Fluid Optimisation Workflows for Highly Effective Automotive Development Processes

Shape optimisation for CFD problems in the automotive industry

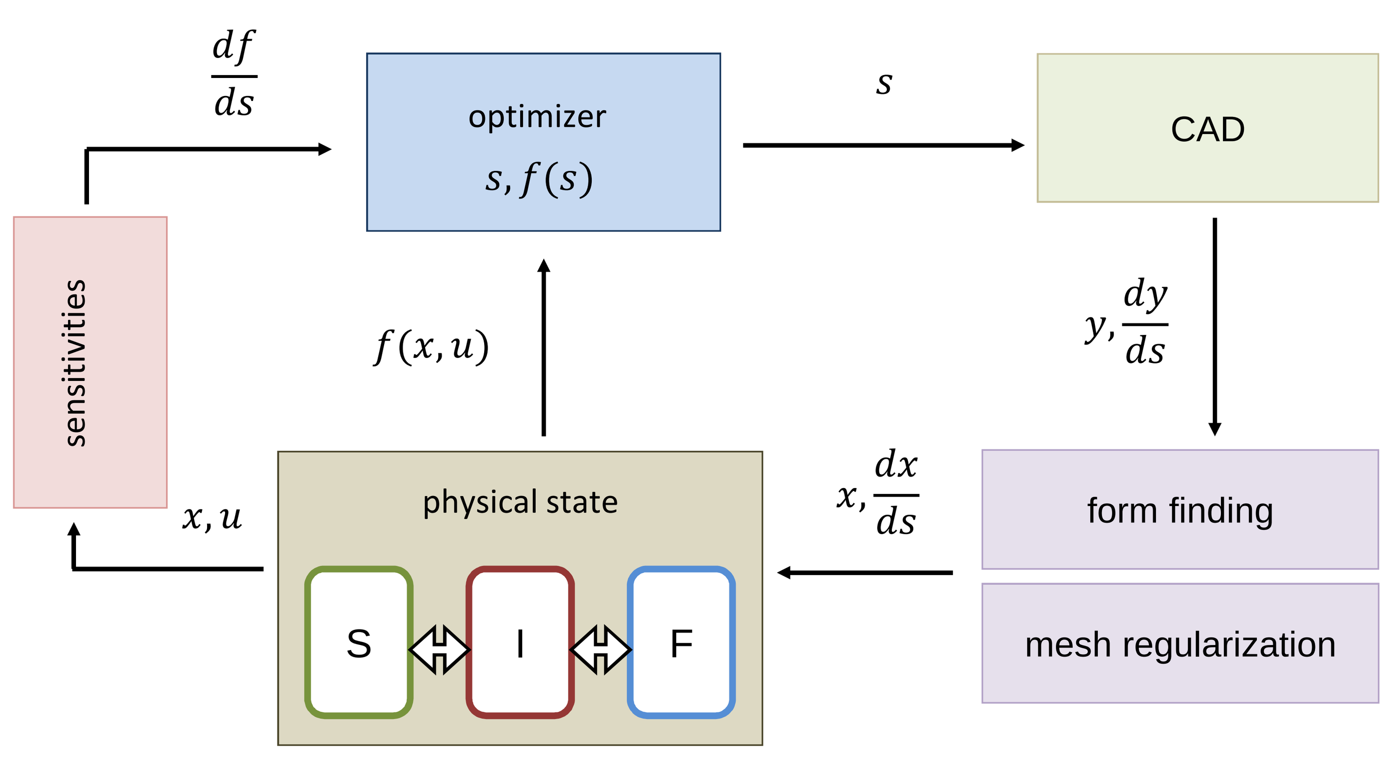
Electra Stavropoulou, Majid Hojjat, Kai-Uwe Bletzinger

FLOWHEAD is a 'small to medium size focused research project' funded by the European Commission with the goal to develop adjoint-based optimization methods for shape and topology optimization of fluid flow with application to the automotive industry. In this context, TUM has developed a modular and automated parameter-free shape optimization framework using adjoint sensitivities. Furthermore, the in-plane and out-plane mesh regularization methods required for this type of problem were developed. TUM verified the success of the shape parameterization and the regularization techniques through its internal workflow consisting of in-house optimization software CARAT and OpenFOAM for the primal and adjoint flow solution.

