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SENSITIVITY ENHANCEMENT OF THE GENERALIZED POLYNOMIAL CHAOS FOR EFFICIENT OPTIMIZATION UNDER UNCERTAINTY

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Spectral uncertainty quantification (UQ) techniques based on the Generalized Polynomial Chaos (gPC) [1] compute statistics accurately, however their computational cost increases to intractable demands as the number of uncertain parameters increases, due to the curse of dimensionality. In this work, the gPC is augmented with a sensitivity enhancement term, computed via Lagrange multipliers, that computes the statistical moments with a first order accuracy, at a computational cost that is decoupled from the dimension of the stochastic space. The method is tested on a 2D, inviscid and transonic NACA0012 airfoil, the geometry of which is modeled by 38 uncertain and uncorrelated stochastic parameters. One direct and one adjoint evaluation are found to be enough to compute the moments of the lift coefficient, with errors smaller than 1% when compared to a Monte-Carlo simulation. For this case with 40 parameters, the computational cost of the sparse grid method of Smolyak Quadrature is found to be 200 times larger compared to its sensitivity enhanced counterpart. The method is also tested to various other applications that are commonly found in mechanic, and problems with up to 100 stochastic parameters are used as benchmark cases. Furthermore, if more uncertain parameters are to be added, the computational cost of the method does not scale This is a large deviation from other approaches, where it can be impossible to get estimations of statistics when the underlying problem is modelled by a large number of stochastic parameters.

The method is then extended to compute the statistics of the gradient of the objective function, allowing for a stochastic robust optimizer that has a computational cost that is decoupled from the dimension of the stochastic space. The hope of the authors is that this sensitivity-enhanced approach to UQ can UQ problems with a very high number of stochastic parameters computationally tractable. The method, referred to as the sensitivity enhanced gPC (se-gPC) can be extended to include higher order approximations of the statistics, at a computational cost that is state of the art but reliant to the dimension of the stochastic space.

REFERENCES

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