Killian VUILLEMOT

PhD in applied mathematics

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Profile

PhD in applied mathematics with a specialization in **non-conforming finite element methods** (φ-FEM), **finite difference method**, and **coupling between numerical methods and neural networks** (FNO, UNET). Solid experience in **Python implementation** of numerical methods for the simulation of complex physical phenomena, with an application to organ modelling (digital twins) and to the resolution of PDEs on complex geometries.

Keywords: Numerical analysis • Scientific computation • Partial differential equations • Finite element methods • Finite difference method • Immersed boundary methods • Hybrid solvers • Scientific machine learning • Fourier Neural Operator • Physics informed neural networks (PINNs)

Professional experience

2022–2025 **PhD student in applied mathematics**, *Institut Montpelliérain Alexander Grothendieck – Université de Montpellier*, Montpellier, France

- Development of φ-**FEM** for real time construction of digital twins of organs, in collaboration with computer-aided surgery experts.
- **Innovative coupling between φ-FEM and FNO**:
  - Implementation in **Python (PyTorch)** to bypass the limitation of FNO to simple geometries.
  - Validation on complex problems and **publication in *Communications in Nonlinear Science and Numerical Simulation* (2026)**.
- Optimisation of numerical solvers:
  - Well-conditioned finite difference method for general geometries (**publication in *Journal of Scientific Computing*, 2025**).
  - Gain in performance and precision for realistic problems (heat transfer, structural mechanics).
- Collaborations with **Inria (MIMESIS)** and **ICube (MLMS)**.

2021–2022 **Intern in numerical methods development**, *ICube (MLMS) & Inria (MIMESIS)*, Strasbourg, France

Supervisors : Michel Duprez & Stéphane Cotin

- Development of φ-**FEM** computer-aided surgery.
- Implementation in **Python/C++** and validation on numerical test cases.

Key projects

φ-FEM Development of a non-conforming finite element method: implementation, numerical analysis of several φ-FEM schemes.

φ-FEM-FNO Coupling between φ-FEM and FNO to solve PDEs on complex geometries.

φ-FD Non-conforming well-conditioned finite difference method. Implementation and numerical analysis for the case of elliptic PDE on general geometries.

Skills

Numerical methods Finite element methods (conforming/non-conforming, φ-FEM), finite difference method, immersed boundary method, neural networks (Fourier Neural Operators), coupling FEM/FDM + neural networks methods.

Languages & Tools **Python** (NumPy, SciPy, FEniCS(X), PyTorch, TensorFlow, Pandas), C++, Linux, Git, SQL, SAS, RStudio, SOFA, LaTeX.

Education

2022–2025 **PhD in applied mathematics**, *Université de Montpellier*, Montpellier, France.
Titre : *Nonconformal Finite Element methods applied to the real time design of digital twins of organs*.
Supervisors : Michel Duprez, Vanessa Lleras, Bijan Mohammadi.

2016–2019 **Master's degree in applied mathematics (MIGS)**, *Université de Bourgogne*, Dijon, France
- Scientific computing, numerical analysis, optimisation, data analysis, algorithmic, programming.
- Projects: φ-FEM to solve the heat equation. Parallelisation in time for EDO resolution (Parareal algorithm)

2013–2016 **Bachelor's degree in Mathematics**, *Université de Bourgogne*, Dijon, France
- Project: Bézier curves and B-Splines.

Publications

Preprint A multigrid and neural network approach to reduce the computational cost of φ-FEM. R. Bulle, M. Duprez, V. Lleras and K. Vuillemot. 2026

Preprint A penalized φ-FEM scheme for the Poisson Dirichlet problem. R. Bulle, M. Duprez, V. Lleras and K. Vuillemot. 2026

2026 φ-FEM-FNO: a new approach to train a Neural Operator as a fast PDE solver for variable geometries. M. Duprez, V. Lleras, A. Lozinski, V. Vigon and K. Vuillemot. *Communications in Nonlinear Science and Numerical Simulation*. DOI : 10.1016/j.cnsns.2025.109131

2025 φ-FD: A well-conditioned finite difference method inspired by φ-FEM for general geometries on elliptic PDEs. M. Duprez, V. Lleras, A. Lozinski, V. Vigon and K. Vuillemot. *Journal of Scientific Computing*. DOI : 10.1007/s10915-025-02914-0

2023 φ-FEM for the heat equation: optimal convergence on unfitted meshes in space. M. Duprez, V. Lleras, A. Lozinski and K. Vuillemot. *Comptes Rendus Mathématiques*. DOI : 10.5802/crmath.497

2022 φ-FEM: an efficient simulation tool using simple meshes for problems in structure mechanics and heat transfer. S. Cotin, M. Duprez, V. Lleras, A. Lozinski and K. Vuillemot. *Partition of Unity Methods* (Wiley). DOI : 10.1002/9781118535875.ch7

Presentations

Conferences: ECCOMAS 2024 (Lisbon), CANUM 2024 (Île de Ré), DTE-AICOMAS 2025 (Paris), **Seminars** : IMB (Dijon), IRMA (Strasbourg), MIMESIS/MLMS (Strasbourg), IMAG (Montpellier).

Languages

French Native

English Fluent: spoken, read, written (publications and conferences in English)