Shape Optimization and CFD RANS Codes: an Adjoint-based Strategy for Drag Reduction in Automotive Applications

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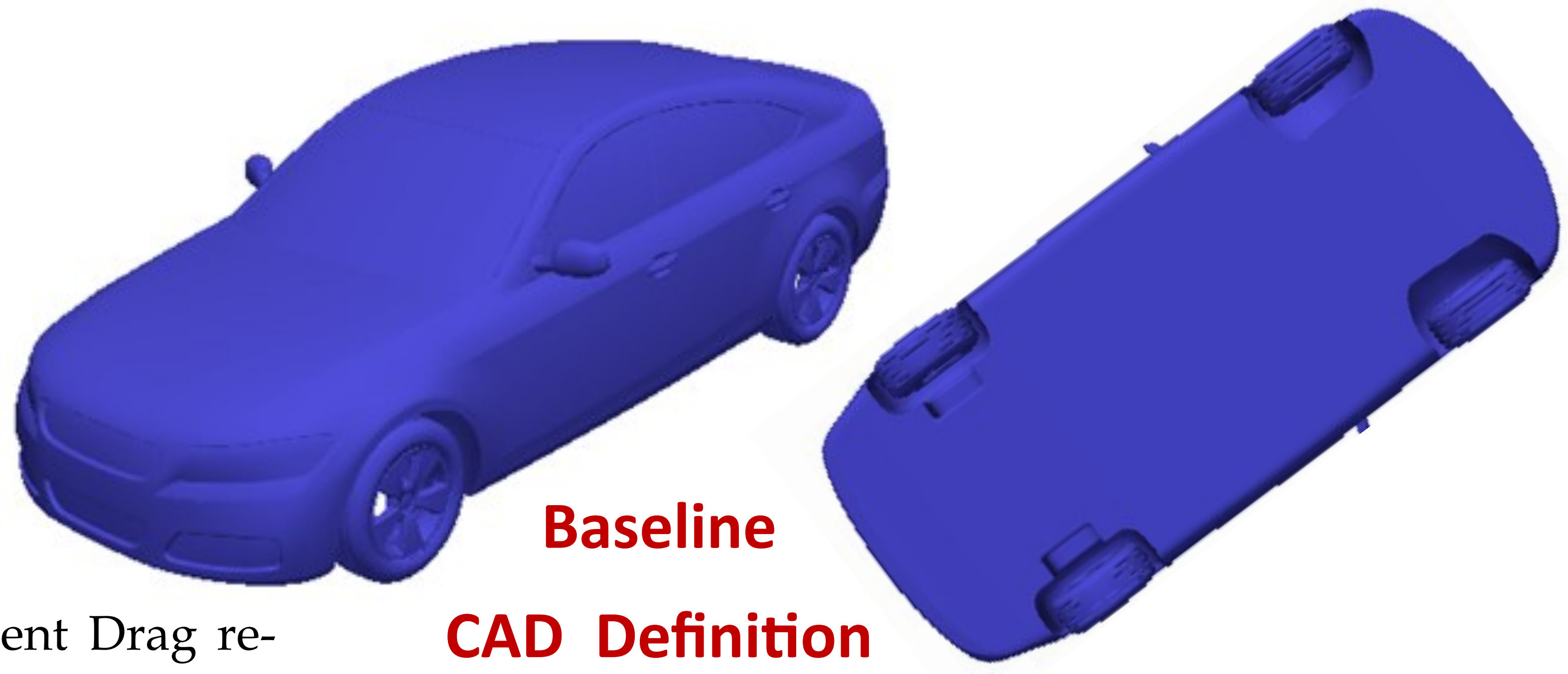
Introduction. Looking at the evolving technology trends in CFD-based shape optimization chains, there is a strong request for robust and flexible **Adjoint Optimization based solutions**. In external aerodynamics shape optimization the most convenient approach relies on the use of some aerodynamics indices as targets (drag for instance). The overall desired effect is to **improve aerodynamic efficiency (drag reduction)** using the outcomes of an Adjoint CFD RANS simulation to drive the CAD morphing.

