An original discrete fracture network mesh approach and their different applications using open source software

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Introduction

Modeling transfers in fractured media remains a challenging task. To deal with issues like polluted groundwater, nuclear waste storage ([1]), CO_2 sequestration ([2]) or oil field production, geothermal applications, this challenge has to be addressed. The major issue to model transfers in fractured media comes from the complex geometry of discrete fracture networks (DFN). With the goal to obtain high-accuracy flow and transfer simulations we look for a conforming mesh approach. Recently, a new 3D DFN meshing approach was proposed ([3]). The main idea is to decompose each fracture into a number of connected closed contours in which fracture intersections are located on their boundaries. Special focus is put on fracture intersections to ensure the mesh conformity. As a result this mesh is conform and closely respects the geometry of the DFN. A drawback of this approach is that it requires fine discretizations, and consequently computational costs can be unexpectedly very high. In the oil field context, fracture sets are finely characterized on well logs and outcrops (at a scale of few meters). From this characterization a DFN can be built and may contain over 10^4 fractures. Due to the large number of fractures, our approach cannot be used in an industrial context. It still remains to simplify the DFN mesh using additional assumptions about the details of flow ([4], [5], [6]). Nevertheless, in order to test the accuracy of these assumptions, reference numerical simulations have to be carried-out using a detailed DFN geometry. This justifies the use of a conform mesh approach to obtain reference simulations to validate further simplifications. In addition, conform meshes allow for classical numerical schemes to model flow and transfers. This means that there is no need to adapt numerical codes to deal with flow at fracture intersections.

The presentation will explain the meshing procedure, a performance evaluation of this approach and few reference simulations obtained on different fracture networks will also be presented.

DFN mesh and applications

Basic idea

The basic idea of our mesh method (FraC, Fracture Cut method) is to cut each DFN fracture into a set of connected closed contours (Figure 1). The triangulation and contour merging processes is done using the Los Alamos Grid Toolbox ([7]). Special focus is put on common the contours boundaries to obtain a conforming Delaunay triangulation. The advantage of this approach is that the final mesh is conform and closely respects the geometry of the DFN.

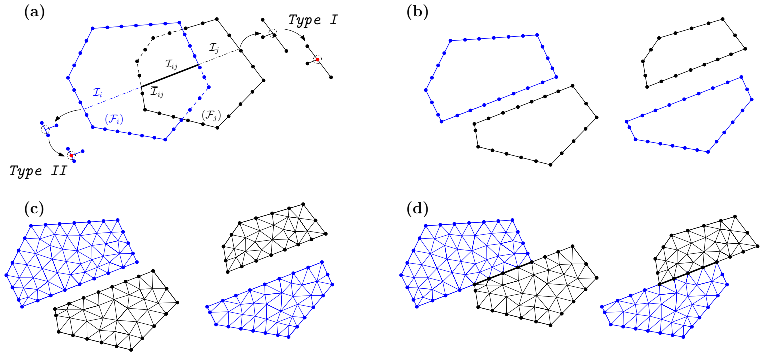
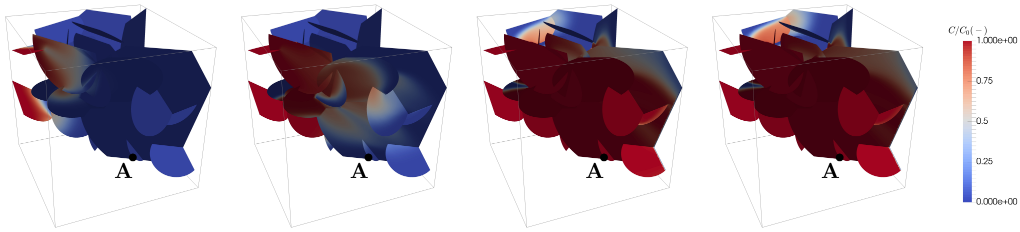


Figure 1: Illustration of the meshing steps: fracture intersection (a) and fracture cutting (b); polygon triangulation (c); and merging meshed polygon (d).

Preliminary results

This mesh method is included in an efficient workflow that provides high-accuracy solute transport or well-test simulations using conforming meshes. The workflow uses the FraC approach for meshing and DuMux for simulation frameworks in order to profit from its Euclidean-based transport modeling capability. The workflow is able to handle with non-trivial DFN configurations, which remain a major challenge for classical methods. Furthermore, the numerical framework can easily be extended to consider multiphase, multi-component flow, transient single-phase flow or reactive transport as well as other hydrological modelling issues using DFN models.



(a) $t = 1$ hours **(b)** $t = 5$ hours **(c)** $t = 25$ hours **(d)** $t = 30$ hours

Figure 2: Snapshots of solute concentration distribution over time on the 33-fracture DFN mesh: (a) t = 1h , (b) t = 5h , (c) t = 25h, (d) t = 30h.

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