Giulia Sambataro

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Personal webpage
Nationality: italian

Research interests

Numerical methods for partial differential equations (especially model order reduction)

Multiphysics coupled systems, domain decomposition

Variational inequalities (application in contact mechanics)

Optimization, machine learning techniques

Education

2019 - 2022 **Doctor of Philosophy**
Applied Mathematics and Scientific Computing
Institut des Mathématiques de Bordeaux, University of Bordeaux, France

2016-2019 **Master of Science**,
Mathematical Engineering
Politecnico di Milano, Milan, Italy
Final grade: 106/110

Appointments and research experience

Friedrich-Alexander-Universität Erlangen-Nürnberg — February 2025-January 2026
Chair for Dynamics, Control, Machine Learning and Numerics — Post-doctoral associate
Adviser: Prof. E. Zuazua

École Nationale des Ponts et Chaussées — February 2023-January 2025
Cermics laboratory, MATHERIALS team (Inria) — Post-doctoral associate
Adviser: Prof. V. Ehrlacher

INRIA Bordeaux South-West — October 2019-December 2022
MEMPHIS team, Institut des Mathématiques de Bordeaux — PhD student
Advisers: Prof. A. Iollo, Dr. T. Taddei

Politecnico di Milano — April 2018-April 2019
Laboratory for Modeling and Scientific Computing (MOX) — Internship student
Adviser: Prof. C. Vergara

Teaching experience

Analyse des équations aux dérivées partielles (Link to the course)
École Nationale des Ponts et Chaussées — September 2023-January 2024
Full course (theoretical and exercise lessons)

Analyse des équations aux dérivées partielles (Link to the course)
École Nationale des Ponts et Chaussées — September 2024-January 2025
Substitutions for the cours (theoretical and exercise lessons)

Programmation en Python (Link to the course).
École Nationale des Ponts et Chaussées — November 2024-January 2025
Full course (theoretical and exercise lessons)

- *Analyse des équations aux dérivées partielles*:cours description.
  At the end of this module, students should be familiar with the main classes of partial differential equations; be familiar with the fundamental mathematical concepts needed to analysis and solve partial differential equations, in particular the leading theories of 21st century analysis, such as measure theory and distribution theory; be able to use the essential methods for solving partial differential equations (characteristic methods, series decomposition or Fourier transform); be able to implement these methods numerically for solving partial differential equations using algorithms implemented in the Python language.

- *Programmation orientée objet en Python*: cours description.
  The primary aim of the module is to present the key concepts of object-oriented programming and to illustrate these concepts, which are largely independent of the programming language, using the Python language. The module therefore follows on from the teaching of procedural Python in preparatory classes. The second objective of the module is to show how object-oriented programming can be used to produce higher-quality code that is easier to understand, maintain, and extend. To achieve this, the basic aspects of modeling are covered, i.e. the techniques, practices, and notation that enable the description of a problem in natural language to be translated into a program. These two complementary objectives should enable students to be effective in writing and developing Python programs, so that the programming aspects do not cause difficulties or slow down other modules.

Publications

Gigante, G. et al. (2020). "Optimized Schwarz methods for spherical interfaces with application to fluid-structure interaction". In: *SIAM Journal on Scientific Computing* 42.2, A751–A770.

Iollo, A. et al. (2022). "An adaptive projection-based model reduction method for nonlinear mechanics with internal variables: Application to thermo-hydro-mechanical systems". In: *International Journal for Numerical Methods in Engineering.*

– (2023a). "A one-shot overlapping Schwarz method for component-based model reduction: application to nonlinear elasticity". In: *Computer Methods in Applied Mechanics and Engineering* 404, p. 115786.

– (2023b). "An optimization-based model order reduction approach for coupled problems: application to thermo-hydro-mechanical systems". In: URL: https://api.semanticscholar.org/CorpusID:265356225.

PhD Thesis

https://theses.hal.science/tel-04006932/document

Pre-print

V. Ehrlacher, G. Sambataro. (2025). "A nonlinear reduced-order model for parametrized variational inequalities: application to crowd motion". HAL link

Summary of research activities

This section describes the main research activities I carried out during my PhD and my first postdoctoral work.

