DISCRETE ADJOINT SENSITIVITIES IN OPENFOAM

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The adjoint method enables the use of gradient-based optimization methods for problems with a high input dimension n (such as topology / shape optimization, reverse parameter estimation) by reducing the complexity to obtain a full gradient from $O(n)$, which one would see using a classical approach like finite differences, to $O(m)$ where m corresponds to the dimension of the cost function which is to be optimized (often $m = 1$, e.g. the lift over a wing). The adjoint method has been a focus of research in the (CFD-) optimization community for several years [1, 2, 3]. It can either be implemented in a continuous or discrete fashion. The continuous way involves analytically developing and solving additional adjoint equations alongside the primal equations [4]. The discrete way works on a source code level by algorithmic differentiation (AD), by using either source code transformation or an operator overloading approach [5].

A very basic continuously differentiated solver called *adjointShapeOptimizationFoam* is already included in OpenFOAM, but it lacks the flexibility with respect to different cost functions and physical models (e.g. including different turbulence models, calculating compressible flows, heat transfer...) a discrete adjoint implementation has to offer. Furthermore with AD also higher order derivatives (e.g. Hessians) can be obtained at reasonable cost which might for example be needed for robust optimization.

We present a discrete adjoint approach we implemented in OpenFOAM-3.0.x [6, 7] and foam-extend-3.1 [8] which allows calculating derivatives of a cost functional with respect to arbitrary quantities. The discrete adjoint is obtained through AD by operator overloading. This enables the computation of exact derivatives (with machine precision) by overloading the basic arithmetic operations with a custom data type. We are working on an open-source release for our framework and thus want to contribute to the FOAM community.

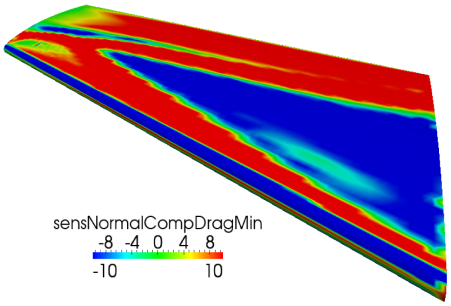

Figure 1: Surface Sensitivities of a OneraM6 wing with respect to drag

In our talk we will focus on how to benefit from and apply these capabilities from a users point of view. Solvers for performing topology and shape optimization (see figure 1) are implemented in our framework and will be presented by us. The mentioned methods are applicable to a wide range of problems from industry and academia in the fields of automotive and aerospace design, process and chemical engineering, turbomachinery and other fields which need precise derivative information.

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