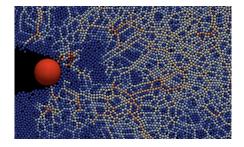
## **Postdoctoral Position:**

## Development of a Hybrid Model Reduction Method for Accelerating Parametric Studies in Granular Material Simulations

## **Advisors:**

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Scientific Context: Granular materials (such as sand, powders, and aggregates) exhibit complex, highly nonlinear behavior arising from discrete particle interactions. Microscopic numerical modeling, taking into account each grain of the material is a powerful tool for studying processes such as compaction, flow, and fracture in granular systems. The team involved in this project developed the C++ open-source software SCoPI, based on Contact Dynamics models, and allowing to simulate collections of several thousands of grains. However, the computational cost of these simulations remains prohibitive when performing extensive parametric studies involving variations in geometry, contact properties, or boundary conditions. To make such studies feasible, it is essential to develop Model Order Reduction (MOR) strategies capable of reproducing the relevant physical responses at a dramatically reduced computational cost.



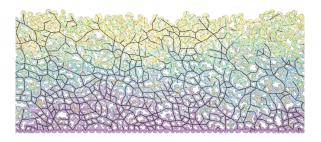


Figure 1: Numerical simuations achieved with SCoPI. Left: Sphere moving into a granular media (grains colored with pressure). Right: Stationary profile flow above an inclined plane (grains colored with velocity, contacts represented by lines)

Objectives: The goal of this postdoctoral project is to design and implement a **novel** hybrid model reduction approach tailored to discrete simulations of granular materials. The method will combine linear reduction techniques (e.g., Reduced Basis or Proper Orthogonal Decomposition — POD) with artificial intelligence methods, in particular deep neural networks, to capture complex nonlinear relationships and parametric dependencies. The specific objectives are to:

- Extract reduced bases from high-fidelity simulations, achieved with the code SCoPI, that describe the dominant modes of granular behavior;
- Train neural network models (e.g., autoencoders, convolutional or recurrent architectures) to learn reduced dynamics and parameter mappings;
- Integrate the resulting hybrid reduction framework within the SCoPI simulation environment, ensuring compatibility with its existing pre- and post-processing tools.

**Team:** The post-doctoral researcher will collaborate with Virginie Ehrlacher, an expert in model order reduction, with Aline Lefebvre-Lepot, whose research focuses on modeling and simulating granular media and suspensions, and with Loïc Gouarin, a research engineer and expert in scientific computing. Aline Lefebvre-Lepot and Loïc Gouarin developed the code SCoPI.

Candidate Profile: Applicants should hold a Ph.D. in Computational Mechanics, Applied Mathematics, or Scientific Computing, with experience in numerical simulation, data-driven modeling, and machine learning. Proficiency in C++ and high-performance computing (HPC) environments is desirable. Prior exposure to granular material modeling or reduced-order modeling will be considered an asset.

## References:

- 1. SCoPI webpage https://lefebvre-lepot.perso.math.cnrs.fr/SCoPI/
- 2. Benner, P., Gugercin, S., & Willcox, K. (2015). A survey of projection-based model reduction methods for parametric dynamical systems. SIAM Review, 57(4), 483–531.
- 3. Brunton, S. L., & Kutz, J. N. (2019). Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control. Cambridge University Press.
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- 5. Lobo-Guerrero, S., & Vallejo, L. E. (2005). *DEM analysis of crushing of granular materials under confinement*. Granular Matter, 7(3), 173–182.
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