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Parallelization schemes in OpenGeoSys and applications to density driven flow and crack evolution in geosystems.

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We demonstrate the scalability and performance of the open-source multi-platform modeling package OpenGeoSys (OGS, www.opengeosys.org) on the basis of two benchmarks with highly non-linear processes (density-driven flow and fracture propagation). The code shows strong scalability and high efficiency for up to several thousands cores. The simulations were conducted on the JUWELS cluster at the Juelich Supercomputing Center.

The first benchmark features a cube intersected by a highly permeable fault, has a semi-analytical solution, and is well studied in previous work [Magri2016]. It is analysed on different discretization sizes; scalability is tested with a spatial resolution of approximately 7 million nodes up to 5500 cores. Performance shows linear scaling up to 2160 cores; employing more cores decreases the parallel efficiency likely due to communication overhead resulting from a small number of degrees of freedom per core. The benchmark was furthermore successfully tested with up to 55 million nodes and 6000 cores, showing good comparability with the semi-analytical solution.

The second benchmark employs a mechanical problem modelling fracture propagation with the phase-field method [Bourdin2012]. The geological discontinuities are represented implicitly by an additional phase-field order parameter. Propagation of an existing crack in a cylindrical body induced by fluid injection is studied with different discretizations up to 8 million nodes. Preliminary analysis shows good performance of the code with up to 2000 cores for the highly non-linear problem.

Our result conclude that the development of highly parallelized versions of process-based numerical simulation toolboxes offers the possibility for fast simulations of very large and high-resolution geological domains. This opens new possibilities to resolve detailed analysis of small-scale effects, which also depend on surrounding larger scale properties and to analyse the uncertainty of parameters. Such simulation approaches can subsequently be applied to the analysis of representative large-scale systems.

[Magri2016]
Malkovsky, V. & Magri, F. Thermal convection of temperature-dependent viscous fluids within three-dimensional faulted geothermal systems: Estimation from linear and numerical analyses. Water Resources Research, 2016, 2855-2867

[Bourdin2012]
Bourdin, B., Chukwudozie, C. P., & Yoshioka, K. A Variational Approach to the Numerical Simulation of Hydraulic Fracturing. Society of Petroleum Engineers, 2012. doi:10.2118/159154-MS