Fluid Optimisation Workflows for Highly Effective Automotive Development Processes

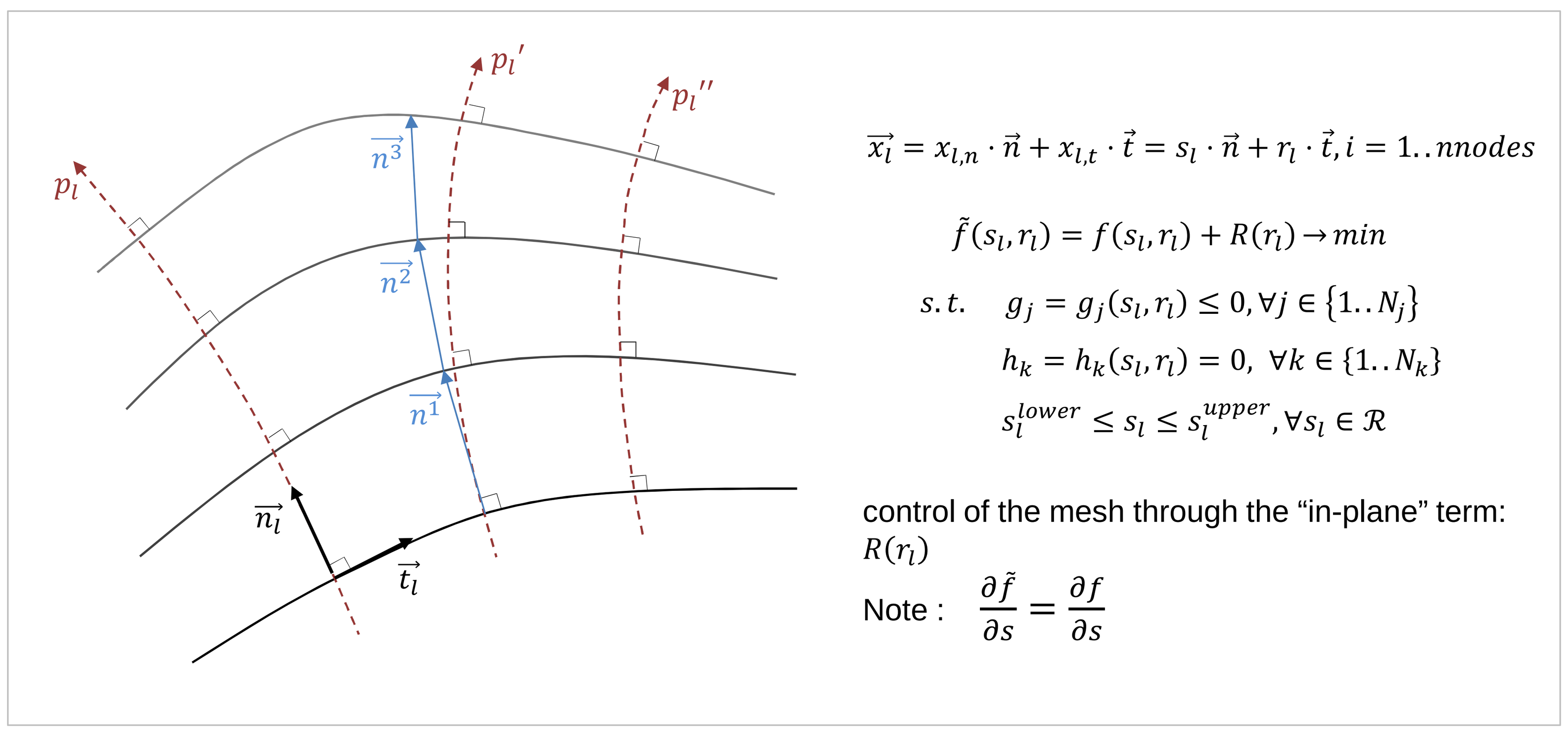
Shape optimisation for CFD problems in the automotive industry

