Offre de thèse / Thesis offer

MSCA Cofund - MISCEA

Template EURAXESS

Note for laboratories/potential supervisors : only fill in the *green and italic parts*

Job Information

Organisation/Company : **Ecole nationale des ponts et chaussées (ENPC)**

Department : *Laboratoire Navier / Navier Laboratory*

Research Field : *Géotechnique / Geotechnics*

Researcher Profile : **First Stage Researcher (R1)**

Country : **France**

Type of Contract : **Temporary**

Job Status : Full-time

Is the job funded through the EU Research Framework Programme? : **Horizon Europe (HE) / Marie Skłodowska-Curie Actions COFUND**

Is the Job related to staff position within a Research Infrastructure? : **No**

This project is co-funded by the European Union as part of the **HorizonEurope programme, Marie Sklodowska-Curie Actions, call COFUND-2022** and under grant agreement number 101126720

Offer Description

Thesis offer :

Title of the thesis

A data-driven machine learning approach for decision-making in the context of abandoned underground mines.

Keywords

stability; assessment; machine learning; in-situ database; synthetic data generation; predictive tool.

Thesis supervision

Thesis supervisors:

Lina Maria GUAYACAN CARRILLO, Research Associate, Geotechnical Team, Navier Laboratory (ENPC/UGE/CNRS). Ecole des Ponts ParisTech. Contact: lina.guayacan@enpc.fr

Nathalie CONIL, R&D Engineer, Sites and Territories Department, Post-Mining, Cavities and Quarries Risk Unit (SIT/RMC2), French National Institute for Industrial Environment and Risks (Ineris) Contact: nathalie.conil@ineris.fr

Co-supervisors of the thesis:

Jean-Michel PEREIRA, Director of the Navier Laboratory (ENPC/UGE/CNRS). Professor of Soil Mechanics at the Ecole des Ponts ParisTech. Contact: jean-michel.pereira@enpc.fr

Jean SULEM, Senior researcher, Geotechnical Team, Navier Laboratory (ENPC/UGE/CNRS). Professor of Rock Mechanics at the Ecole des Ponts ParisTech. Contact: jean.sulem@enpc.fr

Scientific Committee: Kamel DRIF (Ineris, SIT/AS2G), Marwan AL HEIB (Ineris, SIT/RNOS).

Context

France is characterized by a vast number of underground shallows abandoned mines due to its geological features and industrial legacy. It is estimated that there are hundreds of thousands of these mines, many of which remain unidentified. Over time, these underground mines deteriorate, potentially leading to their collapse or/and ground movements such as subsidence, as well as localised or large-scale collapses. Particular attention must therefore be given to old, abandoned mines. It is essential to address the consequences of ceased mining operations in order to prevent risks to people, property and the environment. The mining risk at former mining locations should be determined by considering different factors: predisposition, the triggering or aggravating factor of external origin and intensity. As an aggravating factor, the climate change is expected to increase the frequency of extreme hydroclimatic incidents, such as severe droughts, heavy rains or floods. These climatic events may cause substantial changes in groundwater or watercourse levels, as well as significant water infiltration. However, this

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factor alone cannot fully explain the risk of collapse; other aspects, such as the geometric and geomechanical characteristics of the mines must also be considered.

Recent advances in the geotechnical and geomechanical fields have led to a significant increase in the usage of machine learning (ML), thanks to its computational power and ability to solve complex problems. However, challenges concerning its efficacy when data availability is limited remain, which is a common issue in these fields. In such cases, models may overfit, resulting in inaccurate predictions when new datasets are introduced. To address this, there has been a concerted effort to integrate traditional numerical methods with ML to improve our understanding of complex behaviours. Various methodologies have been developed, including physics-informed ML approaches that use numerical modelling to create synthetic datasets (e.g. Tristani et al., 2025). Additionally, approaches combining multiple ML models have been explored to optimise predictions, enabling algorithms to collaborate and achieve better results. Ensemble methods, in particular, have demonstrated superior performance and reliability with constrained datasets (e.g. Guayacán-Carrillo et al., 2025; Richa et al., 2025; Tristani et al., 2024). Furthermore, for practical applications in these fields, it is crucial to incorporate interpretable tools that offer transparency and assist engineers in understanding model outputs. One promising technique for this purpose is symbolic regression (SR), which aims to identify a mathematical expression that accurately describes the input–output relationship. The effectiveness of SR has been clearly demonstrated in underground projects (e.g. Guayacán-Carrillo & Sulem, 2024).

This PhD project will analyse data from Ineris comprising almost 4,000 records of localised collapse cases in abandoned French mines. The primary goal is to assess the effectiveness of applying machine learning tools to this dataset to gain deeper insights into the mechanics of collapses. Subsequently, the project will focus on developing a predictive tool to assist local authorities in making informed decisions about abandoned mines at risk of collapse.

The research is divided into three main and current parts:

* ***Creating a foundational database for machine learning application:*** this involves implementing a strategy designed specifically to meet the project's unique requirements, which demands expert knowledge. The process also includes merging different data types into a single repository to enable fast, effective and secure access. An initial review of the Ineris inventory is therefore planned. Furthermore, comprehensive pre-processing and statistical analyses will be conducted. Additionally, unsupervised learning methods will be employed on the dataset to reveal hidden patterns and identify influential factors that might otherwise remain invisible or difficult to detect.

