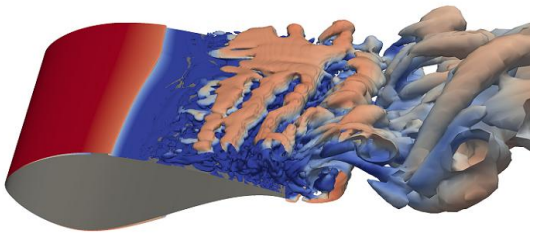
HSLU Hochschule Luzern

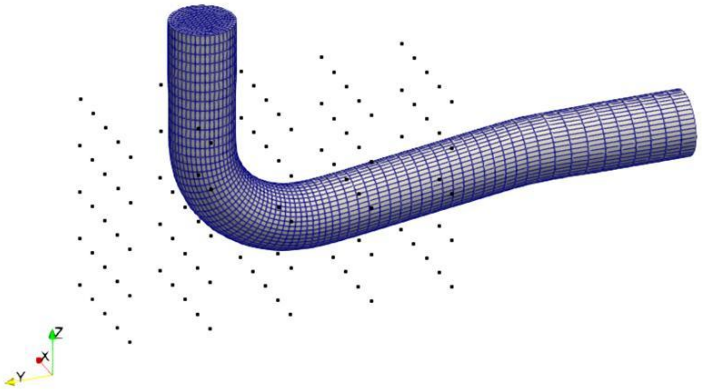
Technik & Architektur

Master of Science in Engineering

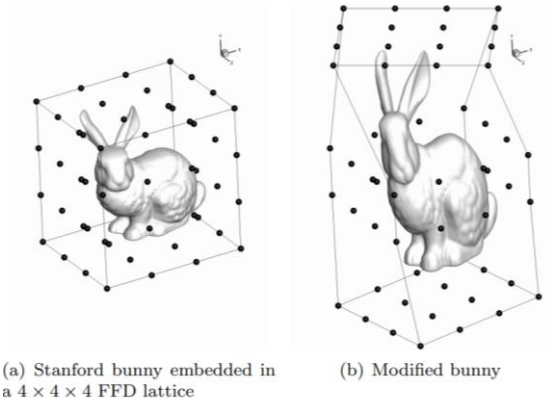
Mesh Deformation Techniques for CFD Optimization



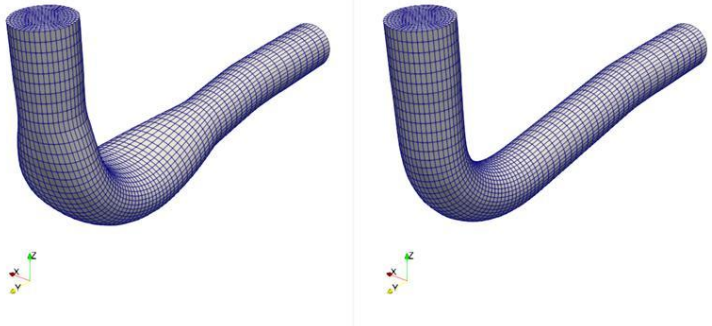
CFD Simulation of an airfoil



FFD control lattice around a pipe bend



Example of free-form deformation applied to the Standford bunny



Optimized vs initial pipe bend geometry

Problem Statement

Adjoint-based shape optimization in computational fluid dynamics requires robust mesh deformation methods to ensure smooth geometry changes and preserve mesh quality. Inadequate deformation can lead to distorted meshes, loss of boundary-layer resolution, and unreliable optimization results.

The in-house CFD solver coupledNumerics includes a framework for prescribed-motion mesh deformation, but lacked a unified approach suitable for adjoint-driven shape optimization. Direct deformation methods were found to be insufficient for producing smooth and physically consistent surface modifications.

This thesis addresses the need for a flexible and general mesh deformation framework that supports adjoint optimization. The focus is on integrating a Free-Form Deformation (FFD) approach into the existing solver and extending it to enable advanced deformation capabilities.

Solution Concept

A unified mesh deformation framework based on Free-Form Deformation is integrated into the CFD solver. Surface deformations are smoothly propagated into the volume mesh using IDWarp, enabling robust adjoint-based shape optimization.

Results

The developed deformation framework enables smooth and robust mesh deformation for adjoint optimization. Test cases demonstrate stable convergence, preserved mesh quality, and consistent reduction of the objective function for both standard and advanced deformation configurations.

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