Majid Hojjat, Electra Stavropoulou, Kai-Uwe Bletzinger

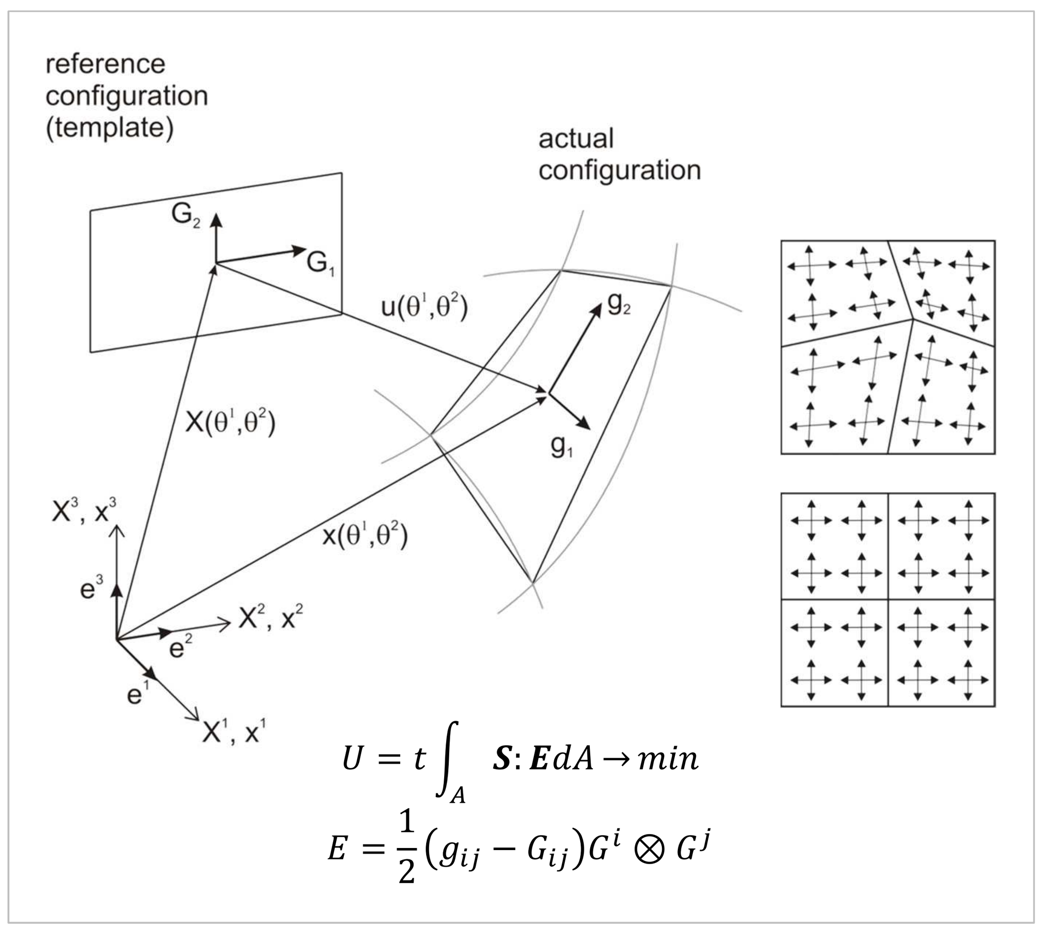
FLOWHEAD is a 'small to medium size focused research project' funded by the European Commission with the goal to develop adjoint-based optimization methods for shape and topology optimization of fluid flow with application to the automotive industry. In this context, TUM has developed a modular and automated 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. The in-plane regularization assures the quality of the surface mesh through the shape evolution. The developed regularization method is mechanically motivated and has the computational cost of a solution of one linear system.

