# Advanced Course in "Uncertainty Analysis"

### 14-18 September and 28 September-2 October 2015

### IST, Universidade de Lisboa, Lisboa, Portugal

A Consortium of Portuguese Universities launched recently a PhD program on "Analysis and Mitigation of Risks in Infrastructures" (<u>http://infrarisk.tecnico.ulisboa.pt</u>).

An advanced course on "Uncertainty Analysis" will be taught during 14-18 September and 28 September-2 October, 2015, at Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal, by experts in the field of uncertainty modelling within risk analyses, covering topics such as uncertainty modelling, variability and propagation of uncertainties and sensitivity analysis, and it will include the examples of practical application of the concepts to engineering models examples. The lectures and course materials will be provided in English.

This course will be an important opportunity to acquire the basic knowledge for uncertainty modelling and to be introduced to the available methods for propagation and analysis of uncertainty, to methods for combining different types of uncertainty and to sensitivity analysis. The detailed course syllabus can be found below.

### Program

Modelling uncertainty and variability: Classical and Bayesian interpretation of probability. Random variables. Common probabilistic models. Descriptive statistics of samples. Estimation and model building from data. Bayesian estimation methods.

Propagation and uncertainty analysis of the response of engineering models. Analytical and statistical sampling methods. First Order Second Moment Methods and Monte Carlo simulation techniques. Variance reduction techniques in Monte Carlo simulations. Discretization and simulation of random fields. Response surface methods. Sensitivity analysis.

### Lectures involved

**Carlos Guedes Soares**: Professor at IST, being the Head of CENTEC, the Centre for Marine Technology and Engineering. One of his main areas of research is uncertainty modelling and risk and reliability assessment, having been one of the Founding Members of the European Safety and Reliability Association (ESRA) and is Editor of the Reliability Engineering and System Safety Journal for more than 20 years.

Ângelo Palos Teixeira: Assistant Professor at Instituto Superior Técnico (IST), University of Lisbon, since 2004 and Principal Investigator of the research group on Safety and Logistics of Maritime Transportation of the Centre for Marine Technology and Ocean Engineering (CENTEC). His main scientific areas of research are related to risk assessment, maritime safety, structural reliability analysis of marine structures and systems reliability and maintenance.

António Araújo Correia: Research Fellow at the Earthquake Engineering and Structural Dynamics Division of the National Laboratory for Civil Engineering (LNEC), currently also serving as Technical Secretary at Sub-Commission 8 (Eurocode 8) of Technical Committee 250 (Structural Eurocodes) of the European Standardization Committee (CEN/TC250/SC8). His main expertise research and interests are in the fields of: seismic risk, structural vulnerability and code developments, as well as on the experimental assessment and numerical modelling of the seismic response of structures.

Vitor Sousa: Assistant Professor at the Construction Management Group of the Department of Civil Engineering, Architecture and Georesources, IST – University of Lisbon. His main expertise is in hydraulics and risk management and the current research interests include risk and asset



management systems implementation, in particular on entities responsible for extensive engineering infrastructures networks.

### **Bibliography**

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C. Bucher, Computational Analysis of Randomness in Structural Mechanics. Taylor & Francis, 2009.

# **Detailed course syllabus**

- 1. Introduction to uncertainty analysis and modelling (day 1)
- What is uncertainty?
- Uncertainty in engineering problems.
- Types of uncertainty and terminology.
- Different interpretations of the probability.

## 2. Probability concepts (day 2)

- Events and probability. Elements of set theory.
- Axioms of probability. Conditional probability. Statistical independence.
- Total Probability Theorem. Bayes' Theorem.
- Discrete and continuous random variables.
- · Probability distributions of random variables.
- Moments of random variables.
- Joint probability distribution function.
- Conditional probability distribution function and Independence.

### 3. Uncertainty modelling from data (day 3, 4, 5)

- Common probability distribution models for discrete and continuous random variables.
- Descriptive Statistics. Confidence Interval.
- Fitting probability distributions to data: Method of Moments, Least Squares Fit of Transformed Data (Probability plot). Method of Maximum Likelihood.
- Model validation: Chi-squared goodness-of-fit test, Kolmogorov-Smirnov test.
- Bayesian probabilistic model framework: The discrete and continuous case.

### 4. Uncertainty propagation (day 6,7,8)

- Analytical methods for propagation and uncertainty analysis: First Order Second Moment Methods.
- Sampling techniques. Inverse-transform method. Acceptance-rejection method.
- Monte Carlo Simulation. Variance reduction techniques: Importance sampling.
- Simulation of correlated random variables: Rosenblatt and Nataf transformations.
- · Discretization and simulation of random fields.

### 5. Response Surface Methods (day 9)

- · Polynomial regression models.
- Kriging interpolation models.
- Determination of parameters and model prediction.

### 6. Sensitivity analysis (day 10)

- Local sensitivity analysis methods.
- · Global sensitivity analysis methods.