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A C++ parallel solver for flow in networks of fractures

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The present work deals with the highly efficient parallel implementation of an optimization-based solver for the flow in Discrete Fracture Networks (DFNs).
A DFN is a sets of mutually intersecting planar polygons in the three dimensional space, resembling a system of fractures in the subsoil. Fracture networks are stochastically generated to tackle uncertainty and lack of observations on geometrical properties of the fractures (density, orientation, size) and on hydraulic properties (transmissivity). These random networks can be extremely complex, with a large number of fractures and intricate intersections, such that conventional simulation approaches have limited applicability in this context, mainly for the necessity of generating a conforming mesh of the whole network.
Recently a novel approach was presented to overcome the issue of mesh conformity in DFN flow simulations [1 2 3 4 5]. The method is based on the PDE-constrained minimization of a cost functional, which is introduced to handle matching conditions at fracture intersections with non conforming meshes. The minimization of the functional can be performed via a conjugate gradient approach, and the computation of the descent direction at each iteration of the method only asks for the resolution of small linear system on each fracture of the network. This structure naturally leads to a parallel approach. Here details on the implementation of this approach in the C++ language on distributed memory devices is discussed. The code aims at minimizing the number of communications among different processes, and the communication phases are organized in order to maximize the time occurring between the delivery of the data to their reception, thus shadowing the communication overhead.

References

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