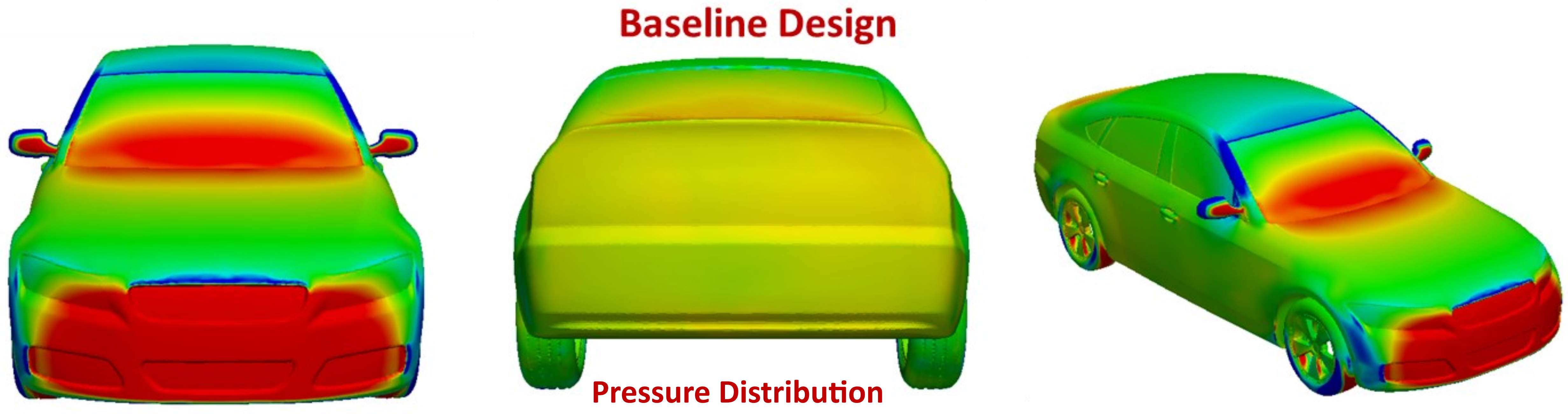
Main Targets of the Project. For these reasons, within a Master Thesis, an **Adjoint Solver for turbulent external aerodynamics problems has been developed in the open-source CFD Toolbox (OpenFOAM)** .
The main target is to perfrom a single shot Adjoint CFD computation and verify to which extent Drag reduction is obtainable.


Baseline CAD Definition

CAD Definition and Problem selection. As a first application we applied the developed solver to a well-established automotive problem: the **3D DrivAer car model** given by TUM.

