www.dx-dt.at e.u.

Thomas Paier
thomas.paier@dx-dt.at
+43 660 5271777

# Fluid Dynamic Shape Optimization: Methods in Comparison

Fluid dynamic shape optimization has evolved from purely local modification of existing profiles to data-driven and AI-supported frameworks. While classical methods (Hicks-Henne, CST) are based on mathematical functions, modern approaches like AirDbM use the morphing of database geometries and SARMOO uses adaptive, machine-learned surrogate models to overcome computation time and stability issues.

## Strategies of Geometry Parameterization

### Top-Down vs. Bottom-Up Approaches




Hicks-Henne/CST modify existing shapes



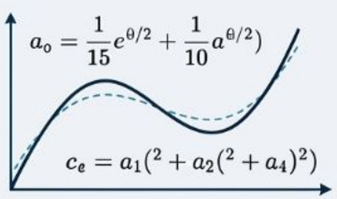
Para+ builds structures adaptively from the ground up

### Data-driven Dimensionality Reduction



AirDbM reconstructs 99% of the UIUC database with only 12 base elements through interpolative and extrapolative morphing

### Analytical Precision through CST



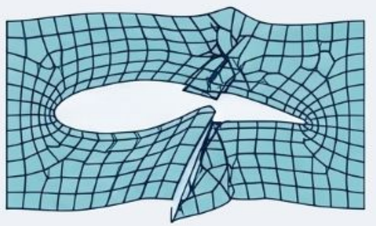

Uses Bernstein polynomials (4th to 10th order) for the exact representation of smooth, fluid dynamically highly flexible bodies.

## Vergleichsmatrix: Methoden im direkten Vergleich

| | Hicks-Henne / CST | AirDbM (Morphing) | Para+ in SARMOO |
|---|---|---|---|
| Philosophy | Modification / Analytics | Data-driven Combination | Adaptive Structural Assembly |
| Biggest Hurdle | Automated Mesh Instability | Limitation by Base Set | Complexity of ML Training |
| Optimization | Gradient-based / Adjoint | Reinforcement Learning / GA | Active Learning / Surrogates |

## The Technical Hurdle: Mesh Stability

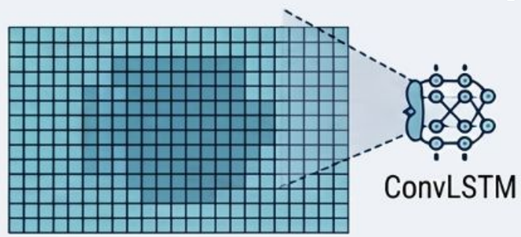
### The Bottleneck of FEA Meshing



SOLVER CRASH

Classical methods often fail due to solver crashes caused by heavily deformed meshes during large geometry variations.

### SARMOO Solution: Fixed Grid & Surrogates




Para+ uses a fixed grid (mapping) and ML models (ConvLSTM) to predict eben in unstable simulation regions