PhD position in image analysis of neutron X-ray tomography of fluid flow in geomaterials

Application deadline: 20th of May 2022

Project summary

The recently developed capability to acquire **simultaneous neutron and X-ray tomographies** underpins a revolution in the study of numerous materials and processes. A notable example is the study of **coupled hydro-mechanical processes**, enabled by the unique complementarity in contrasts of the two techniques [Tengattini *et al.*, 2021].

Neutron imaging suffers nonetheless from a flux lower than X-rays. This entices longer exposure times, lower resolutions or, alternatively, higher noise. When studying a process through multiple subsequent acquisitions, much of the information is maintained along subsequent steps. This has been exploited in X-ray imaging [Leclerc *et al*., 2015;] but the exploration of its potential for neutron imaging has barely been tapped [Jailin *et al.*, 2018]. Furthermore, the **complementarity of the simultaneous X-ray acquisitions** has only been used to quantify different aspects of the behavior (*e.g.,* opening of cracks and fluid penetration) or to identify phases, but there is a huge potential in using it to directly **improve the effective spatio-temporal resolution** of neutrons (thanks to an approach called **super-resolution** [Park *et al.*, 2003]).

We propose to **develop a suite of image processing algorithms** to take advantage of the incremental nature of the processes as well as of the complementary information provided by the X-rays to significantly increase (up to two orders of magnitude) the spatio-temporal resolution of the neutron tomographies.

These algorithmical developments are crucial to characterize the hydro-mechanical couplings in cemented granular materials (*e.g.,* sandstones), which currently suffer from the lower spatio-temporal neutron resolution. These hydro-mechanical couplings drive numerous open engineering processes, from securing drinking water by a better understanding of reservoir physics and the mitigation of pollution, to the better and more efficient use of geothermal energy, to securing long term stability of existing nuclear waste storage.

We propose to **combine multimodal tomographies** to the aforementioned image processing developments **to quantify the interplay between the progressive damage of cemented granular materials undergoing mechanical loading and its effects on the permeability field**.

The implications of these cutting-edge algorithmic developments go well beyond this specific application, which is nonetheless uniquely relevant because of its societal implications.

The **main goals** of the project are:

- Development of image analysis algorithms to improve neutron tomography information (exploiting the spatio-temporal information as well as the complementary x-ray tomography)
- The experimental characterization of hydro-mechanical couplings (fluid flow in geomaterials such as sandstones)

Expected profile

We are looking for outstanding candidates with the ability to excel in research. The candidates must have a strong motivation to work in the interface between fluid/solid mechanics and mathematics. Specific skills needed for the position are:

- Degree allowing enrolment for a PhD (such as MSc, Master 2 de Recherche, Laurea or equivalent) in physics/mechanics/applied mathematics or closely related field. Familiarity with geomechanics and experiments would be an ulterior bonus.

- A background in programming is desirable. Basic programming skills and knowledge of Linux-based operating systems will be considered as a strong plus. Experience (or high interest in learning) data analysis/3D image analysis using preferably (but not exclusively) Python and developing open-source tools is a plus, as well.
- Experimental mechanics: previous experience with hydro-mechanical and/or imaging tests (*e.g.,* fluid flow, loading tests, tomography) experiments will also be an asset
- Personality: Good organization and planning skills, self motivation and ability to work as part of a multidisciplinary team

We offer

• A Research Project with High Value: you will explore hydromechanics at the cutting edge of research by combining advanced experimental techniques and developing novel image analysis algorithms.
• Team and Location: you will join a strong mechanics and image analysis group spanning over 4 institutions, which are world leaders in this research.
• Opportunity to work in unique large-scale experimental facilities (*e.g.,* foreseen experiments at the Institut Laue Langevin)
• A Full Time Position: French standard PhD student working time for three years. You will receive a net salary of roughly 1400 €/month.

Location and practical info

This is a full time 3-year PhD contract starting in October 2022, that will benefit from a collaboration between Université Grenoble-Alpes (www.univ-grenoble-alpes.fr) and specifically Laboratoire 3SR (Soils, Solids, Structures, Risks), Ecole Normale Supérieure, Paris-Saclay (www.ens-paris-saclay.fr) and specifically the Laboratoire de Mécanique Paris-Saclay, as well as large scale facilities (Institut Laue Langevin, European Synchrotron Radiation Facility).
The successful applicant will be enrolled at the Université Grenoble-Alpes and hosted by Laboratoire 3SR– https://3sr.univ-grenoble-alpes.fr – , in Grenoble, France. He/she will work under the supervision of Dr A. Tengattini (at 3SR), Dr S. Roux (at ENS), and Dr O. Stamati (at ESRF).

Application

Interested applicants should submit:

- 1 page cover letter describing motivation and qualification for the position
- Curriculum vitae
- Official transcripts of bachelor/master (lists of courses and grades)
- Contact information of 2 references (and recommendation letters, if any)

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For further information contact:

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References

[Jailin *et al*., 2018] Jailin, Clément, Ante Buljac, Amine Bouterf, François Hild, and Stephane Roux. "Fast 4D tensile test monitored via X-CT: Single projection based Digital Volume Correlation dedicated to slender samples." Journal of Strain Analysis for Engineering Design 53, no. 7 (2018):

[Leclerc *et al*., 2015] Leclerc, Hugo, Stéphane Roux, and François Hild. "Projection savings in CT-based digital volume correlation." Experimental Mechanics 55, no. 1 (2015): 275-287.

[Park *et al*., 2003] Park, Sung Cheol, Min Kyu Park, and Moon Gi Kang. "Super-resolution image reconstruction: a technical overview." IEEE signal processing magazine 20, no. 3 (2003): 21-36.

[Tengattini et al., 2021] Tengattini, Alessandro, Nicolas Lenoir, Edward Ando, and Gioacchino Viggiani. "Neutron imaging for geomechanics: A review." Geomechanics for Energy and the Environment 27 (2021): 100206.