CFD-CAA analysis & optimization methods, with industrial applications

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Smart **M**itigation of flow-induced **A**coustic **R**adiation and **T**ransmission for reduced **A**ircraft, surface tra**NS**port, **W**orkplaces and wind en**ER**gy noise

Host institution

National Technical University of Athens

Motivation

During the last decades, there have been tight regulations for noise pollution highlighting the importance of an effective noise source mitigation strategy. Numerical optimization methods should be employed to design quieter and more efficient products. **Adjoint-based optimization methods**, with a computational cost which is **independent of the number of design variables,** are already in use in Aerodynamics and should be extended in Aeroacoustics, too.

Research Objective

- Development of a **CAA tool,** based on **the Ffowcs Williams-Hawkings** (FW-H) analogy, coupled with the **GPU-enabled** compressible CFD solver of PCOpt/NTUA;
- Development of the **(continuous) adjoint to the coupled CFD-CAA** model;
- Validation of the proposed methods and the programmed software;
- Adaptation of the non-intrusive polynomial chaos approach **for UQ in CFD-CAA problems**.

Methodology

Acoustic pressure at receiver location is computed by the FW-H integral

$$H(f)\,\hat{p}'(\vec{x}_o,\omega) = -\oint_{f=0} \hat{F}_i(\vec{x}_s,\omega)\frac{\partial G(\vec{x}_o,\vec{x}_s,\omega)}{\partial x_{s_i}}ds - \oint_{f=0} i\,\omega\,\hat{Q}(\vec{x}_s,\omega)\,G(\vec{x}_o,\vec{x}_s,\omega)ds$$

Continuous adjoint is developed for an objective function as the total energy contained in the spectrum of the sound pressure. $J = \int_{\omega} |\hat{p}'(\omega)|\,d\omega$