The augmented optimization problem:

In order to control the surface mesh quality in node-based shape optimization the optimization problem is modified by an additional term called in-plane regularization. Altering the surface points in the tangential direction, this term is responsible only for maintaining the discretization quality throughout the optimization process.



The augmented optimization problem

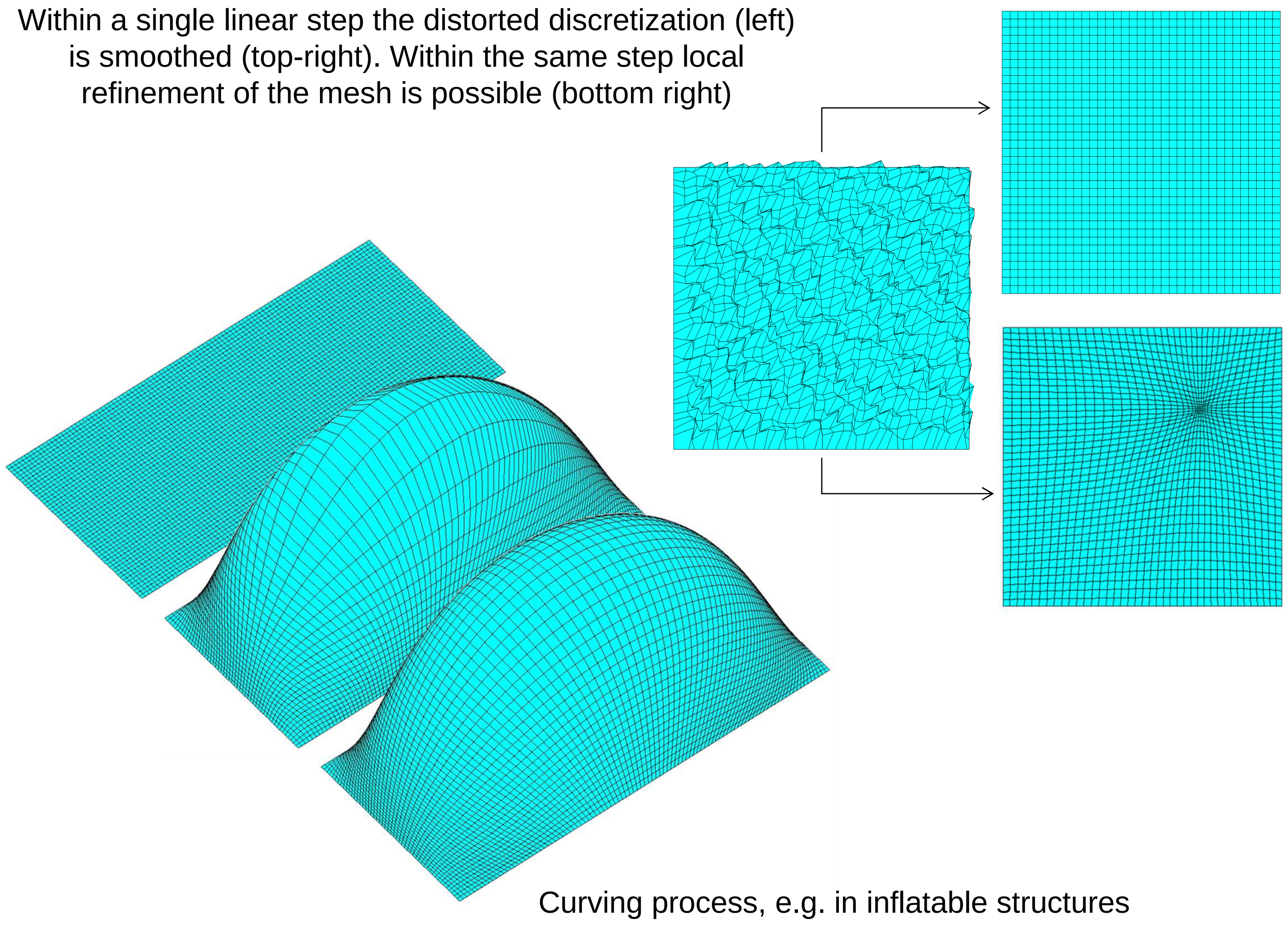


The in-plane regularization method:

The developed in-plane regularization is a global method for smoothing the surface mesh to a desired condition.