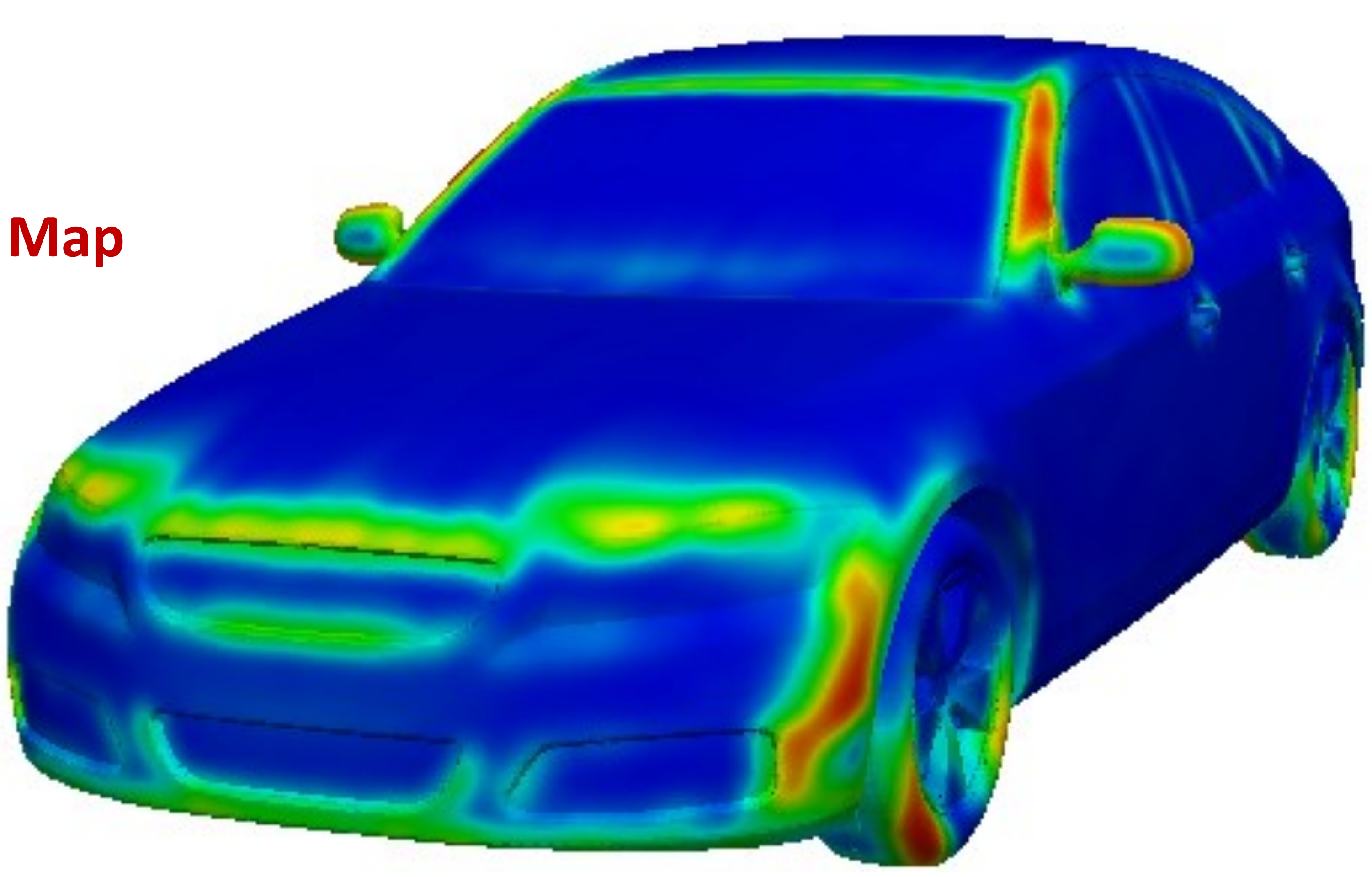
Baseline CFD. The baseline CFD simulation is performed using the CAD definition provided keeping the wheel as fixed as the floor. The velocity of the car is set to 58 km/h and all other physical paramters are related to air at reference conditions. The solver is a steady-state RANS with a k-omegaSST turbelence model.