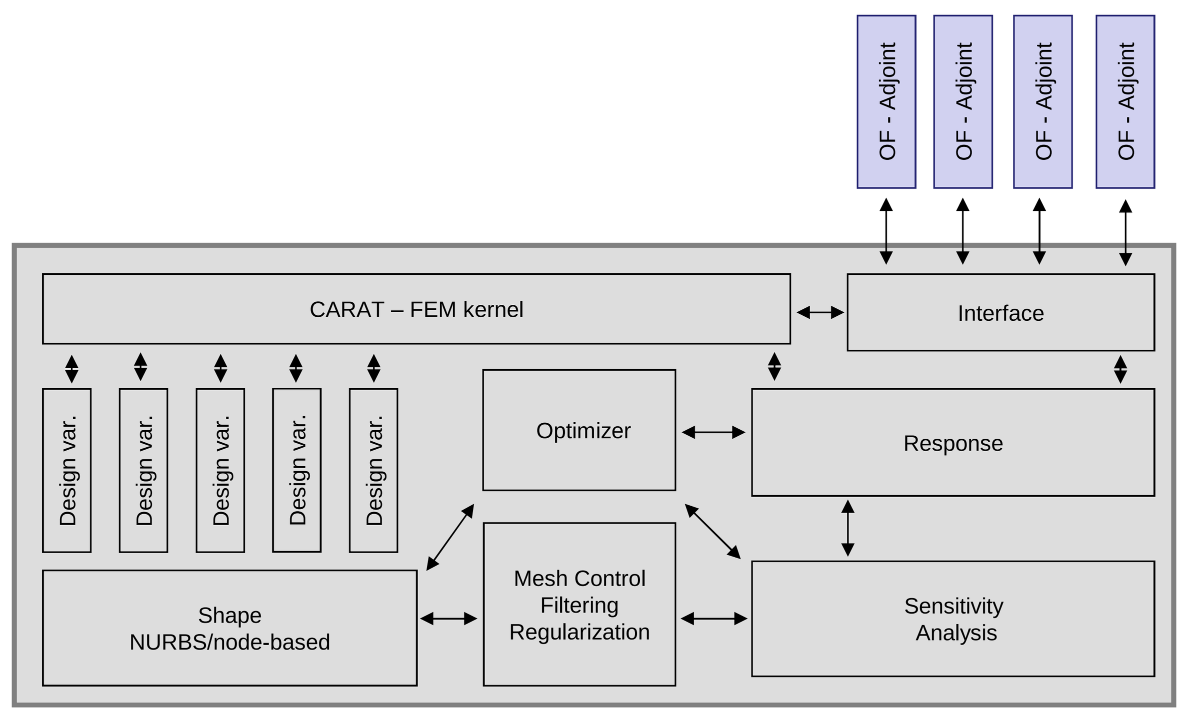
Shape optimization Workflow:

Based on the chain rule of differentiation, the workflow is designed in separate modules with clear input and output.

OpenFOAM, as a black-box adjoint solver is coupled to CARAT. Shape parameterization and the evaluation of shape variations in each optimization step is performed within CARAT's optimization workflow. This structure allows for parallelization and thus shape optimization of real industrial problems.



