PhD
High Performance Linear Solver for Thermo-Hydro-Mechanics with Regularization

Context

We are interested in the modeling of thermo-hydro-mechanical problems (THM), which describe the behavior of a soil, represented as a porous medium within which evolves a weakly compressible fluid [Granet, 2017]. This is the Biot's consolidation problem or poro-elasticity problem. It is used for studying galleries of underground storage, the simulation results are of major importance in discussions with the authorities and our partners. For example, we seeks to achieve the numerical modeling of two crossing galleries. This simulation remains difficult today mainly for reasons of numerical performances of 3D poromechanical calculations.

Goals

Important work has been done on iterative solvers for structural mechanics. The ability of multigrid methods to solve in a scalable manner simple mechanical problems (not involving Lagrange multipliers i.e. resulting in symmetric positive definite systems) was notably highlighted [Sellenet et al., 2013]. However, in the case of the Biot's problem, the linear systems to be solved are not definite positive.

Preliminary work has been carried out in EDF R&D on a simplified version of these equations, involving only mechanics of solids and hydraulics [Tardieu, 2017]. The method developed in code_aster intensely exploits a multigrid algorithm in a block preconditioning algorithm. Numerical results on a model problem and a more realistic problem reflect the good performance of the proposed preconditioner. A good parallel efficiency is observed which culminates at 94% between 48 and 96 processes and a resolution time of ten seconds for 2.5 million unknowns on 144 processes. To illustrate the scalability of the approach, a system with 50 million unknowns was solved over 400 processes in 7 minutes.

Despite these encouraging results, a theoretical work remains to be done. Due to the nature of the THM equations, regularization terms, called second gradient terms, are systematically used in industrial storage studies [Fernandes, 2008]. Their mathematical nature makes the application of the block preconditioning approach non-trivial and requires the support of academics.

Besides the case of storage, this work would also be applied to other applications in geo-mechanics, as the evaluation of the strength of dams and the influence of site effects of earthquake ground motion.

Possible university collaborations

Cerfacs is a strategic partner of EDF R&D and the feedback of a previous PhD work dealing with non-linear solvers in code_aster [Mercier, 2015] is very positive (quality, cost, delivery time). Professor Ulrich Rüde is the new pilot of the Algo team. His international reputation and expertise are highlighted. In addition, he is already working with EDF R&D in the PAMSIM Project, which shows to be very positive and fruitful. To start this research work with him would be a great opportunity.

Contact

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References

[Granet, 2017] Modélisation THM : Généralités et Algorithmes, Sylvie Granet, Documentation théorique de code_aster, 2017. R7.01.10.

[Sellenet et al., 2013] Évaluation de la faisabilité de calculs industriels massivement parallèles en mécanique des structures avec Code_Aster (affaire A12DA), N. Sellenet, Thomas De Soza, Jacques Pellet, Jean-Pierre Lefebvre, note interne H-T62-2013-04244-FR

[Tardieu, 2017] Préconditionneurs par blocs pour la résolution parallèle des problèmes de consolidation en hydro-mécanique, Nicolas Tardieu, note interne EDF 6125-1713-2017-00125-FR.

[Fernandes, 2008] A simplified second gradient model for dilatant materials: theory and numerical implementation, Fernandes, R., Chavant, C., & Chambon, R. (2008). International Journal of Solids and Structures, 45(20), 5289-5307.

[Mercier, 2015] Solveurs non linéaires rapides en mécanique des solides, Sylvain Mercier, thèse CIFRE, 2015.