Development of a Flexible Constrained Optimization Workflow for a Novel Adjoint CFD Solver

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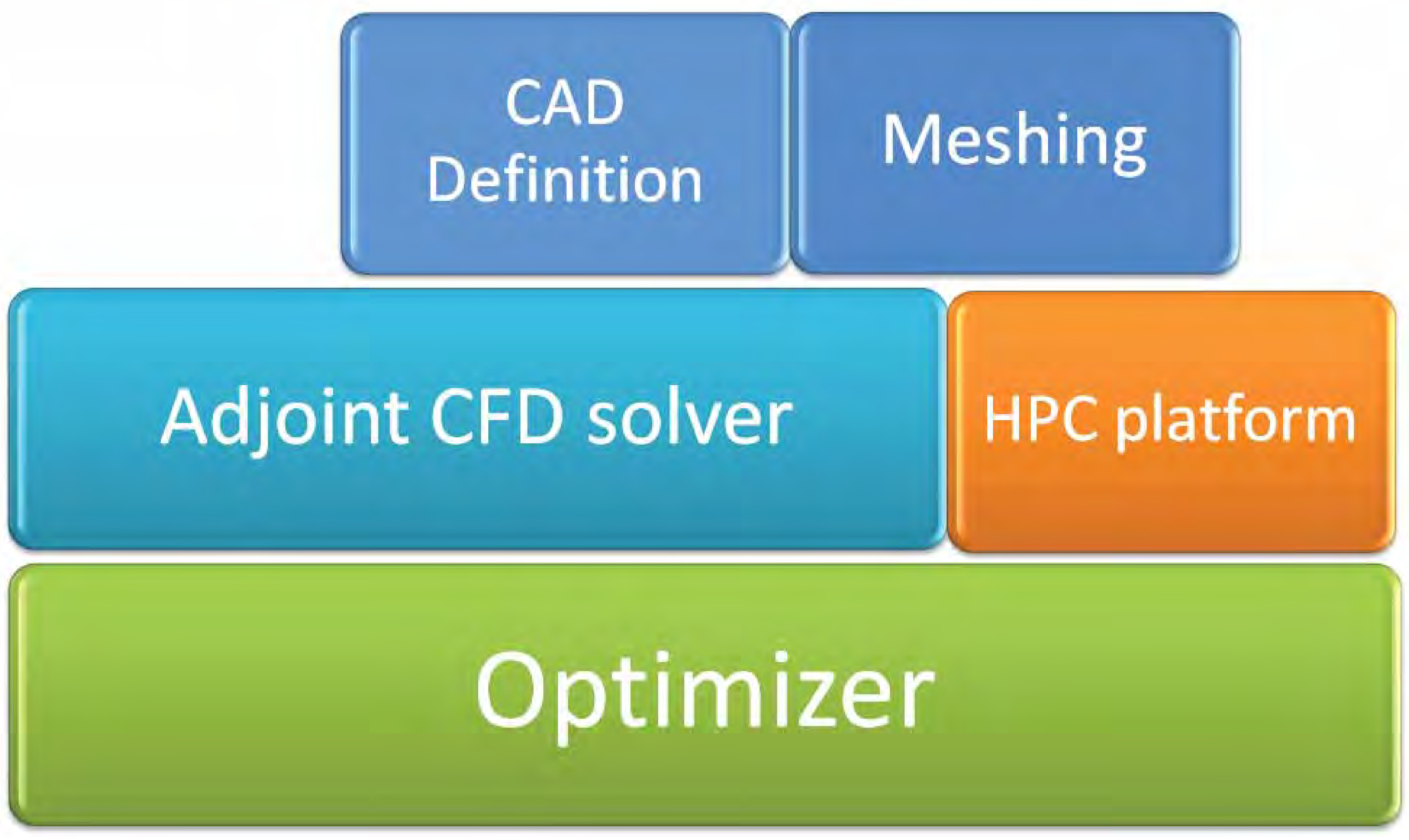
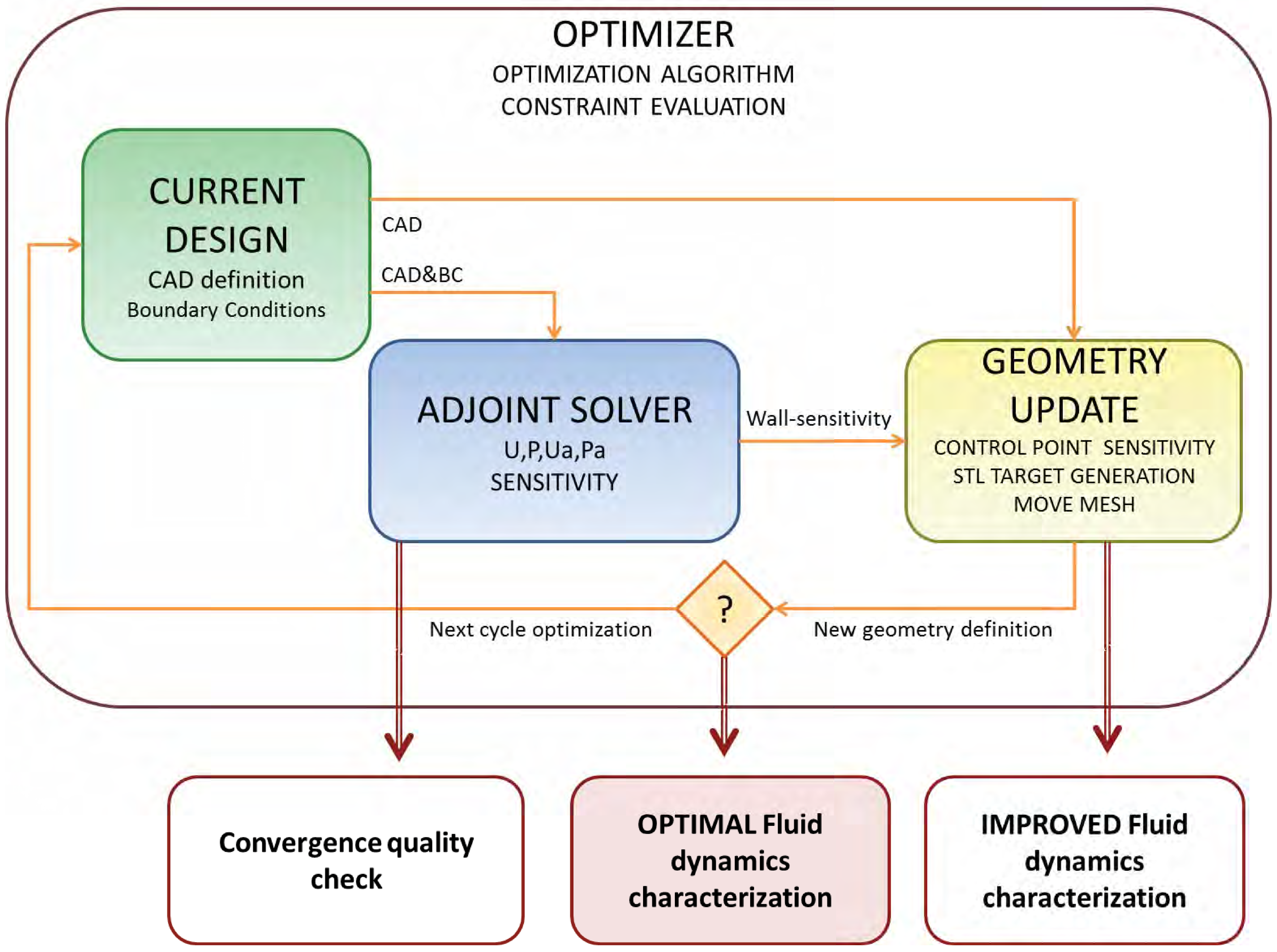
Introduction. Looking at the evolving technology trends in CFD-based shape optimization chains, it is pretty clear that beside well-established Design of Experiments (DOE) approaches there is a strong request for robust and flexible Adjoint Optimization based solutions.