Shape optimization workflow



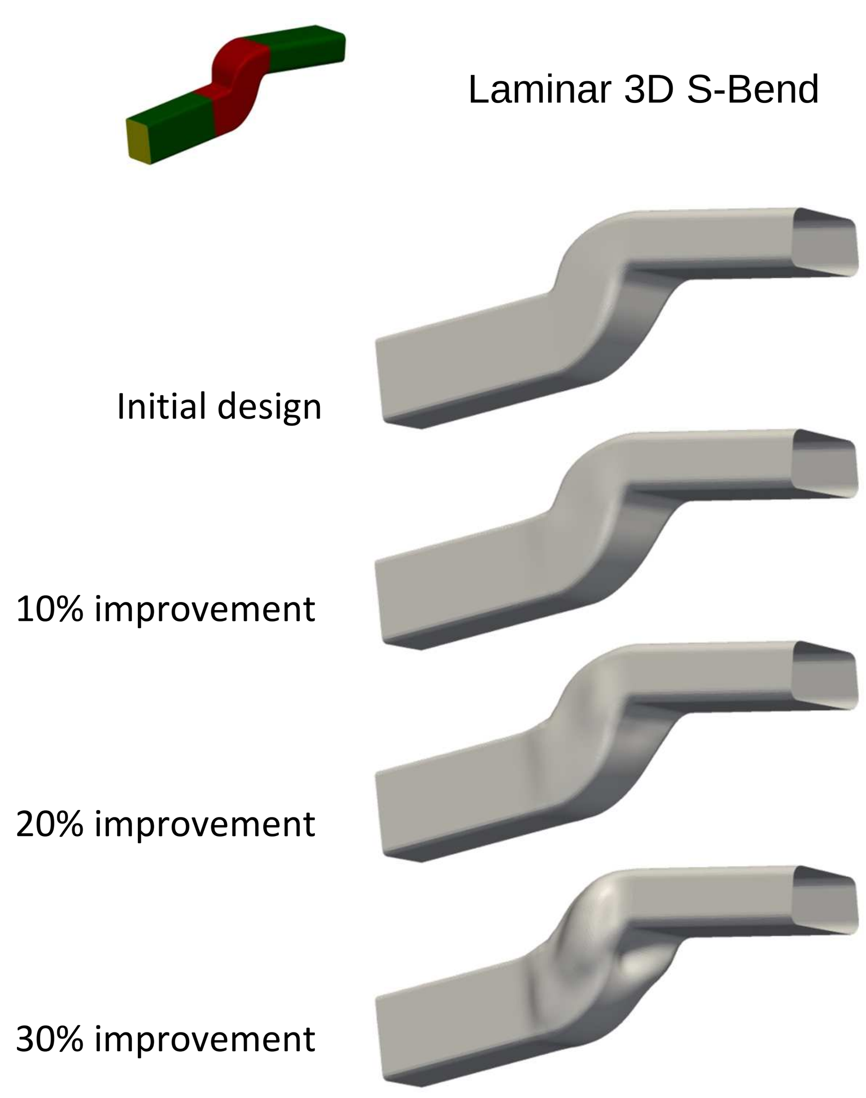
CFD shape optimization