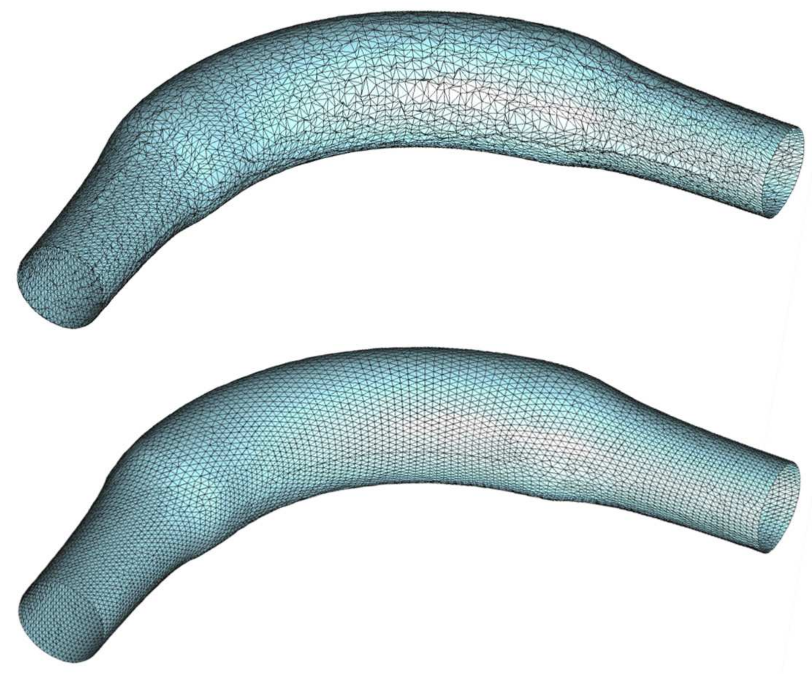
In this method an artificial stress field is applied on the surface or on the volume mesh and using finite elements a global linear system for equilibrium is solved. The applied stress adapts each element toward an ideal predefined template geometry and at the end a globally smooth mesh is achieved. In this way both the shape and the size of each element is effectively controlled.

Within a single linear step the distorted discretization (left) is smoothed (top-right). Within the same step local refinement of the mesh is possible (bottom right)



Curving process, e.g. in inflatable structures

A flat plate (top left) has been inflated without (middle figure) and with (right bottom) in-plane regularization.

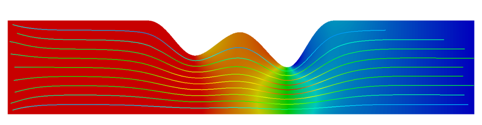


Mesh noise removing:

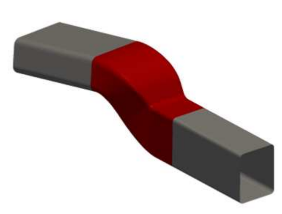
Regularization of a 3D noisy triangular surface mesh (top) with equilaterals as template to a regular mesh (bottom)

CFD shape optimization:

