UNIVERSITÀ DI PISA
DOTTORATO DI RICERCA IN INGEGNERIA INDUSTRIALE

Doctoral Course

Introduction to uncertainty quantification and stochastic sensitivity analysis

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Contents

Experimental and numerical investigations are inherently affected by uncertainty due to incomplete knowledge or intrinsic variability. Quantifying and understanding these effects is essential for obtaining robust and reliable predictions. This course introduces methodologies for uncertainty quantification and stochastic sensitivity analysis to assess the impact of uncertain inputs on model outputs.

Engineering experiments and simulations often involve multiple uncertain parameters, whose influence on output variability must be properly evaluated. Traditional deterministic approaches based on extensive testing become impractical when simulations or experiments are computationally or economically expensive. Stochastic methods offer an efficient alternative, enabling the construction of accurate stochastic response surfaces with a reduced number of deterministic evaluations and allowing the identification of the relative contribution of each uncertain input. The course focuses on non-intrusive stochastic techniques for uncertainty propagation, in particular generalized polynomial chaos and stochastic collocation. Practical engineering examples are presented, and by the end of the course, students will be able to set up and perform an uncertainty quantification analysis for a problem of interest.

Schedule

The course consists of four three-hour lectures. More details on the topics covered in each lecture are provided below.

1. **Introduction to uncertainty quantification (UQ):** definition and motivation, classification of the main techniques, and application fields. Overview of non-intrusive stochastic approaches (Monte Carlo methods). Comparison between deterministic and stochastic approaches, highlighting their main advantages and disadvantages. (3 hours)
2. Surrogate models for response surface generation: **generalized polynomial chaos**. Stochastic quantification of output variability (partial sensitivities, Sobol indices). (3 hours)
3. Surrogate models for response surface generation: **stochastic collocation methods** (sparse grids and multilevel approaches). (3 hours)
4. **Inverse UQ and multilevel approaches.** Examples and practical exercises on stochastic sensitivity analysis applied to different problems. (3 hours)

Timetable

All lectures will be held in the room AERO1 (via G. Caruso 8, Pisa) and on Microsoft Teams and will be scheduled as follows.

Lecture number	Date	Time	Lecturer
1	2/2/2026 (Monday)	14:00–17:00	Alessandro Mariotti
2	9/2/2026 (Monday)	14:00–17:00	Alessandro Mariotti
3	10/2/2026 (Tuesday)	14:00–17:00	Alessandro Mariotti
4	11/2/2026 (Wednesday)	14:00–17:00	Alessandro Mariotti

About the lecturer

Alessandro Mariotti is a Professor of Fluid Dynamics at the Department of Civil and Industrial Engineering of the University of Pisa, where he heads the wind tunnel laboratory. His main research activities include experimental and numerical analyses of complex flows, wind tunnel testing, high-fidelity simulations, aerodynamic optimization, and uncertainty quantification in fluid dynamics applications (e-mail: alessandro.mariotti@unipi.it).