Gradient-based optimization under uncertainties applied to potential flow airfoil optimization using adjoint sensitivity analysis

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**ABSTRACT**

Optimization in engineering can be seen as a powerful tool to aid the engineers in the design process. In the first design iterations, several considerations are taken into account and requirements may vary quickly. At this stage, it is convenient to make use of accurate tools which require a low computational effort, allowing for fast decision-making in the design. In the context of aerodynamics, full-potential flow solvers stand as a fast and accurate option for subsonic and close to transonic flows. If combined with immersed or embedded methods, the resolution of the flow can be performed with almost no preprocessing effort, as the geometry can be described implicitly in a generic computational mesh.

Nonetheless, deterministic optimization may lead to unreliable solutions, as the optimal design obtained is valid only for a specific configuration of the input parameters. Robust optimization stands as an alternative, where uncertainties in the input parameters are taken into account by optimizing with respect to a risk measure of an underlying random quantity of interest. In aerodynamics, input uncertainties typically come from randomness in the operating conditions or in the geometry of the design. Random quantities of interest such as force or moment coefficients are considered. Candidates for the risk measure include the Conditional Value at Risk or the Mean-Variance risk measure.

In this document, a complete workflow for the optimization under uncertainties applied to airfoil optimization is presented. An embedded potential flow solver is employed to allow for fast resolution of the flow for any given geometry, where adaptive refinement is used to improve the description of the geometry. Sensitivity analysis is performed using the adjoint formulation of the solver, which allows to compute the sensitivity of a quantity of interest with respect to many geometry parameters simultaneously. Monte Carlo and Multi-Level Monte Carlo methods are exploited to estimate the sensitivity of the risk-measure with respect to design parameters for use in gradient-based algorithms for robust optimization. The combination is demonstrated on a problem of interest to the aerodynamics community.
REFERENCES