* ***Generating synthetic data***: This project will explore the effectiveness and validity of using machine learning approaches to generate synthetic data in order to address incompleteness and improve the training datasets of machine learning models. Additionally, synthetic data informed by physical principles will be also utilised. Significant advances have been made in understanding field phenomena observed in underground mines through empirical and numerical methods. Physics-based learning could enhance model quality and generalisation by providing a physical foundation using synthetic data from these methods.

* ***Developing machine learning surrogate models:*** Drawing on engineering expertise and insights from previous stages, this phase has two main objectives:

(1) To assess and verify the effectiveness of ensemble methods with the database established in this project. Building on the proven effectiveness of ensemble techniques such as random forests (RF) with limited or incomplete datasets (Guayacán-Carrillo et al., 2025), the study will evaluate various ensemble approaches. These will include RF and XGBoost which are well-known for their efficiency with small datasets.

(2) To develop accessible predictive tools for engineers and local authorities. In this endeavour, symbolic regression will be utilised. These tools are essential as they provide explicit mathematical expressions linking input and output data, thereby enhancing the model's relevance to engineers and facilitating informed decision-making.

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References

Guayacán-Carrillo LM, Conil N, Kadri Aissam (2025). Using Machine Learning for Predicting Collapse extending in Abandoned Underground Mines. EUROCK 2025. Trondheim, June 2025.

Guayacán-Carrillo LM & Sulem J (2024). Symbolic regression based prediction of anisotropic closure in deep tunnels. Comp & Geotech, 171, 106355. doi: 10.1016/j.compgeo.2024.106355

Richa T, Guayacán-Carrillo LM, Pereira JM, Chapron G (2025). Apprentissage automatique en géotechnique : étude de cas dans le domaine des tunnels. Techniques de l'Ingénieur, v1-c231. https://doi.org/10.51257/a-v1-c231.

Tristani A, Guayacán-Carrillo LM & Sulem J (2024). A physics-informed machine learning surrogate model to assess the long-term ground-lining interaction in viscoelastic plastic grounds. Paper presented at the 59th U.S. Rock Mechanics/Geomechanics Symposium, Santa Fe, New Mexico, June 2025. doi: https://doi.org/10.56952/ARMA-2025-0533.

Tristani A, Guayacán-Carrillo LM & Sulem J (2024). Data-driven tools to evaluate support pressure, radial displacements and face extrusion for tunnels excavated in elastoplastic grounds. Int J Num & Anal Meth Geomech. doi: 10.1002/nag.3889.

Description of the project and the candidates' eligibity criteria :

This position will be part of the EU-funded project **MISCEA**, which is an ambitious inter- and multidisciplinary Doctoral Training Network under the Horizon-Europe Marie Skłodowska-Curie Actions.

PhD candidates' can be of any anationality but you have to meet these eligibity criteria :

- **Not being a current employee** working at ENPC.
- Not having resided or carried out their main activity (work, studies, etc) in France **for more than 12 months** during the past 36 months immediately before the deadline of the MISCEA Programme's call. Compulsory national service, short stays such as holidays and time spent as part of a procedure for obtaining refugee status under the Geneva Convention are not taken into account.
- **Holding a Master's degree** or having a University degree equivalent to a European Master's degree (5-year duration) at the deadline of the MISCEA Programme's call.
- Researchers must be doctoral candidates, i.e. not already in possession of a doctoral degree at the deadline of the co-funded programme's call. Researchers who have successfully defended their doctoral thesis but who have not yet formally been awarded the doctoral degree will NOT be considered eligible.
- **Signing a declaration** of the veracity of the information provided (Declaration of honour, free of form).

If you comply with the eligibility criteria and you wish to submit your application, you must :

- Contact the thesis supervisor and explain your thesis project to her/him so that she/he validates your application.

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- Submit a **5-pages thesis proposal** under the proposed research areas, with the agreement of the future supervisor. Additionally, to the submission of the 5-pages thesis proposal, the applicant will have to complete an ethics checklist based on ethics guidance from the HorizonEurope programme guide.
- **English-translated transcripts** from the master's degree or equivalent.
- **Any specific requirements of the Doctoral School** corresponding to the targeted MISCEA
  fellowship offer.
- English curriculum vitae, including information about the level on English language knowledge.
- A motivation letter.
- One letter of reference, at least.

Templates are available on the MISCEA website (link).

Then your candidature is complete, please send inquiries and applications to miscea-program@enpc.fr

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Requirements

Research Field : *Génie Civil / Civil engineering*

Education Level : Master Degree or equivalent

Skills/Qualifications : *Expérience dans des projets de stage/recherche en géotechnique et notions en apprentissage automatique sera fortement apprécié / Experience of a geotechnical internship or research project and of machine learning concepts would be highly valued.*

Languages : ENGLISH

Level : Excellent

Where to apply

E-mail : miscea-program@enpc.fr

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