Uncertainty Quantification (UQ)

In industry, the exact configuration of a product and the physical conditions in its application environment are always to some extent charged with uncertainty. The aim of UQ is to quantify the influence of this uncertain input on numerical simulation results. It is examined in the form of stochastic moments such as mean and variance. In non-intrusive approaches, a conventional code is run several times and a stochastic evaluation is performed on the results. In monolithic intrusive approaches, a new stochastic solver has to be developed.

Monte Carlo Methods

In Monte Carlo methods, input parameters are drawn randomly for a large number of samples and an individual simulation is carried out for each drawn input (left image). This approach is very reliable, but needs a very large number of sample computations in order to obtain accurate results. Multilevel Monte Carlo methods are more efficient. Here, a large number of computations is carried out with reduced resolution and therefore lower computational cost. On each level, the solution is corrected by differences between two corresponding computations on increasingly finer meshes. Only few samples are required for this correction, which increases efficiency (right image).

Generalized Polynomial Chaos Methods

In the generalized polynomial chaos approach [1], the underlying random field is approximated by polynomials. The task is to compute the coefficients belonging to the polynomial basis. Two major approaches can be distinguished: In non-intrusive polynomial chaos methods, standard deterministic computations are carried out on prescribed integration nodes to determine the coefficients (left image). For intrusive polynomial chaos methods, in contrast, an orthogonal basis is chosen and a single fully coupled system of coefficients is solved for the whole stochastic domain (right image).

Aeroacoustics

Aeroacoustics studies the noise generated through pressure fluctuations in a flow field. Such flow induced noise emissions play an important role for various engineering applications such as jet screech, helicopters, new open rotor turbines and wind power plants. In the automobile industry the main aeroacoustic noise sources are the side mirrors and small cavities such as door gaps. Due to the overall noise reduction of cars, this tonal noise has become an important and active field of research.

Cavity Flow

In cavity flows, three types of noise sources can evolve due to the interaction of the incoming boundary layer and the cavity geometry. In the Helmholtz resonator, the mass within the cavity neck starts to oscillate excited by the random pressure fluctuations within a turbulent boundary layer. This oscillating volume generates a sound wave (left image). Pressure fluctuations within the turbulent boundary layer can resonate within the cavity, which results in standing waves (center image). A feedback loop evolves if the upstream traveling pressure wave, which results from the interaction of the shear layer and the trailing edge, perturbs the shear layer in such a way that a self-sustained oscillatory state is reached and noise is emitted from the trailing edge (right image).

Discontinuous Galerkin Software “Flexi”

All of these methods for the quantification of uncertainties need a robust and efficient deterministic flow solver. In this project we work with our in-house discontinuous Galerkin solver Flexi (open source: www.flexi-project.org), which has shown excellent performance in past aeroacoustics simulations.

References