PhD Subject.
Prediction of instability phenomena in mixed rock and ice massifs and run-out of granular flows linked to the thawing of permafrost in high mountains.

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Keywords: Computational Mechanics, Contact and Impact Mechanics, Rockfall trajectory, Natural Hazard mitigation, Fracture, thawing of permafrost in high mountains, Mont Blanc massif.

Context

TRIPOP is a joint research team of the Inria Centre de l'Université Grenoble Alpes and the Laboratoire Jean Kuntzmann. The team is mainly concerned with the modelling, mathematical analysis, simulation and control of non-smooth dynamical systems, with a strong application to the modelling of natural environmental risks in the mountains. Non-smooth dynamics concerns the study of the time evolution of systems that are not smooth in the mathematical sense, i.e. systems that are characterised by a lack of differentiability, either of the mappings in their formulations, or of their solutions with respect to time. In mechanics, the main examples of non-smooth dynamical systems are multibody systems with Signorini's unilateral contact, set-valued (Coulomb-like) friction and impact, or in continuum mechanics, plasticity, fracture or damage. The members of the team have a long experience in modelling non-smooth dynamics together with the development of the simulation software (see Siconos). With the help of Franck Bourrier (INRAe), part of the activities of the theme are now focused on rockfall trajectory modelling and natural hazard mitigation.

Description of the PhD subject

The aim of this work is to contribute to the prediction of instability phenomena in mixed rock and ice massifs associated with the thawing of permafrost in high mountains, and to simulate the flow (run-out) of rock/ice. Accurate models of permafrost landslides or avalanches (rock or ice) must take into account micro-scale ($< 1mm$) processes such as cracks and shear bands, which also include thermal and hydrological effects that will be exacerbated by climate change. Such models do not currently exist.

This involves developing numerical models of the fragmentation of rigid objects (boulders, ice and snow) using cohesive zone models (CZMs) in the Nonsmooth Contact Dynamics Method (Acary and Brogliato, 2008; Dubois et al., 2018). Cohesive zone models usable in dynamics, allowing detailed analysis of energy balances and usable in the context of non-regular mechanics (typically non-regular discrete simulations), have been developed in (Collins-Craft et al., 2022; Jean et al., 2001). This model will be written in 2D and its relevance to the study of block fragmentation during the propagation of rock (run-out) and ice masses will be assessed. In the case of permafrost, a crack model taking into account the thermal and hydrological effects on the cohesion of the

massif will be developed and applied to rockfalls in the Mont Blanc massif. Beyond the mechanics modeling of the phenomenon, a mathematical analysis of the existence conditions of the solutions of the underlying finite dimensional variational inequality will be studied, as well as the development of an open-source solver in a high-performance computing (HPC) framework Siconos.

Required skills. Student profile

The candidate should have skills in applied mathematics and numerical modelling. In addition, the candidate should have a strong interest in software development in computational mechanics. He/she should also be motivated by applied research in collaboration with researchers from different disciplines. A good level of English and writing skills are also required.

Additional information

- Environment
  - Team–Project and name of the team Leader: Tripop - Vincent Acary
  - Name of the supervisors :
    - Vincent Acary (HdR, INRIA, Tripop) `vincent.acary@inria.fr`
    - Franck Bourrier (INRIA, Tripop and INRAe) `franck.bourrier@inrae.fr`
  - Domain : Applied Mathematics, Computation and Simulation
  - Research theme : Optimization and control of dynamic systems
  - Location : Research center Grenoble. Montbonnot
- How to apply ? Send a motivation, recommendation letters and CV to the supervisors.

References

Acary, Vincent and Bernard Brogliato (2008). *Numerical methods for nonsmooth dynamical systems: applications in mechanics and electronics*. Springer Science & Business Media.

Collins-Craft, Nicholas Anton, Franck Bourrier, and Vincent Acary (2022). "On the formulation and implementation of extrinsic cohesive zone models with contact". In: *Computer Methods in Applied Mechanics and Engineering* 400, p. 115545.

Dubois, Frédéric, Vincent Acary, and Michel Jean (2018). "The Contact Dynamics method: A nonsmooth story". In: *Comptes Rendus Mécanique* 346.3, pp. 247–262.

Jean, Michel, Vincent Acary, and Yann Monerie (2001). "Non-smooth contact dynamics approach of cohesive materials". In: *Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences* 359.1789, pp. 2497–2518.