Challenge 2.

Mathematical Challenges in Uncertainty Quantification

In areas as diverse as climate modelling, manufacturing, energy, life sciences, finance, geosciences and medicine, mathematical models and their approximate counterparts (computer models) are routinely used to simulate processes, assess risk and inform decisions. Models are used not only to predict future events and their impacts, but also to test hypotheses and aid in the design of new products such as aircraft engines, electronic devices, smart materials, and drug therapies. A crucial question is therefore, how accurate and reliable are predictions made using models? The scientific field of Uncertainty Quantification (UQ) attempts to address this.

No model is a perfect surrogate for reality. We often lack knowledge about the real processes taking place. The process of interest may also be inherently stochastic. Hence, there is always uncertainty associated with the models we use. How can we quantify and estimate model error and discrepancy? Most mathematical models have input parameters that are not precisely known. Hence, we have to deal with parameter uncertainty and understand how uncertainty in inputs propagates to quantities of interest related to model outputs. Often, the quantity of interest is actually an input to a model, and not an output. If we have observations (data) related to the model outputs, then we need to solve an inverse problem to estimate the parameters. Most mathematical models of complex processes cannot be solved exactly. Numerical algorithms that generate approximations must be applied instead. Estimating the numerical errors associated with the resulting computer models is also crucial.

Modern applications typically involve complex mathematical models, high numbers of uncertain parameters and very expensive (slow to run) computer models. In this session, some of the associated mathematical challenges in UQ will be explored from both an academic and end-user perspective.

Panel of Speakers

Professor Max Gunzburger is an applied and computational mathematician at the Department of Scientific Computing at Florida State University. The main foci of his current research interests are uncertainty quantification and control for complex systems, nonlocal modeling in diffusion and mechanics, and ocean modeling.
Talk title: An applied mathematician's perspective of the mathematical challenges in UQ.

Dr. Tim Waite is a statistician in the School of Mathematics at the University of Manchester. His research is primarily focused on statistical design of experiments and related issues. He is particularly interested in how to select the observations to be taken in a scientific experiment in order to best inform empirical statistical models, mechanistic or phenomenological

mathematical models encoding scientific knowledge, and also hybrid models combining both approaches.
Talk title: Statistical and mathematical challenges in experiments for UQ.

Dr. Inês Cecílio is a research programme manager and scientist at Schlumberger Cambridge Research. Schlumberger is the world's leading supplier of technology and services to the oil and gas industry. Inês' research interests are in Bayesian modelling and inference as well as nonlinear time series analysis applied to model inversion, signal processing and data analysis.
Talk title: Why is UQ vital to increase safety and efficiency in drilling oil and gas wells?

Session Chairs

Dr. Catherine Powell (University of Manchester), Professor Dave Woods (University of Southampton).