Adjoint Optimization Techniques rely on the possibility to obtain the value of both the function object and its partial derivatives with respect to the design variables at a computational cost tunable by the user and in any case much smaller compared to any DOE when the number of design variables grows. According to these benefits the adjoint solver can be efficiently driven by a constrained optimization algorithm. In external aerodynamics shape optimization the most convenient approach relies on the use of some aerodynamics indices as targets, keeping other indices constrained. The overall desired effect is to **improve aerodynamic efficiency**.

Main Targets of the Project. For these reasons, within a Master Thesis, we developed an **Adjoint Solver** in the open-source CFD Toolbox (**OpenFOAM**), suitable to be driven by an optimizer and designed to take into account external aerodynamics coefficient into the adjoint formulation (**drag and lift coefficient**).

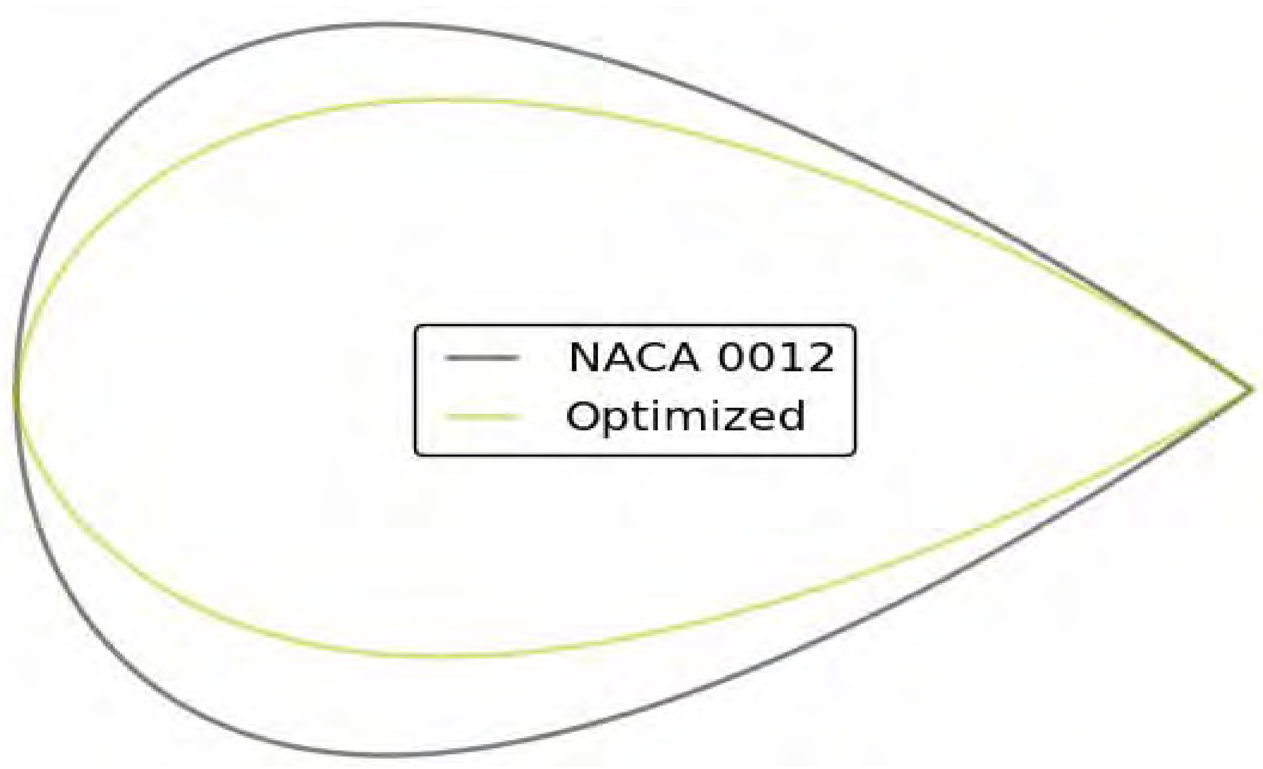
The overall developed workflow is therefore made of a set of independent and interlaced bricks necessary to efficiently run a full optimization cycle based on the continuous self-sculpting of the profile shape, according to the **CFD Adjoint solver** outcomes and keeping the constraints value within the selected bounds.

