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A mesh-free approach to numerical rock mechanics simulations

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Numerical simulation of the nucleation, growth, and coalescence of fracture networks is a fundamental aspect of lithospheric geodynamics and engineering applications such as enhanced geothermal systems, hydraulic fracturing and CO_2 sequestration. Modeling the underlying mechanics is challenging because of several numerical difficulties. In particular, fracture path evolution predicted by mesh-based models can be heavily affected by numerical resolution of the chosen discretization scheme. Additionally, large deformations can lead to numerical errors associated with highly deformed elements.

We are developing algorithms that simulate fracture nucleation and growth using mesh-free methods that overcome the difficulties arising from the mesh-sensitivity of conventional mesh-based methods. We implemented a mesh-free local Petrov-Galerkin method (MLPG), which is based on the local weak form of the problem under consideration. This method requires no mesh for interpolation or integration, and thus may be well-suited to handle strain localization occurring during fracture development. Interpolation is performed using moving least squares approximation (MLS) shape functions, and since nodal integration is performed locally, this approach can be parallelized efficiently.

We present a mesh-free 2D elasto-plastic model for geomaterials that includes frictional hardening and cohesion softening using the Mohr-Coulomb failure criterion to simulate fracture network evolution and dynamic fracture propagation. Model performance is further enhanced through parallelization by utilising a hybrid CPU/GPU cluster using the *PETSc* library. We outline the implementation of the developed code, and evaluate its performance from a series of benchmark simulations.