# Uncertainty quantification – overview

Over the years, CTR Summer Programs have included projects covering many multidisciplinary fields at the intersection of physics, numerical analysis and computational science. In 2010, four groups worked in the area of Uncertainty Quantification (UQ) joining forces with Stanford's researchers in the Predictive Science Academic Alliance Program (PSAAP). These groups addressed different aspects of uncertainty quantification in applications related to high-speed fluid dynamics.

The first project led by Constantine, Doostan and Wang revolved around the concept of stochastic inference: the solution of an inverse problems in which boundary conditions are reconstructed given noisy outputs such as measurements affected by errors. A Bayesian mathematical framework was used to determine the operating conditions of an air-breathing hypersonic vehicle from wall pressure sensors collecting data during the flight. Various methodologies were compared during the summer, but an important direction explored in this work was the determination of an optimal placement for the pressure sensors to minimize the uncertainty in determining the flight conditions.

Two projects dealt with the issue of uncertainty propagation in complex, compressible fluid mechanics problems with the objective of determining the outputs given input variability. The project by So *et al.* focused on uncertainty analysis for a classical shock/bubble interaction problem. The first part of the project was dedicated to the determination of appropriate metrics to study the interaction problem; both global quantities (topological characterization of the interaction) and local measures (the baroclinic vorticity generation) were considered. The uncertainty analysis was based on stochastic collocation method. The work by Congedo *et al.* focused on the study of the dynamics of dense gases, specifically aimed at determining the uncertainties that might emerge in designing experiments aimed at demonstrating the occurrence of rarefaction shocks. During the summer, the group also investigated the use of stochastic inference to determine how much measurement errors would be tolerable for a reliable observation of expansion shocks. This methodology extends the usual approach of using computations to design experiments.

The fourth project addressed the challenging issue of determining structural uncertainty due to modeling assumptions in turbulence models. Dow and Wang used an adjoint formulation to estimate the errors resulting from eddy viscosity closures in Reynolds averaged computations. The methodology was based on the use of Direct Numerical Simulations to construct a database of turbulent flows which serves as a basis to estimate the eddy viscosity errors. The initial results were promising although additional work is required to generalize the current formulation.

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