- The application that motivated **my doctoral thesis** is the storage of high-level radioactive waste in geological environments. The work is driven by applications to thermo-hydro-mechanical (THM) systems (I collaborated with Andra — the French National Agency for Radioactive Waste Management. THM equations model the behavior of temperature, interstitial water pressure, and solid displacement in the vicinity of geological repositories, which contain radioactive waste and are responsible for a significant thermal flux toward the Earth's surface. From a mathematical perspective, the THM system we solve is a coupled, time-dependent, and highly nonlinear system. Furthermore, the solution to the problem depends on several parameters, which may be related to the geometric configuration (e.g., the number of repositories, their distance, or their size) or to the material properties of the medium. For example, changes in the position and/or number of radioactive waste repositories could lead to significant variations in predicted quantities of interest; therefore, we would need to solve the numerical model multiple times. This represents a multi-query problem and requires the application of component-based parametric model order reduction (CB-pMOR). First, I developed a high-fidelity finite element discretization for the two-dimensional THM problem. I then built a monolithic reduced model based on Galerkin projection and analyzed its performance against predictions. Next, I proposed a CB-pMOR formulation for stationary problems in nonlinear elasticity. Finally, I extended the CB formulation and methodology to time-dependent nonlinear problems with internal variables to solve the THM problem of interest.
- **During my postdoc**, I adapted recent approaches in nonlinear model reduction to predict solutions for time-dependent, parameterized problems describing crowd motion in the presence of obstacles. A prototypical example of an interesting problem is the discrete contact model proposed in B. Maury, J. Venel, ESAIM, 2011, where each agent in the crowd is modeled individually. In this problem, at each discrete time step, the set of velocities of all agents in the crowd is obtained by solving a constrained least-squares optimization problem. The parametric variations of the problem (associated with the geometric configuration of the domain where agents move) strongly affect the solution's variability, both in terms of agent positions and contact forces between them. The latter are given by the Lagrange multipliers associated with the non-penetration constraints. More precisely, the Kolmogorov width of the solution set decreases very slowly. Motivated by this challenge, I explored novel numerical approaches that combine the reduced-basis method with supervised machine learning techniques. I developed a hybrid method enabling more accurate and efficient predictions of particle velocities and contact forces compared to traditional methods.

Other research activities

SCoPI code for contact problems CMAP, École Polytechnique. Collaboration with Dr. A. Lefebvre-Lepot et Dr. L. Gouarin	September 2023—

Selected invited conference presentations

June 2023, Chania (Greece)	Coupled 2023 X International Conference on Computational Methods for Coupled problems in Science and Engineering Chair: Dr. Irina Tezaur
February 2024, Trieste (Italy)	SIAM UQ24 X SIAM Conference on Uncertainty Quantification Chair: Dr. D. Lombardi, F. Nobile
June 2024, Lisbon (Portugal)	ECCOMAS 2024 9^{th} European Congress on Computational Methods in Applied Sciences and Engineering Chair: M. Manucci, J. Nicodemus, B.Unger
July 2024, Vancouver (Canada)	WCCM-PANACM 16^{th} World Congress on Computational Mechanics Chair: N. Akkari, C. Farhat, F. Casenave, T. Gonon.

Seminars

14 June 2024 (online)	Scuola Internazionale Superiore di Studi Avanzati (SISSA), Italy SIAM Student Chapter (Link to the video)
∼ March 2025	Friedrich Alexander Universität, Erlangen, Germany Chair of Dynamics, Control, Machine Learning and Numerics
27 March 2025	Paul Painlevé laboratory of Lille University, France Seminars on "Numerical analysis and partial differential equations"

Responsibilities

- I took part to the organisation of "Data transitions", a series of seminars on data science. I had an active role from the creation of the seminar in June 2024 until the end of my contract at CERMICS on the 31st of January 2025. My responsibilities have been diverse, ranging from the practical organization of events (such as poster printing and room reservations) to selecting scientific topics for various talks.
- I was reviewer for the Journal of Computational and Applied mathematics in October 2024. I was invited to review topics on domain decomposition and model order reduction methods.

Skills

Matlab, Python, LaTeX, FreeFem++, Scilab, C++, Paraview

Languages

- Italian: mothertongue
- English: C1 CEFR level
- French: C1 CEFR level