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HELMHOLTZ Zentrum für Umweltforschung

TECHNISCHE UNIVERSITÄT BERGAKADEMIE FREIBERG
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Topic

Performance of Iterative and Direct Solvers in the Variational Phase Field Approach

Background

Computational fracture mechanics is crucial for predicting crack propagation in various materials. The variational phase field approach, derived from Griffith's theory, has become popular for its ability to handle fracture nucleation, propagation, and path identification without requiring complex crack geometry tracking or re-meshing. However, real-world applications with fine meshes and millions of degrees of freedom result in high computational costs.

Research Objectives

The phase field approach is implemented in the finite element THMC open-source software OpenGeoSys. The following are our research objectives to evaluate the performance of the VPF method:

Efficiency of Solvers. Identify the most efficient solvers for the staggered phase field method in both serial and parallel computing architectures and analyze their impact on computational cost and scalability.

Staggered Method Overview: Solve the displacement field (mechanical deformation) and phase field (fracture) sequentially:

- ***Displacement Field Solution:*** Fix the phase field and solve for the displacement field using direct solvers (e.g., MUMPS, PARDISO) or iterative solvers (e.g., Conjugate Gradient).
- ***Phase Field Solution*****:** Fix the displacement field and solve for the phase field using iterative solvers (e.g, SNES, TAO) with irreversibility methods (history variable or active set).

Parallelization Techniques: Compare MPI implementations for mesh decomposition and parallel direct solvers like PARDISO for local subdomain solves.

Impact of Linear Solvers and Preconditioners. Assess the performance impact of various linear solvers and preconditioners on the variational phase field method.

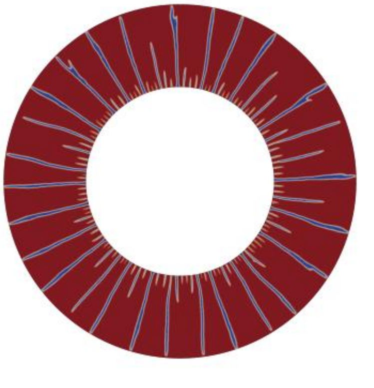
- Evaluate the efficiency and convergence rates of various linear solvers (e.g., Conjugate Gradient, GMRES) and preconditioners (e.g., hypre, Jacobi, block Jacobi, algebraic multigrid).
- Determine optimal combinations for reducing iteration count, simulation time, and improving overall computational efficiency and accuracy.

Your Tasks:

- Compare the efficiency of direct and iterative solvers in serial and parallel computing environments
- Evaluate the impact of different linear solvers and preconditioners on computational performance.
- Conduct simulations to study fracture nucleation and propagation.
- Preparation of phase field process getting start manual in OpenGeoSys (OGS) and preparation benchmarks in Jupyter Notebooks.

What we expect:

- Interest in computational mechanics and numerical modeling techniques.
- Basic programming knowledge (e.g., C++, Python).



What you can expect:

- Support and initial training in the use of OpenGeoSys
- Flexible working environment, with the option to work in Freiberg or Leipzig.

Curious? ☐ Get in touch!