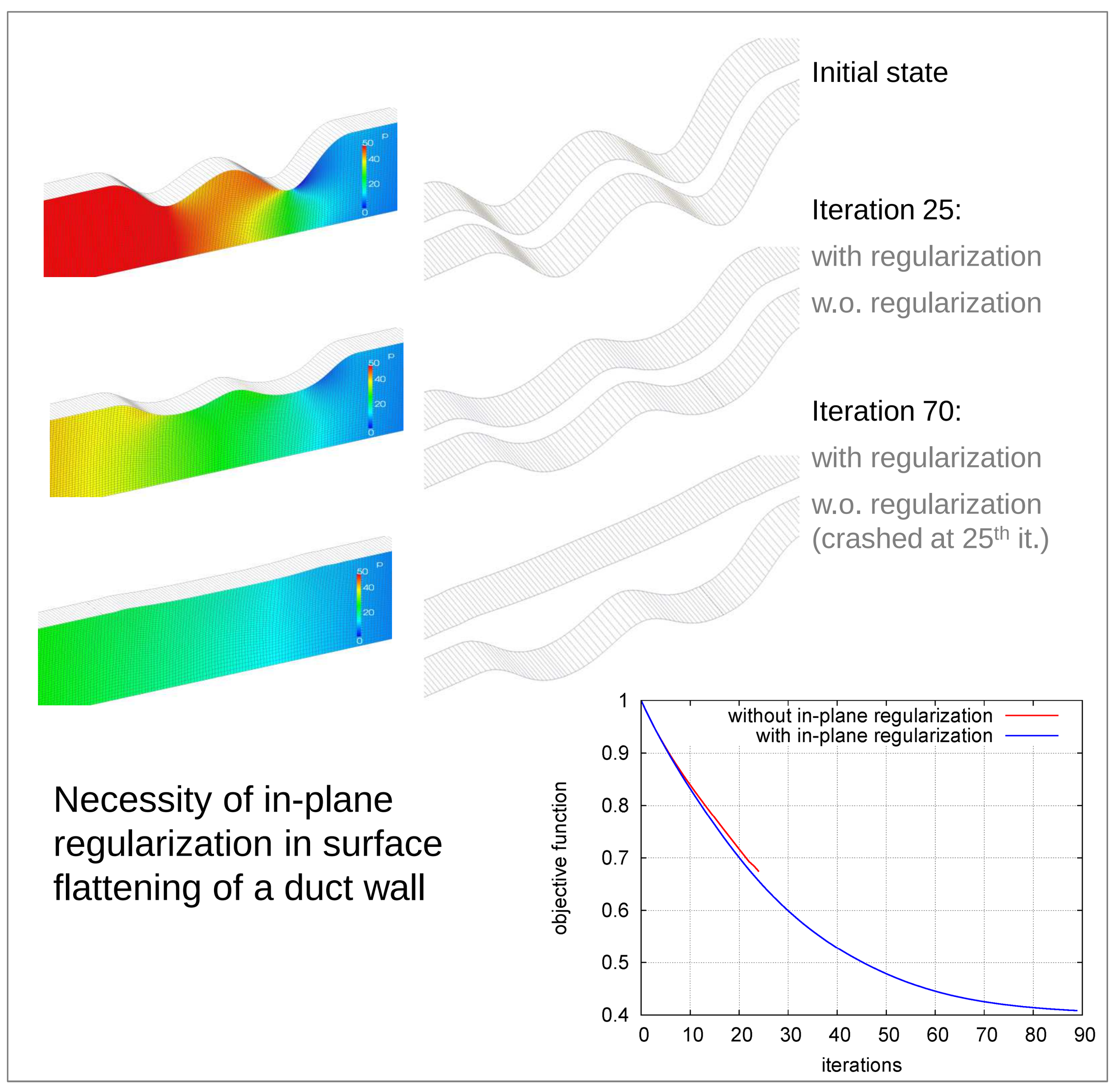
The importance of the method in CFD shape optimization through various examples is observed. Absence of in-plane regularization results in degenerate elements in an early stage of the optimization and thus limited variation in the design is possible.



