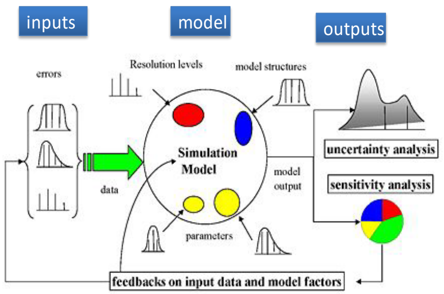
Summary School on Uncertainty and Sensitivity Analysis of Model Output in Engineering Applications



Saltelli et al., 2008

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Keywords:

Global Sensitivity Analysis | Modeling and Simulation | Monte Carlo Simulations | Measurement and data uncertainty | Systems Engineering | Multisector & multidisciplinary applications

General course objectives:

Modeling is actively used in various scientific and engineering disciplines for a variety of ends: from the development of process understanding to design, control, and operation of engineering and natural systems.

Most numerical models simulating such systems tend to be complex with many parameters, state variables, and non-linear relations resulting in many degrees of freedom. Using a fine-tuning method (manually or statistically), these models can be made to produce virtually any desired behavior to fit the observations on the system in question. What is challenging, however, is to ascertain a degree of reliability and credibility of the models before one applies them in reality.

The objective of this course is to introduce modern techniques for analyzing uncertainty and sensitivity of model outputs. We aim to provide participants with a sound understanding of theory and hands-on practice (in Matlab®) on applying a range of methods from local to global techniques *for model-based engineering applications*.

Course content:

Fundamental as well as contemporary methods in advanced uncertainty and sensitivity analysis will be covered in the course as presented below:

Uncertainty analysis	**Sensitivity analysis**
Linear error propagation	**Differential analysis**
Bayesian inference	**Monte Carlo based regression**
Monte Carlo technique	**Derivative based global sensitivity**
Bootstrap sampling	**Elementary Effects (Morris)**
	Variance decomposition (Sobol)
	GSA for dependent inputs
	Meta-modelling based GSA
Parameter estimation	Identifiability analysis
Nonlinear regression (MLE)	Mean sensitivity-based screening
Bootstrap method	Collinearity index
MCMC sampling/Bayesian Inference	

For parameter estimation uncertainties, two fundamental theories—MLE and Bayesian inference—in addition to the bootstrap method are covered. For sensitivity analysis, local as well as global contemporary techniques will be covered. For global analysis, methods developed for both independent inputs and correlated inputs will also be covered. Convergence test for Monte Carlo methods under presence of heavy tails are discussed.

As the course aims at giving hands-on experience with the topics studied, therefore, the lectures are structured as follows: first the theory will be introduced in class, which is followed by practical exercises and examples. Examples are taken from the textbook, the literature, and ongoing research at PROSYS Research Centre covering simple test functions to real life engineering models.

Course literature:

Saltelli A, Ratto M, Andres T, Campolongo F, Cariboni J, Gatelli D, Saisana M, Tarantola S. Global Sensitivity Analysis: The primer. England, John Wiley & Sons, 2008.

Gelman, Carlin, Stern and Rubin, Bayesian data analysis, 2nd ed, Chapman & Hall, CRC, 2004. Plus, several more relevant articles.

Taleb NN. Statistical Consequences of Fat Tails: Real World Preasymptotics, Epistemology, and Applications (Technical Incerto). STEM Academic Press, 2020.

Sin, G. (2024). Global sensitivity analysis using Monte Carlo estimation under fat-tailed distributions. *Chemical Engineering Science*, *294*, 120124.

Remarks:

Basic knowledge of Matlab or python is needed to work with the exercises. Using modern LLMs many scripts can be easily translated to other programing languages like R. *Participants are expected to have their own laptops to carry out the computer exercises.*

Course type and credits:

Participants who are interested to get credits from this activity may do so by meeting additional requirements. The summer school is registered as a Ph.D. level course equivalent to 7.5 ECTS in DTU. Therefore to get credits, the interested participants need to perform a case study application of the methods to a given model and write a report critically analyzing the results.

Scope and form:

The school is designed as one week intensive learning with 9 sessions each focusing on one particular method. The lectures first introduces the theory and then followed by practical work/exercises with the methods. Those interested in getting credits, will have to work on an appropriate case study application of the methods to a model system. This part will be done remotely and may take 3 weeks to complete.

Registration:

There is a registration fee researchers (PhDs/postdocs) to participate in this summer school. The fee covers social and networking events (lunches and summer school dinner).

PhD researchers: 3500 DKK

Postdoc researchers: 5000 DKK

For participants from industry/non-academic sectors, who wish to upskill their competences, the course fee is determined by DTU lifelong learning:

Professionals/industry: 15,900 DKK (2025 rate).

Members of KT consortium will have a discount for registration.

Registration takes place via the summer school website and will be confirmed once the payment is received. There is room for 25 persons in the course and the deadline to register is July 30th, 2025.

More information:

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