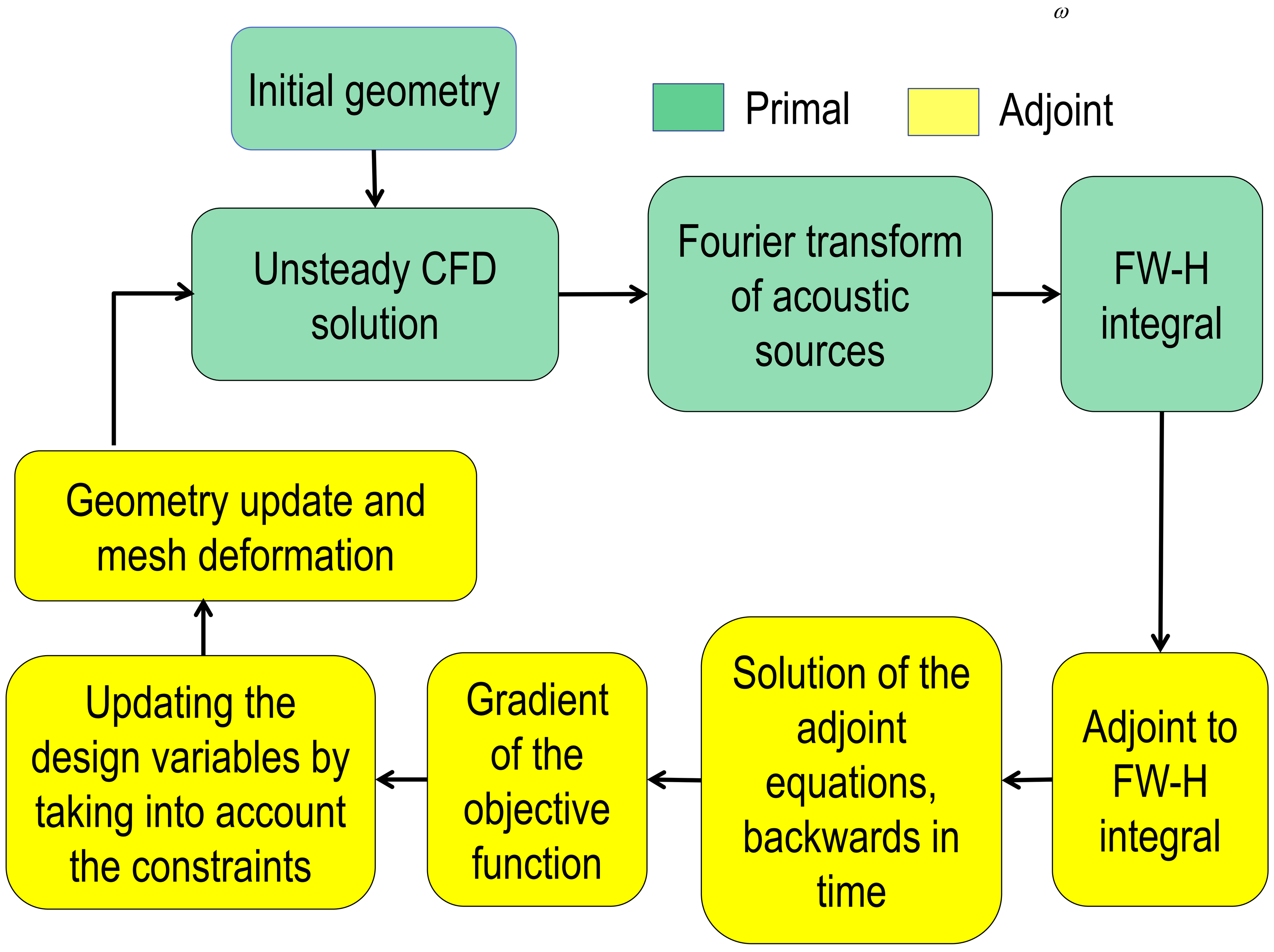

Fig. 1: Work flow of the aeroacoustic shape optimization

Optimization Results

Laminar vortex shedding cylinder (Mach=0.2, Re=1000)

Objective function is defined over 4 receiver locations at almost 21 diameters away from the cylinder.

A minimum volume constraint is considered for optimization.

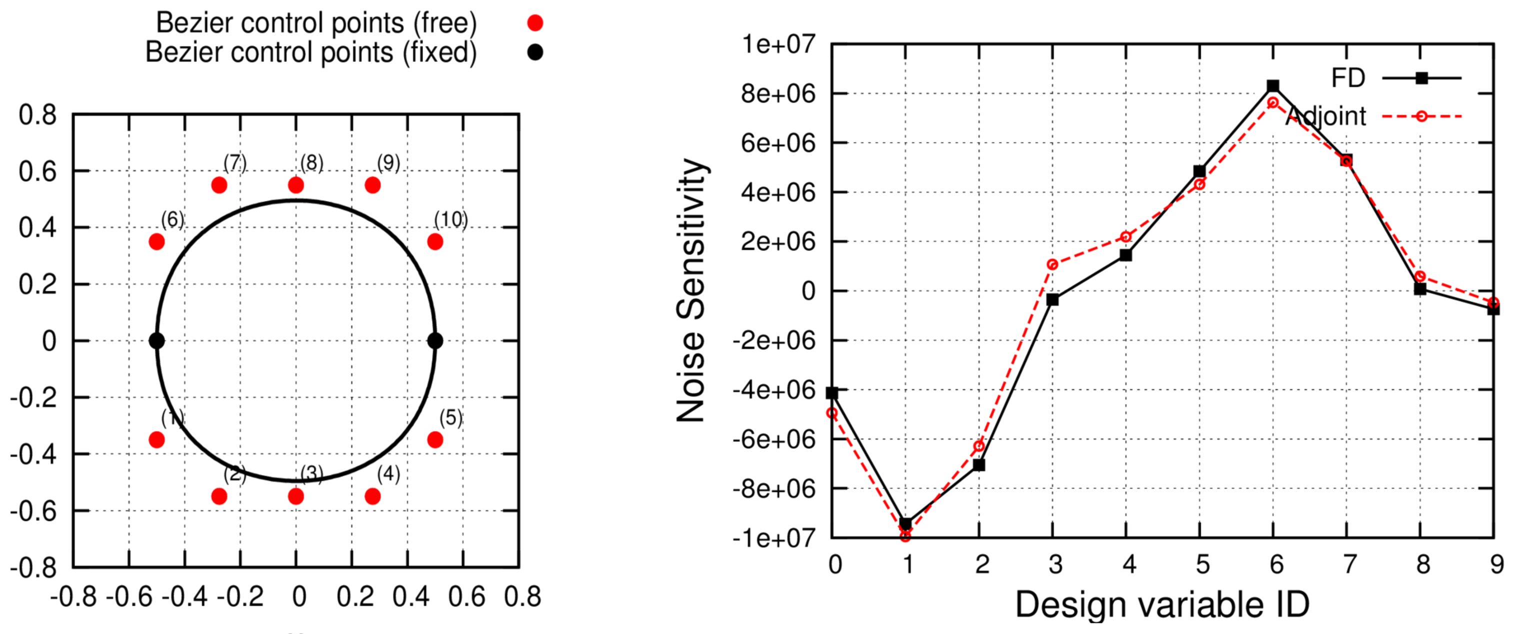

Fig. 2: Parameterization using Bezier curve (left) Good agreement between the adjoint and finite difference gradients (right).

