Offer #2024-07380

Post-Doctoral Research Visit F/M Iterative coupling algorithms and nonlinear solvers for the simulation of Thermo-Hydro-Mechanical models in faulted geological systems.

Contract type : Fixed-term contract

Level of qualifications required : PhD or equivalent

Fonction : Post-Doctoral Research Visit

Level of experience : From 3 to 5 years

About the research centre or Inria department

The Inria centre at Université Côte d'Azur includes 37 research teams and 8 support services. The centre's staff (about 500 people) is made up of scientists of different nationalities, engineers, technicians and administrative staff. The teams are mainly located on the university campuses of Sophia Antipolis and Nice as well as Montpellier, in close collaboration with research and higher education laboratories and establishments (Université Côte d'Azur, CNRS, INRAE, INSERM ...), but also with the regiona economic players.

With a presence in the fields of computational neuroscience and biology, data science and modeling, software engineering and certification, as well as collaborative robotics, the Inria Centre at Université Côte d'Azur is a major player in terms of scientific excellence through its results and collaborations at both European and international levels.

Context

The postdoctoral project is part of a collaboration between Inria, University Côte d'Azur (Roland Masson and Konstantin Brenner) and IFPEN (Isabelle Faille and Guillaume Enchery) in the framework of the Inria-IFPEN partnership and of the project MathSout of the PEPR MathVives.

The position will be held at the Laboratoire de Mathématiques J.A. Dieudonné (LJAD), Université Côte d'Azur, Nice, with regular visits at IFPEN, Rueil Malmaison.

Assignment

Coupled Thermo-Hydro-Mechanical (THM) processes in faulted/fractured geological systems play a fundamental role in many geoscience applications such as geothermal energy and geological storage. This is particularly the case in the field of CO2 sequestration where the pressurized, low-temperature injection of supercritical CO2 is likely to induce a reactivation of faults leading to risks of leakage and/or seismicity which must be mitigated. Numerical simulation is a key tool for better assessing and controlling these risks. Such models couple non-isothermal multiphase flows along the fault network and in the surrounding rock (the matrix), the rock mechanical deformation and the mechanical behavior of the faults. Their numerical simulation raises numerous challenges related to the complexity of the geometries, the heterogeneous and multi-scale properties characteristic of geological systems and the multi-physics and non-linear couplings.

The project focuses on the design of robust nonlinear solvers which constitutes a bottleneck for the simulation of these models. There are three types of approach to solve these coupled processes. The first, often referred to as monolithic, is based on solving simultaneously all equations by a Newton algorithm. It lacks modularity and requires a robust preconditioner for the linearized coupled system, which constitutes a difficult task subject of ongoing research. It also has the disadvantage of solving all the variables at the same time step, preventing the use of smaller time steps for the time integration of the multiphase flow. On the other hand, time splitting algorithms, decoupling the thermo-hydro from the mechanical sub-models, make it possible to adopt such a sub-time step strategy for the flow. They rely on additional stabilization terms leading to either Fixed-Stress [2,7] or Undrained-Split [1] type splitting. However, these algorithms lack robustness in the incompressible limit and suffer from a loss of accuracy during regime changes and in case of strong hydro-mechanical couplings. A good compromise is based on the iterative variant of the previous time splitting algorithms. Such algorithm iteratively solves the thermo-hydro and mechanical sub-models until convergence towards the coupled solution. Compared with the monolithic approach, it is more modular, allows the use of preconditioners adapted to each sub-model and the use of sub-time steps for the flow. Furthermore, their potential lack of robustness can be overcome by the use of acceleration techniques such as Newton Krylov [8,3], Conjugate Gradient [6] or Anderson [4,5] algorithms.

The first objective of the project is to explore iterative coupling algorithms and their acceleration techniques for THM models. Emphasis will be placed on the case of fractured/faulted models taking contact into account, which, to our knowledge, has not been yet investigated. A second aspect of the project concerns nonlinear solvers for the contact mechanics sub-model, which is particularly difficult in the case of stick-slip transitions due to the singularity of the friction laws [9,10].

[1] T. Almani, K. Kumar, Convergence of single rate and multirate undrained split iterative schemes for a fractured Biot model, Computational Geosciences, 6, pp. 975-994, 2022.

