{\min}$ may vary, whenever the discretization needs to be refined, the $l_{\min}$ is decreased over the region of interest.

The tricky part of replacing the discretization can be simply solved by adding new nuclei into region and updating the Voronoi tessellation. The rest of the domain tessellation will remain the same. 2D sketch of the proposed technique is shown in Fig. 1.

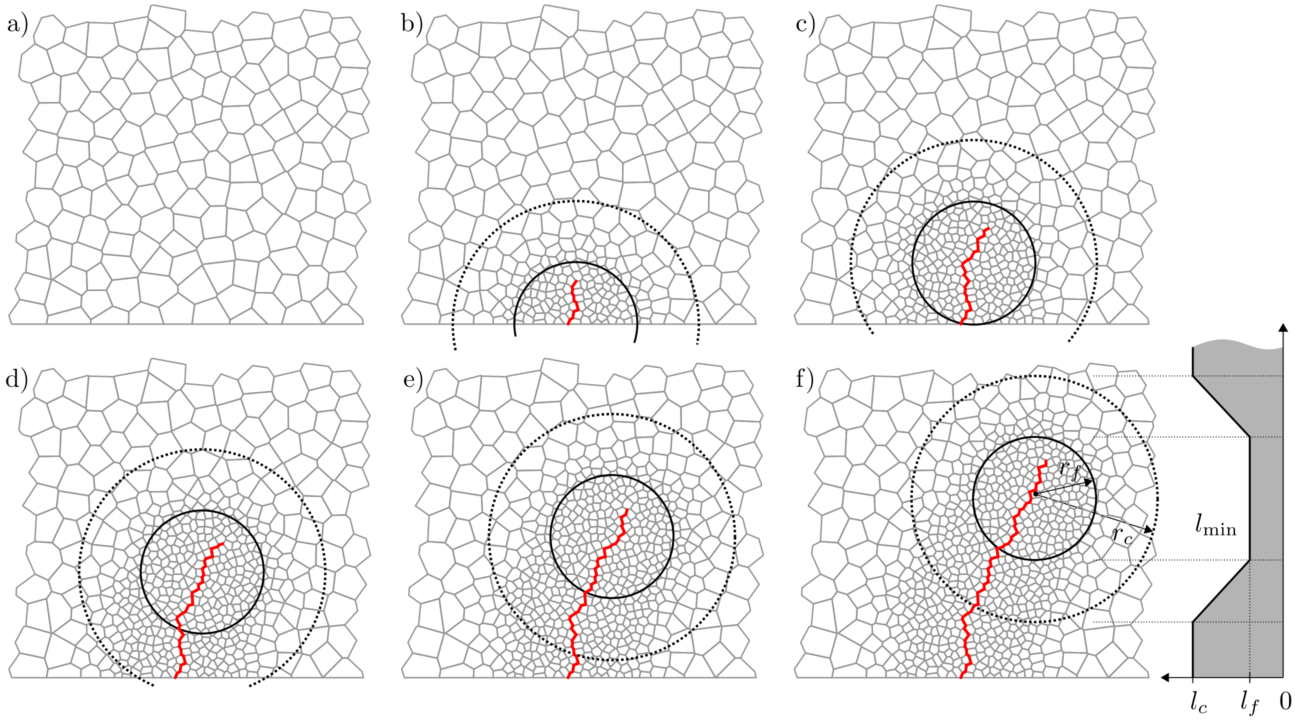

Fig. 1: Adaptive discretization refinement

Summary

Simple algorithm that allows for refinement of discretization of static discrete models of fracture adaptively during the simulation is presented. The refinement technique is tested on initiation and propagation of a crack during simulation of three-point-bending test. Results from densely discretized models are compared to results obtained from models with adaptively updated discretization.

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