PhD 2026-2029

Multi-Physics-Informed Machine Learning for Non-Destructive Evaluation of Material Gradients

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Doctoral School: Doctoral School of Engineering and Systems Sciences https://ed-sis.doctorat-paysdelaloire.fr/en
Funding: Gustave Eiffel University
Speciality: Acoustics, Electromagnetism, Machine Learning
Application procedure: https://amethis.doctorat.org/amethis-client/prd/candidater/2701 (switch to English at the bottom of the screen)
It is strongly advised to contact the PhD supervisors before submitting your application.

Thesis context

According to the European Environment Agency (EEA), buildings in the European Union account for approximately 42% of total energy consumption and 35% of greenhouse gas (GHG) emissions. As of 2020, nearly 75% of the EU building stock was considered energy inefficient. While the renovation of existing buildings could reduce the EU's total energy consumption by 5–6% and decrease carbon dioxide emissions by around 5%, the current renovation rate remains below 1% per year.

In this context, the HORIZON-CL5-2024-D4-02-02 funded project RADIANCE aims to transform construction and renovation practices through the integration of advanced robotics, automation, and digitalization technologies. One of the project's key expected outcomes is the development of innovative robotic solutions for façade renovation. Within this framework, Gustave Eiffel University is developing **a multi-physics non-destructive evaluation (NDE) probe**, designed to be integrated onto drone platforms engineered by project partners, with the objective of assessing the structural integrity of concrete façades.

Objectives

The objective of this PhD thesis is to develop a **Machine Leaning interpretation methodology** that exploits the complementary information provided by the three physical modalities embedded in the NDE probe (namely **electrical resistivity, capacitive sensing, and ultrasonic testing** [1]).

The proposed methodology will enable a **quantitative reconstruction of property gradients** in concrete, such as degree of saturation, elastic modulus, and porosity.

Main Tasks

The Doctoral Candidate will:

- Perform **numerical modelling** of the three NDE techniques to evaluate the influence of relevant material property gradients on each NDE observable generating a sizable synthetic training datasets;
- Design and carry out **laboratory experiments** to produce representative experimental training data;
- Develop **physics-informed machine learning algorithms**, trained on both numerical simulations and experimental measurements (using a transfer learning approach), to recover quantitative material property gradients [2],[3],[4];

- **Demonstrate the utility of the algorithms** in a field-scale experiment on a metric-scale concrete wall, using the multi-physics NDE probe integrated onto drone platforms.

Expected Results

- **A Python-based multi-physics Maching Learning framework for NDE characterization of property gradients**, integrating multi-physics simulations and experimental measurements;
- **Experimental validation** of the proposed methodology using the multi-physics NDE probe in **both laboratory** (handheld) and **on-site** (drone-mounted) configurations;
- **Open-access dissemination of the results**, including peer-reviewed journal publications, publicly available source code (e.g. via GitHub), and curated experimental and numerical datasets.

References

[1] M. Fengal, P. Mora, P. Shokouhi, O. Durand, X. Dérobert, S. Palma-Lopes, M. Lehujeur, G. Villain, E. Gennesseaux, O. Abraham, Coherent and incoherent Rayleigh wave attenuation for discriminating microstructural effects of thermal damage from moisture conditions in concrete, NDT & E International, 156, 2025. https://doi.org/10.1016/j.ndteint.2025.103473

[2] Y. Hu, X. Wei, X. Wu, J. Sun, J. Chen, Y. Huang, J. Chen, A deep learning-enhanced framework for multiphysics joint inversion, Geophysics, 88(1), K13-K26, 2023. https://doi.org/10.1190/geo2021-0589.1

[3] Y. Ren, B. Liu, B. Liu, Z. Liu, P. Jiang, Joint Inversion of Seismic and Resistivity Data Powered by Deep Learning, IEEE Transactions on Geoscience and Remote Sensing, 62, 5929614, 2024. https://doi.org/10.1109/TGRS.2024.3458402

[4] M. Skiadopoulos, D. Kifer, P. Shokouhi, A transfer learning approach to the prediction of porosity in additively manufactured metallic components, NDT & E International, 157, 2026. https://doi.org/10.1016/j.ndteint.2025.103531

Prerequisite

- **Wave propagation physics** (acoustic, seismic, ultrasonic, electromagnetic) and/or **diffusive phenomena** (e.g., electrical resistivity).
- **Strong programming skills** either Python, MATLAB, julia or other scientific computing environments
- Experience with **numerical modelling** techniques, such as finite difference, finite element, or spectral element methods.
- Interest in **inverse problem** formulation and solving and/or **artificial intelligence** techniques in the context of physical modelling.
- Proficiency in **signal and data processing**, including time- and frequency-domain analysis.
- Familiarity with **instrumentation** for non-destructive testing and/or sensing technologies.

We offer

As a full-time Doctoral Candidate connected to the European RADIANCE project, you will have the opportunity to:

- Participate in **experiments with drones** carrying an innovative multi-physic probe
- Access to a set of existing home-made **experimental NDE** equipments and **numerical tools** to validate your developments
- Work alongside leading colleagues in the field of NDT and Machine Learning (including in **collaboration with Prof. Parisa Shokouhi, Penn State, USA**).
- Properly **communicate and disseminate** your research results
- Publish your results in high profile **open access** journals and conferences

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