framework, CARAT

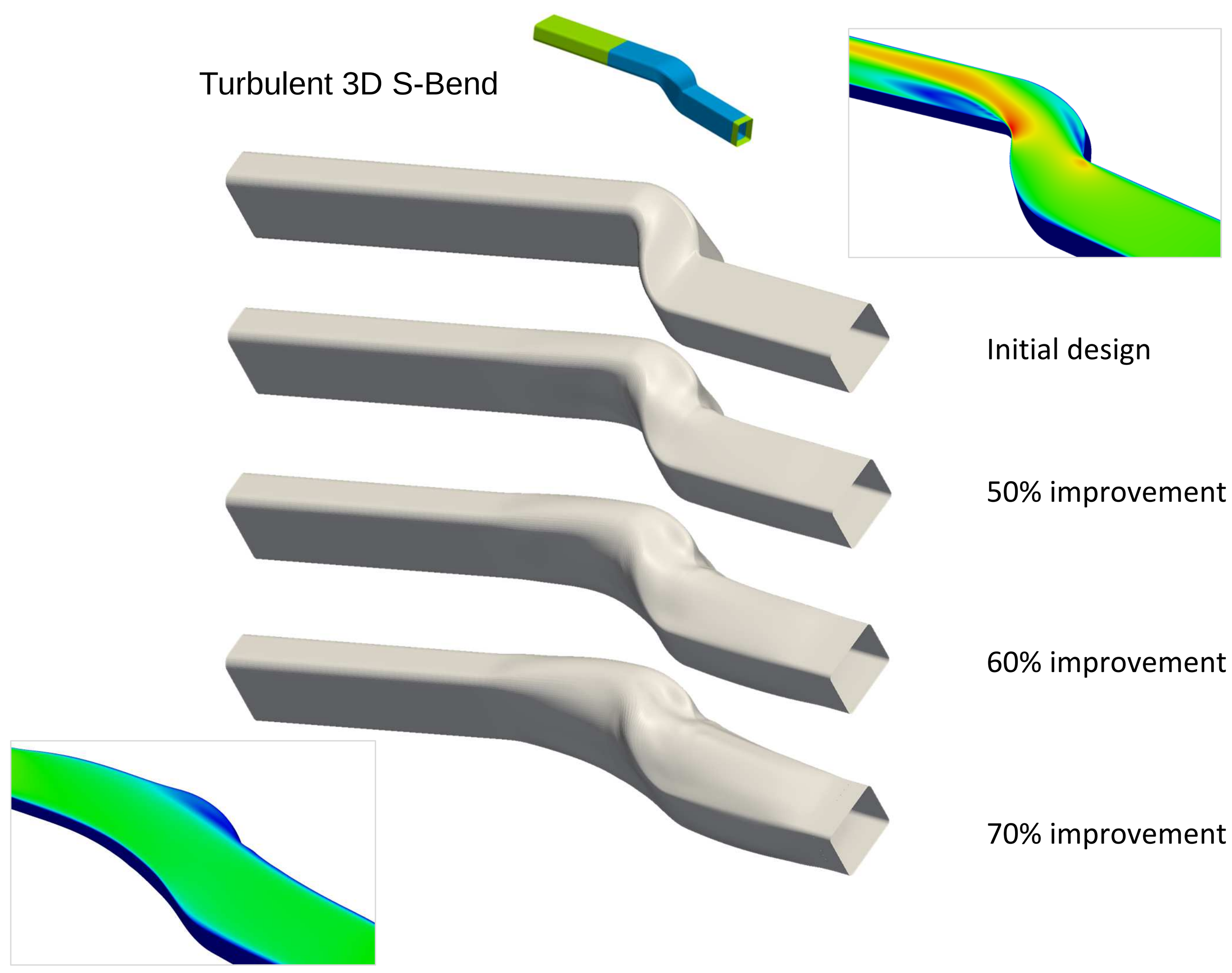
Node-based shape description:

