Structure Exploitation in Aerodynamic Shape Optimization

Stephan Schmidt[1], **Caslav Ilic**[2], **Volker Schulz**[3]

[1]University Trier, Universitätsring 15, 54296 Trier, Germany, Stephan.Schmidt@uni-trier.de
[2]German Aerospace Center (DLR), Lilienthalplatz 7, 38108 Braunschweig, Germany, caslav.ilic@gmx.net
[3]University Trier, Universitätsring 15, 54296 Trier, Germany, Volker.Schulz@uni-trier.de

Keywords: aerodynamic shape optimization, parameterization, Hicks-Henne functions, fast optimization, SQP, OneShot optimization

1. Introduction

Recent advances in optimization have reduced the numerical costs of aerodynamic shape optimization considerably. By coupling the optimization with the iterative flow solver in a so called OneShot-Strategy, the cost of the optimization has been reduced to be comparable to a few forward simulation runs. To decrease the costs even further, these studies are now extended to the parameterization of the shape of the aircraft.

Given the background of fast optimization (Gherman and Schulz, 2005), both the convergence speed and the best obtainable optimum solution have to be considered. Because of the conflicting nature of these two criteria, local adaptivity using hierarchical and multi-level parameterizations will be inspected. Out of the multitude of possible parameterizations (nurbs, B-splines, free-form-deformation, ...), special attention is given to the parameterization via Hicks-Henne basis functions. This form of parameterization - which is very often applied in the aerospace industries - possesses inherent smoothing properties, which leads to the surprising behavior of less optimization iterations with more design parameters.

By using an adjoint approach (Gauger, 2003) for the computation of the gradients, the cost does not scale with the number of design parameters. Therefore, a combination of a OneShot optimization strategy (Hazra and Schulz, 2004, 2005) with a high number of Hicks-Henne functions (Hicks and Henne, 1978) and adjoint based gradients produces a very fast optimization routine.

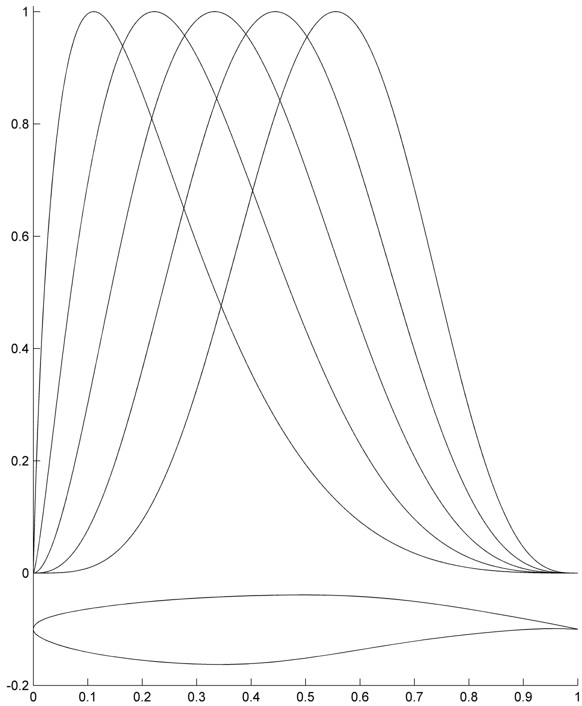

Fig. 1. Hicks-Henne parameterization with 5 basis functions

2. Parameterizations

Out of the multitude of possible parameterizations, special attention is given to the Hicks-Henne functions on the one hand and a free node parameterization on the other hand, because of

- frequent industrial applications
- decrease in optimization iterations with increasing number of design parameters

Here, local adaptivity is a major issue:

Given the optimum solution q_1 of a coarse parameterization level $q_1 \in \mathbb{R}^{n_{q_1}}$, one can reinterpret this as the optimum solution $q_2 = [q_1, \hat{q}]^T$ of a finer level with the additional constraint of $\hat{q} = 0$. The Lagrange-Multiplier of this additional constraint, also known as the ”shadow price”, can then be used as a measurement of local adaptivity of the design space. By the use of an adjoint based gradient, this technique has proven to be computationally cheap, since the gradient evaluation on the finer level does not require any new flow solutions.

Using this technique, it is shown, that for the best obtainable optimum solution for the 2D RAE2822 airfoil, as few as 4-5 strategically well placed Hicks-Henne functions are already sufficient.

3. CONCLUSIONS

The parameterization has a major impact on both algorithmic performance and the quality of the obtainable optimum solution. Because of the inverse behavior of the number of design parameters and optimization iterations needed, special attention is given to the Hicks-Henne parameterization and its smoothing properties. Using a hierarchical parameterization with an artificial ”parameterization constraint”, local adaptivity using shadow prices will be shown.

REFERENCES

Gauger, N.R. (2003): Das Adjungiertenverfahren in der aerodynamischen Formoptimierung. Forschungsbericht Deutsches Zentrum für Luft- und Raumfahrt e.V.

Gherman, I. and Schulz, V. (2005): Preconditioning of One-Shot Pseudo-Timestepping Methods for Shape Optimization. PAMM Vol. 5(1), 741 - 742

Hazra, S.B. and Schulz, V. (2004): Simultaneous Pseudo-Timestepping for PDE-Model based Optimization Problems. BIT Numerical Mathematics 44: 457-472

Hazra, S.B. and Schulz, V. (2005): How to profit from Adjoints in One-Shot Pseudotime-Stepping Optimization. Evolutionary and Deterministic Methods for Design, Optimization and Control with Applications to Industrial Problems, EUROGEN 2005

Hicks, R.M. and Henne, P.A. (1978): Wing Design by Numerical Optimization. Journal of Aircraft vol 15, 407-412