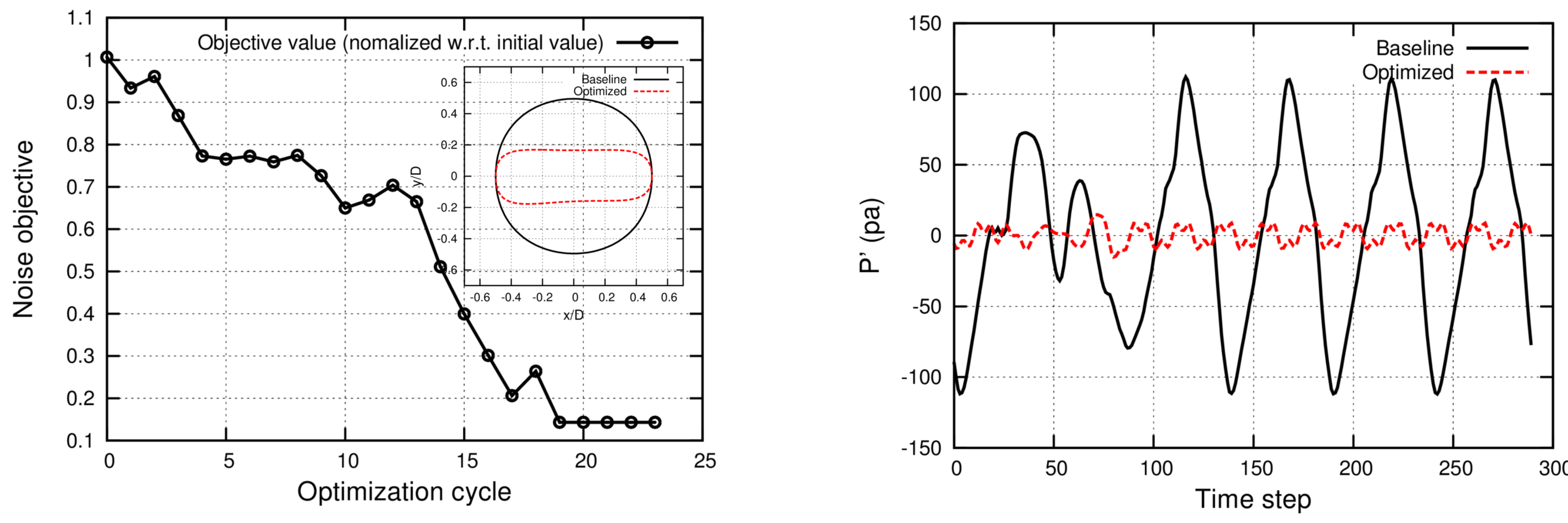

Fig. 3: Convergence of the objective function and geometry after reaching the minimum volume constraint (left). Reduction of fluctuations in the optimized geometry (right).

Rod-airfoil benchmark (Mach=0.2, $Re_{chord} = 4.8\times10^5$)

Receiver is located 1.85m on the top of the mid-chord of the airfoil.

No constraint is applied during the optimization.

