Node-based aerostructural shape optimization in wing preliminary design

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**Topic**
Topic of the dissertation is the shape optimization of structures whose behavior is primarily defined by a surrounding fluid flow. Particular application is the wing of an aircraft. Driving objective is the minimization of the aircraft’s fuel consumption which to a great extend depends on the shape of each wing. In this context the research focuses on the development of relevant computational shape optimization methods which, compared to state-of-the-art solutions, are expected to provide significantly higher design freedom and greater optimization potential. The results may be applied in the wing preliminary design phase.

Key technology is a node-based approach in which the wing shape is controlled using the given model discretization instead of an additional, possibly restricting parameterization. Another key element is the consequent coupled consideration which accounts for the natural interaction between the different disciplines involved, i.e. the structure and fluid mechanical problem. The research hence follows the well-known field of Multidisciplinary Design Optimization (MDO) in general and aerostructural shape optimization in particular [1, 2].

The goal of MDO is to coordinate the individual disciplines affecting the design towards a system design that is optimal as a whole. Following this idea, the research is part of a European project on aerospace multidisciplinary design optimization (www.amedeo-itn.eu) and funded by the European Commission in the framework of a Marie Curie fellowship.

**Methods**
To handle the large number of design variables, gradient-based optimization together with coupled adjoint sensitivity analysis is used. For shape control and mesh regularization the node-based Vertex Morphing Method is applied [3,4].
Vertex Morphing is based on a powerful filtering technique, which allows to conveniently explore the design space. This yields a high design freedom with great optimization potential.

The coupled physical problem is modelled using high-fidelity models. As common practice, a steady-state assumption is introduced. The coupled analyses are carried out in a partitioned manner within a co-simulation environment. Different state-of-the-art solution strategies are used in this context such that accuracy and computational costs are reasonably balanced.

To realize the complete optimization process a software framework including both in-house, proprietary and open-source software is developed. By incorporating in-house tools and open-source software, full access to fundamental parts of the simulation code is guaranteed. The latter is a prerequisite for the method development in the scope of this work.

The combination of all methods will eventually allow to perform aerostructural shape optimization at large-scale wing structures whereas a great design freedom may be employed. An example for a drag-optimized aircraft with forward-swept wings is shown in figure 1. Follow-up work will focus on reconstructing a CAD-model of the discrete shapes obtained in the above optimization process.

Fig. 1: Optimized surface pressure leading to a decreased drag of a forward-swept wing aircraft.

References


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