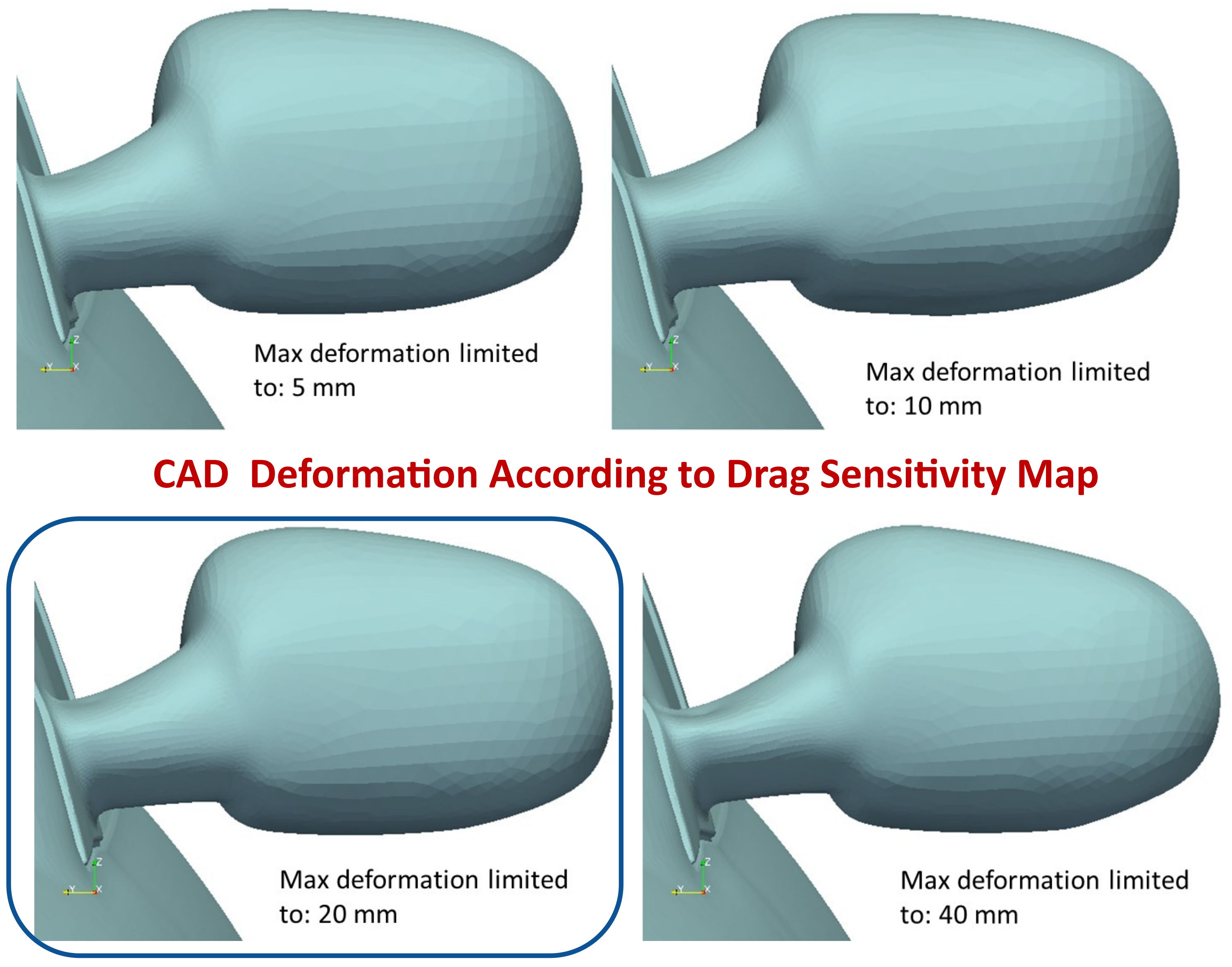
Baseline Design


Pressure Distribution

Adjoint RANS CFD. The outcomes of the baseline CFD solution are used as input to the Adjoint RANS solver. The solver is tailored developed to compute the sensitivity of the whole CAD with the respect to drag changes. The outcome of the adjoint solver is a sensitivity map of the whole car surface points. Red/Blue areas indicates points that should be moved inward/outward to the car surface to reduce drag value. The maximum deformation is a free parameter that designers can tune to obtain a desired morphing of the CAD.

Whole CAD Drag Sensitivity Map


Blue/Red means inward/outward normal deformation



CAD Deformation According to Drag Sensitivity Map

New Design CFD. The New CAD Design is obtained applying a max deformation of 20 mm starting from the baseline CAD. The New Design CFD simulation is performed using the same settings used for the baseline CFD. **The drag reduction obtained is more then 5%.**

New Design


Pressure Distribution

Discussion&Conclusion. The application presented herein shows how a more than **5% drag reduction can be obtained in a single shot adjoint-driven shape optimization for a state of the art automotive CAD definition**. This is a relevant result that could be exploited introducing an optimization engine to drive an optimization loop. The workflow is built on top of an existing HPC platform and is therefore suitable to be exploited on more demanding CFD problems.