



NATIONAL TECHNICAL UNIVERSITY OF ATHENS

**Parallel CFD & Optimization Unit
Laboratory of Thermal Turbomachines**

Robust Design

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(Second-Order, Second-Moment, SOSM, approach)

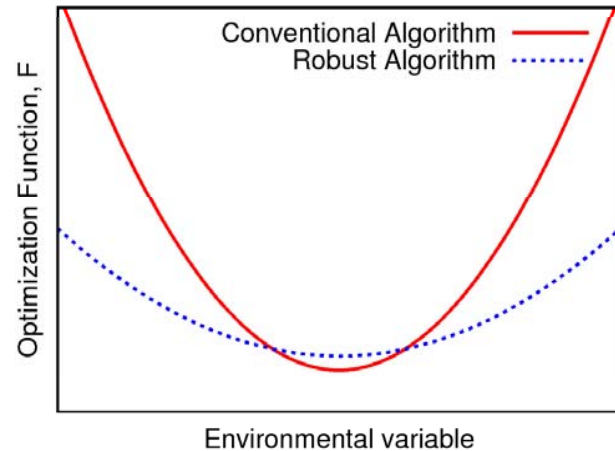
For **N** design (**b_i**) & **M** environmental (**c_i**) variables, minimize

$$\hat{F} = \hat{\mu}_F + k\hat{\sigma}_F$$

where the estimated mean and the standard deviation of **F** are given by

$$\hat{\mu}_F = F_D + \frac{1}{2} \left[\frac{d^2 F}{dc_i^2} \right]_D \sigma_i^2$$

$$\hat{\sigma}_F = \sqrt{\left[\frac{dF}{dc_i} \right]_D^2 \sigma_i^2 + \frac{1}{2} \left[\frac{d^2 F}{dc_i dc_j} \right]_D^2 \sigma_i^2 \sigma_j^2}$$



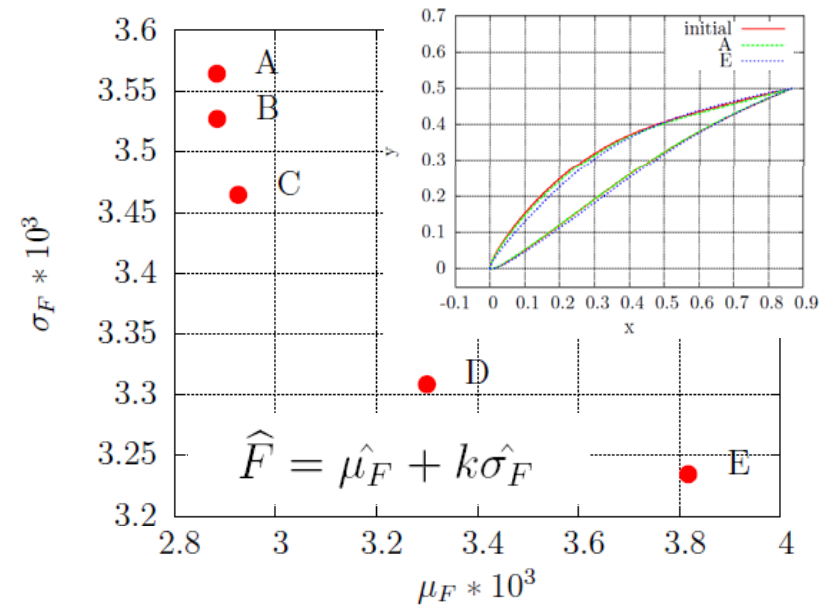
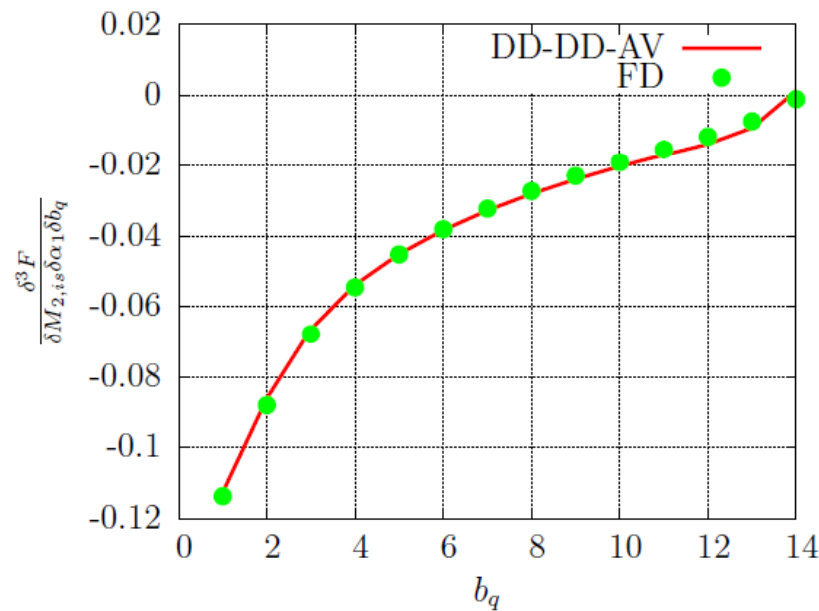
$$\frac{d\hat{F}}{db_l} = \frac{dF}{db_l} + \frac{1}{2} \frac{d^3 F}{dc_i^2 db_l} \sigma_i^2 + k \frac{2 \frac{dF}{dc_i} \frac{d^2 F}{dc_i db_l} \sigma_i^2 + \frac{d^2 F}{dc_i dc_j} \frac{d^3 F}{dc_i dc_j db_l} \sigma_i^2 \sigma_j^2}{2 \sqrt{\left[\frac{dF}{dc_i} \right]_D^2 \sigma_i^2 + \frac{1}{2} \left[\frac{d^2 F}{dc_i dc_j} \right]_D^2 \sigma_i^2 \sigma_j^2}}$$

► The recommended approach, if **M << N**,

DD_c-DD_c-AV_b

exists and has been programmed in both discrete and continuous adjoint.

Robust Design



Robust design of a compressor cascade: Two environmental variables: $M_{2, is}$ and α_1 .

E.M. PAPOUTSIS-KIACHAGIAS, D.I. PAPADIMITRIOU, K.C. GIANNAKOGLU: 'Robust Design in Aerodynamics using 3rd-Order Sensitivity Analysis based on Discrete Adjoint. Application to Quasi-1D Flows', International Journal for Numerical Methods in Fluids, Vol. 69, No. 3, pp. 691-709, 2012.

E.M. PAPOUTSIS-KIACHAGIAS, D.I. PAPADIMITRIOU, K.C. GIANNAKOGLU: Discrete and Continuous Adjoint Methods in Aerodynamic Robust Design problems, CFD and Optimization 2011, ECCOMAS Thematic Conference, Antalya, Turkey, May 23-25, 2011.