DESIGN OF MORPHING WING STRUCTURES BY TOPOLOGY OPTIMIZATION

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The desire for true multi-mission capability in military and civil air vehicle systems has created a need for technologies that allow for drastic changes in the shape of wings during flight. As most aircraft are fixed-geometry, they represent a design compromise between conflicting performance requirements in mission segments such as high-speed cruise, low-speed loiter, and low turn radius maneuver. Through morphing, the aerodynamics of the aircraft can be adapted to optimize performance in each segment by changing, for example, the camber of the airfoils and the twist distribution along the wing. While the optimal aerodynamic configuration can be determined by state-of-the-art aerodynamic design optimization techniques for each mission segment individually, design of the internal structure and mechanisms to achieve the required configurations poses a new challenge to the design community.

The design problem is mainly complicated by the conflicting design requirements, and the fact that the overall performance is dominated by aeroelastic effects. In order to reduce the actuation energy required to change the shape of the wing, the stiffness of the supporting structure including skin and spars should be as small as possible. This, however, may lead to unfavorable aeroelastic behavior with large displacements that affect the aerodynamic characteristics.

In order to find an optimal actuation mechanism, we propose a novel topology optimization approach accounting for the aeroelastic response of the wing structure. This approach allows for simultaneous design of the mechanism and support structures under aerodynamic loads with respect to structural and aerodynamic design criteria. We present a computational framework that integrates a high-fidelity nonlinear aeroelastic model into material-based topology optimization for the design mechanisms. The structure is modeled by geometrically nonlinear finite element methods to account for large displacements. The aerodynamic loads are predicted by a finite volume discretization of the Euler flow.

The proposed approach is verified with the design of a morphing wing represented by a two-dimensional airfoil section. Alternative formulations of the optimization problem in terms of objective and constraints will be discussed and the influence of different actuation inputs will be demonstrated.