Position of each surface discretization point is regarded as a shape parameter. Very large design space and independency of CAD models are advantages of this method.

In and out of plane regularization techniques for the surface mesh control were developed and integrated to the framework.

Several test cases proved the success of the method, e.g. laminar and turbulent 3D S-Bends. Smoothness and mesh quality of the surface is maintained even in large shape variations. Notable reduction of the target function was observed.



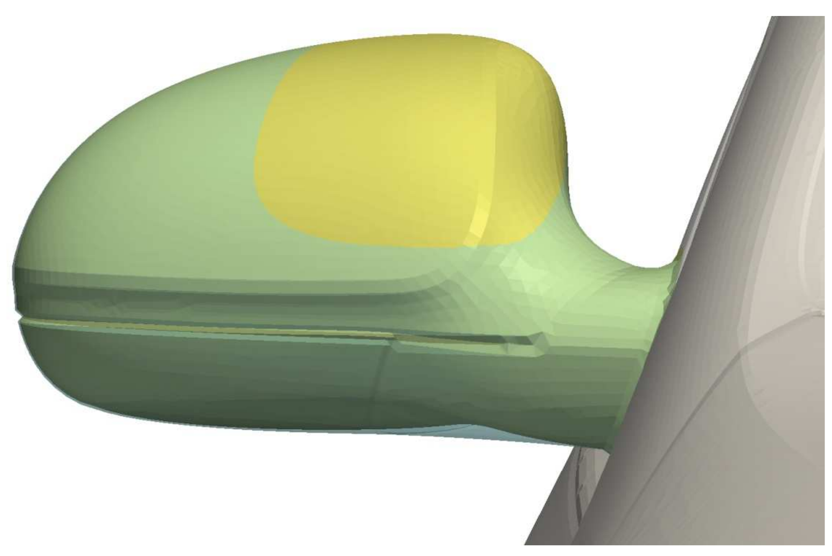


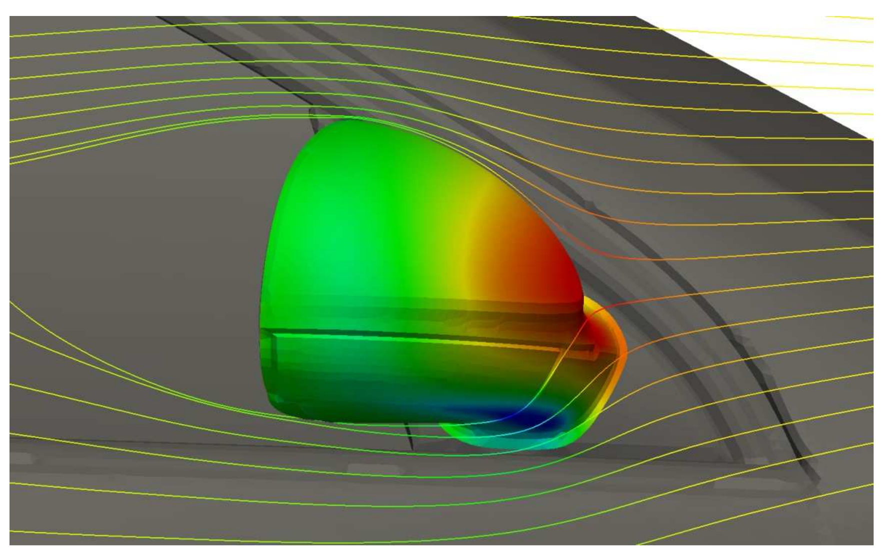
Automotive industry application:

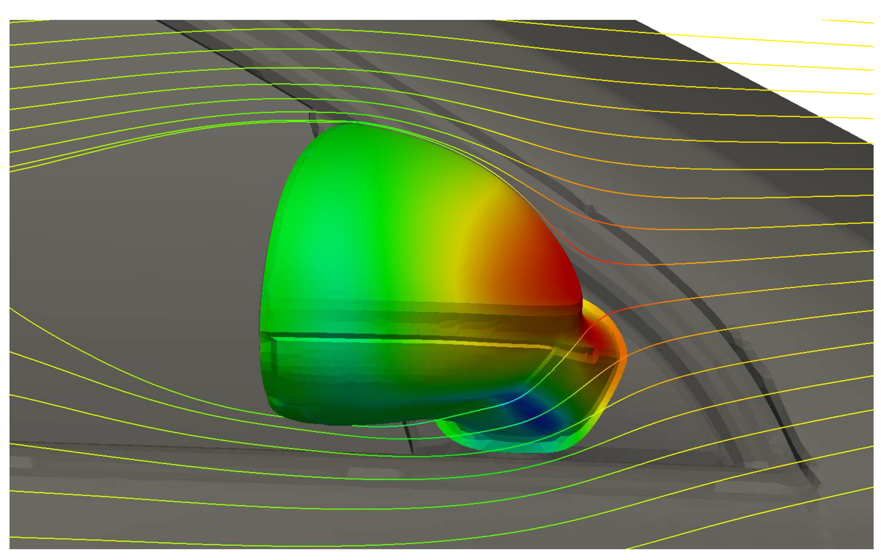
The workflow has been used for CFD shape optimization of industrial cases with up to 25 million finite volume cells, and up to around 1 million design variables. The optimization time has been less than the computation time for the convergence of physical and adjoint problems.

Different body parts of a car, e.g. the side mirrors were optimized to reduce the drag on the full car. The developed shape parameterization maintains design feature lines which is desired for automotive industry.

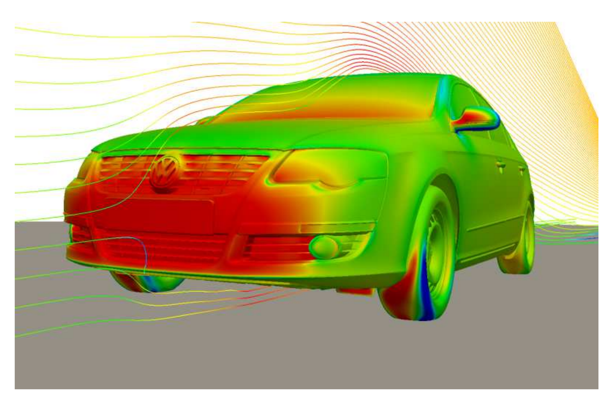
Even though in some cases the geometry variation increases the drag on the design patch, the overall drag as the cost function is always decreased.







Optimized part	Drag change on mirror (%)	Drag change on car body (%) (excluding mirror)	Drag change on whole car (%)
Whole mirror	-7.0%	-0.2%	-0.6%
The back patch	+4.0%	-0.2%	-0.2%



Side mirrors of VW Passat

Top left:

improved mirror (solid yellow) Vs. initial design (transparent blue)

Middle:

Velocity streamlines and pressure contours on initial (top) and improved design (bottom)