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An efficient non-intrusive reduced basis approach for uncertainty quantification in CFD

Dinesh Kumar, Mehrdad Raisee and Chris Lacor
Fluid Mechanics and Thermodynamics Research Group,
Department of Mechanical Engineering, Vrije Universiteit Brussel,
Pleinlaan 2, 1050 Brussels, BELGIUM
chris.lacor@vub.ac.be

The main challenge industrial applications of uncertainty quantification (UQ) are facing, is the curse of dimensionality as a result of a large number of uncertainties; i.e. with increasing number of uncertain parameters the number of simulation calls increases exponentially. For uncertainty management and optimization of engineering products, it is necessary to include all sources of uncertainty in the simulations. This in turn can dramatically increase the computational cost and memory requirement which is undesirable for design purposes. From an industrial point of view, developing efficient reduced order models to reduce the computational cost and data storage is of great interest for the prediction of complex flows involving a large number of uncertain parameters.

To achieve this goal, within the framework of FP7 UMRIDA, we focused on the development of an efficient non-intrusive reduced basis approach for handling large number of uncertainties. The main idea is to extract the optimal orthogonal basis via cheap calculations on a coarse mesh and then use them for the fine scale analysis. The approach is developed within a non-intrusive polynomial chaos context based on regression.

To demonstrate the application and validity of the developed reduced basis model, it is applied to two CFD type applications. Firstly, the transonic flow over a 2D RAE2822 airfoil. Secondly, a 3D and more industrial type of application namely the NASA rotor 37, an isolated transonic axial flow compressor. In both test cases, geometrical uncertainties are considered. The results are compared with those of the standard polynomial chaos method.

The numerical experiments illustrate that the developed non-intrusive model reduction scheme for UQ has similar accuracy as the classical PC approach at a substantially reduced computational cost. It is also found that the memory requirement of the reduced-order model is much lower than that of the standard polynomial chaos method.