[2] D. Bevillon, R. Masson Convergence and stability analysis of partially coupled schemes for geomechanical-reservoir simulations, in the Proceedings of the European Conference on the Mathematics of Oil Recovery, Baveno, 2000.

[3] F. Bonaldi, J. Droniou, R. Masson, A. Pasteau, Energy stable discretization of two-phase flow in deformable porous media with frictional contact at matrix-fracture interfaces, Journal of Computational Physics, January 2022.

[4] J. W. Both, K. Kumar, J. M. Nordbotten, F. A. Radu, Anderson accelerated fixed-stress splitting schemes for consolidation of unsaturated porous media, Computers & Mathematics with Applications 77 (6) (2019) 1479 – 1502.

[5] J.W. Both, N.A. Barnafi, F.A. Radu, P. Zunino, A. Quarteroni, Iterative splitting schemes for a soft material poromechanics model, Comput. Method in Applied Mech. Engrg. 338, 2022.

[6] F. Daïm, R. Eymard, D. Hilhorst, M. Mainguy and R. Masson, A Preconditioned Conjugate Gradient Based Algorithm for Coupling Geomechanical-Reservoir Simulations, Oil & Gas Science and Technology - Rev. IFP, p. 515-523, 2002.

[7] V. Girault, K. Kumar, and M. F. Wheeler. Convergence of iterative coupling of geomechanics with flow in a fractured poroelastic medium. Computational Geosciences, 20 (5), 997–101, 2016.

[8] L. Jeannin, M. Mainguy, R. Masson, S. Vidal-Gilbert, Accelerating the convergence of coupled geomechanical-reservoir simulations, Int. Journal for Numerical and Analytical Methods in Geomechanics, vol. 31, issue 10, 2007.

[9] H.B. Khenous, J. Pommier, Y. Renard, Hybrid discretization of the Signorini problem with Coulomb friction. Theoretical aspects and comparison of some numerical solvers, Applied Numerical Mathematics, 56, p. 163-192, 2006.

[10] P. Laborde, Y. Renard, Fixed point strategies for elastostatic frictional contact problems, Math. Methods in Applied Sciences, 31, p. 415-441, 2008.

Main activities

Design and analysis of numerical methods
Prototyping, validation, numerical investigation
Application test case
Paper writting
Oral presentations

Benefits package

- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Possibility of teleworking (after 6 months of employment) and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities
- Access to vocational training
- Social security coverage

General Information

- **Town/city :** Nice
- **Inria Center :** Centre Inria d'Université Côte d'Azur
- **Starting date :** 2024-10-01
- **Duration of contract :** 2 years
- **Deadline to apply :** 2024-06-30

Contacts

- **Inria Team :** AT-SOP AE
- **Recruiter :**
  Masson Roland / Roland.Masson@inria.fr

About Inria

Inria is the French national research institute dedicated to digital science and technology. It employs 2,600 people. Its 200 agile project teams, generally run jointly with academic partners, include more than 3,500 scientists and engineers working to meet the challenges of digital technology, often at the interface with other disciplines. The Institute also employs numerous talents in over forty different professions. 900 research support staff contribute to the preparation and development of scientific and entrepreneurial projects that have a worldwide impact.

The keys to success

Applicants should have a background in scientific computing/numerical analysis/applied mathematics, and be familiar with the discretization of PDEs and iterative solvers. An experience in computational mechanics will be an additional asset.

She/he should be experienced with a scientific programming language such as Fortran, C or C++
and be interested in applications and team working.

Warning : you must enter your e-mail address in order to save your application to Inria. Applications must be submitted online on the Inria website. Processing of applications sent from other channels is not guaranteed.

Instruction to apply

Defence Security :
This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2011-1425 relating to the protection of national scientific and technical potential (PPST).Authorisation to enter an area is granted by the director of the unit, following a favourable Ministerial decision, as defined in the decree of 3 July 2012 relating to the PPST. An unfavourable Ministerial decision in respect of a position situated in a ZRR would result in the cancellation of the appointment.

Recruitment Policy :
As part of its diversity policy, all Inria positions are accessible to people with disabilities.