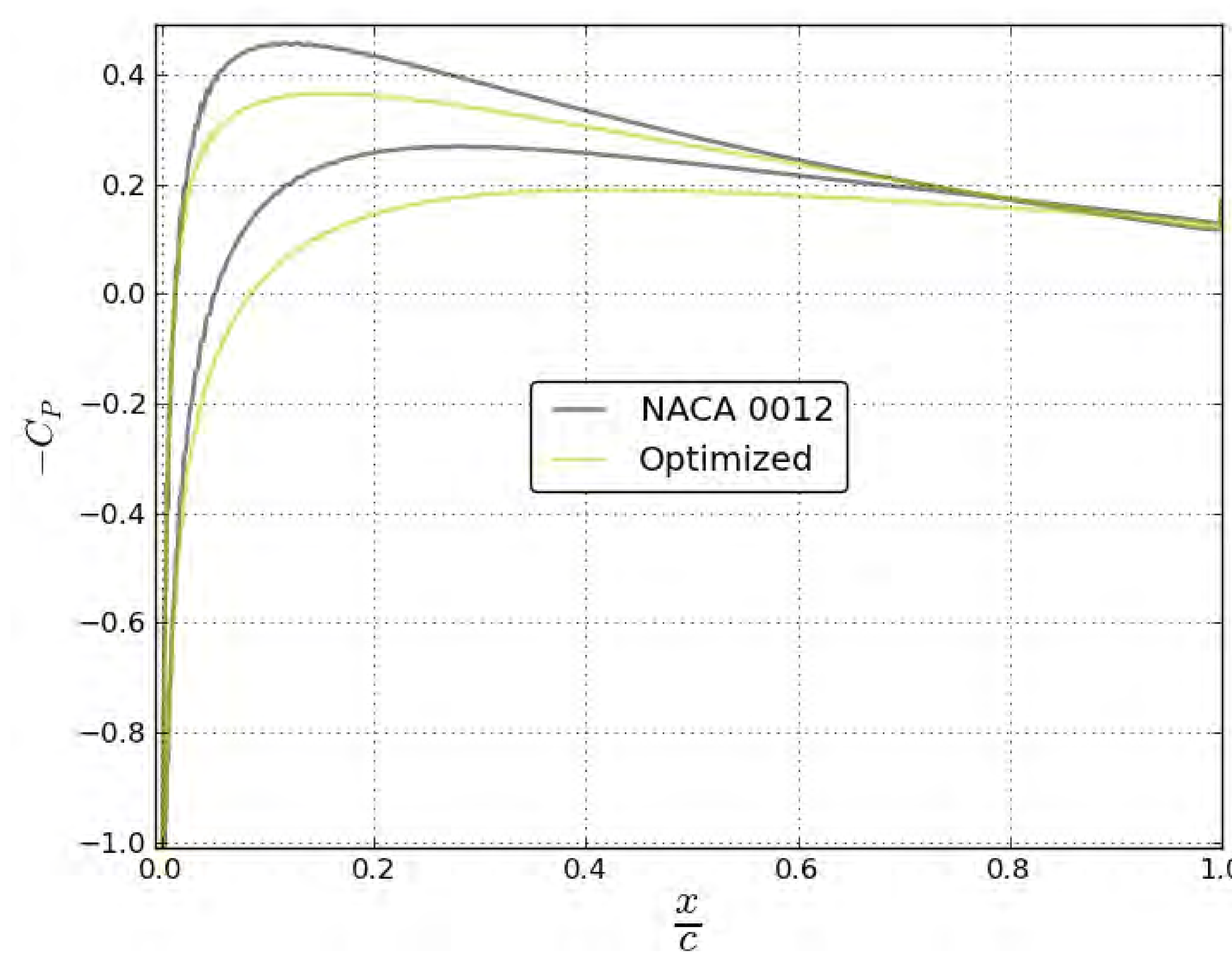


Main Results of the Projects. As a first proof-of-concept we applied the developed workflow to **2D NACA0012 shape optimization,** using alternatively the **drag** and the **lift coefficient** as target design variable and/or constraint variable. We selected **72 control points along the profile chord**.

We tested several fluid dynamics conditions including a wide range of **Angles of Attack (AoA)** for the selected profile. All the obtained results were coherent, showing similar general patterns:

- Shrinking/blunting of the profile shape
- Alignement of the nose with the freestream (AoA)
- Improvement of the aerodynamics efficiency





Discussion&Conclusion. The workflow presented herein has been proven to be effective, allowing to **improve the overall aerodynamics efficiency of about 35% for a selected starting design respecting a defined constraint along the optimization cycle**. Moreover using up to **72 control points** the workflow was able to obtain an optimal novel design using a very limited computational effort (**only 10 CFD runs**) thanks to the **adjoint solver formulation** developed in the project. Finally we underline that the workflow is build on top of an existing HPC platform using only **open-source** code and is therefore suitable to be exploited on more **complex 3D problems**.