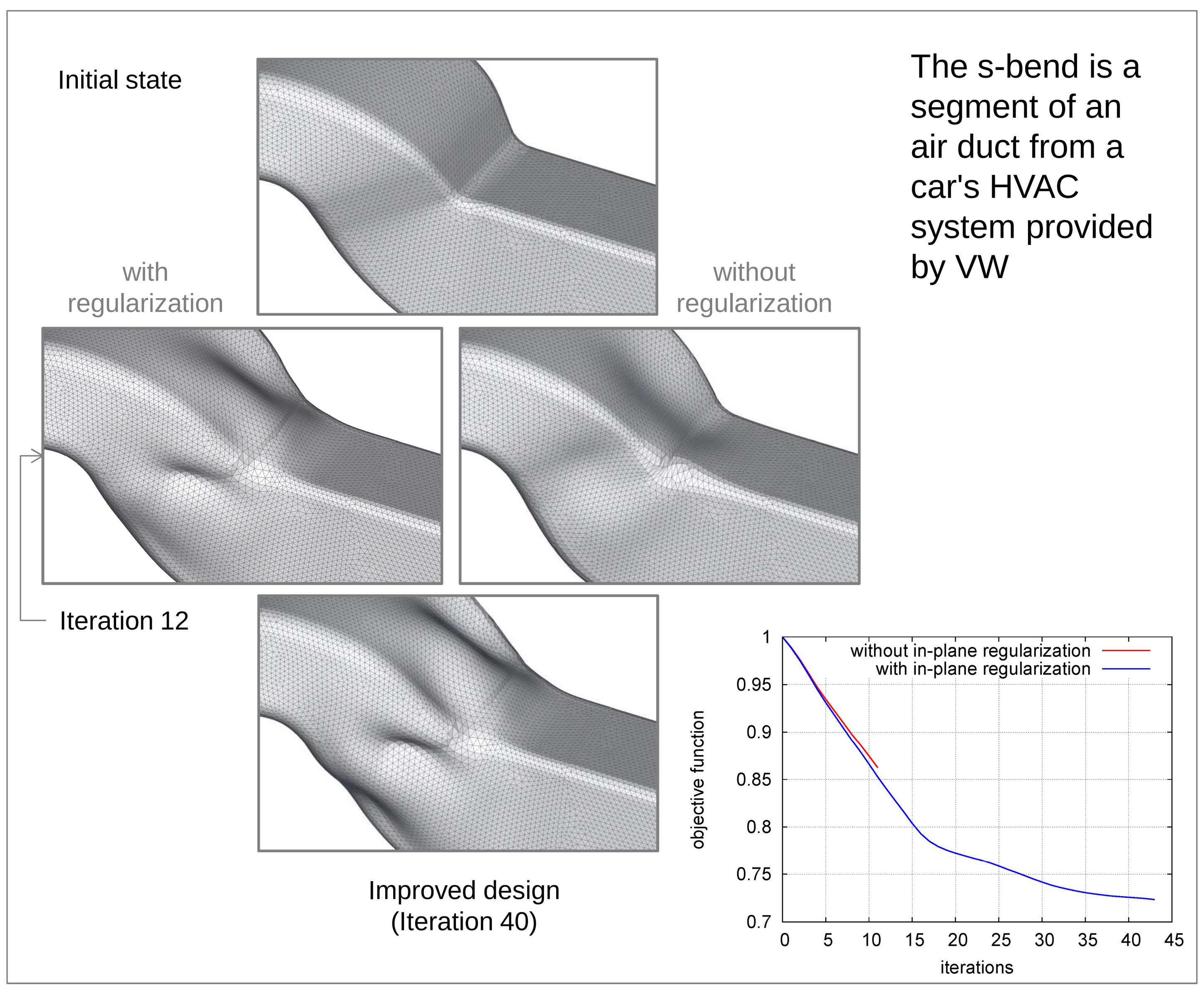
Example 1: Clogged duct



Example 2: 3D S-bend (FLOWHEAD test case)



Necessity of in-plane regularization in surface flattening of a duct wall



The s-bend is a segment of an air duct from a car's HVAC system provided by VW