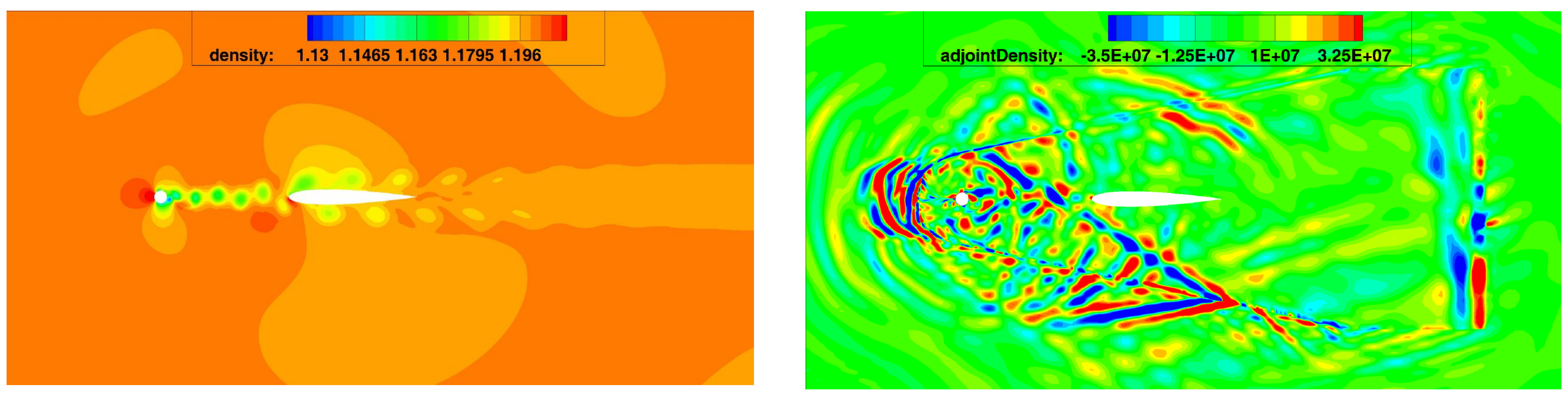

Fig. 4: Density contour (left). Adjoint density contour (right).

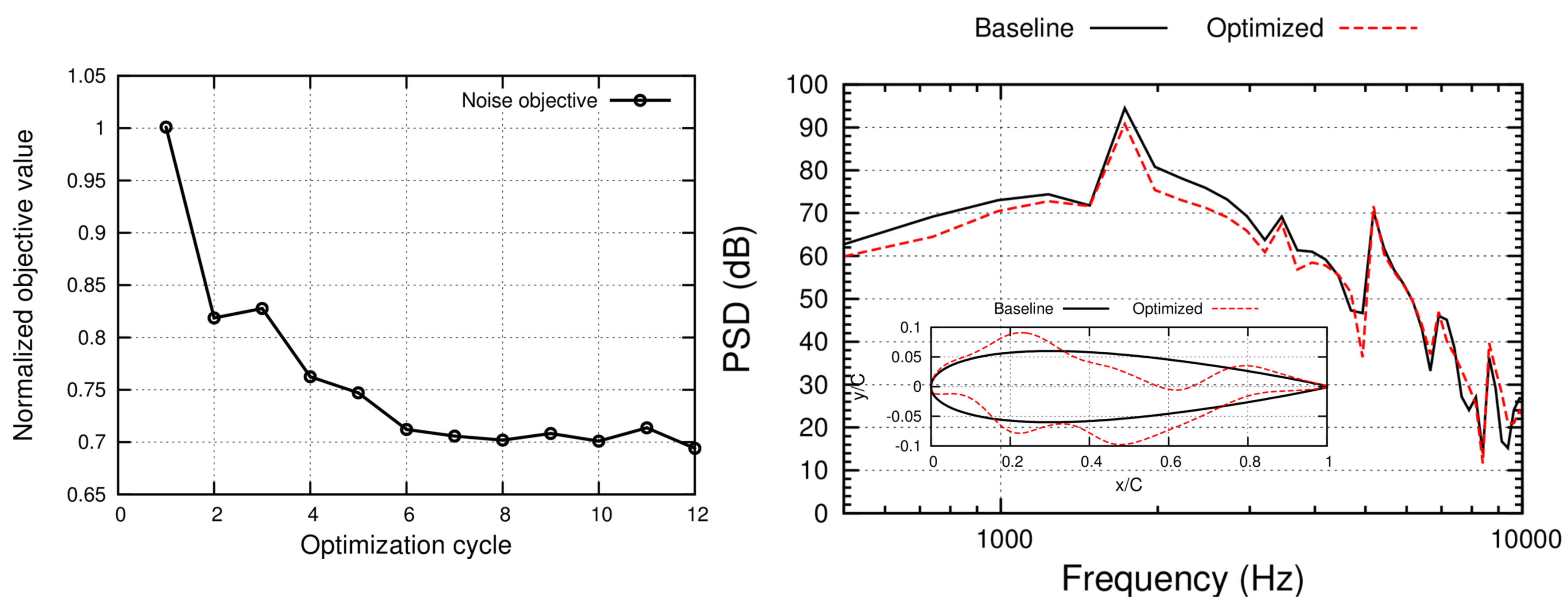

Fig. 5: Convergence of the objective function (left). Comparison of the PSD plot of the sound pressure between the baseline and optimized geometry (right).

References

[1] Lockard, David P. "An efficient, two-dimensional implementation of the Ffowcs Williams and Hawkings equation." Journal of Sound and Vibration 229, no. 4 (2000): 897-911.

[2] Monfaredi et al. "An unsteady aerodynamic/aeroacoustic optimization framework using continuous adjoint." EUROGEN Conf. Guimarães, Portugal, 2019

MARIE CURIE ACTIONS

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