Geometry and Meshing for Simulation

Welcome to the Geometry and Meshing for Simulation Group, in the Department of Computer Applications in Science and Engineering (CASE) at the Barcelona Supercomputing Center (BSC).

We aim to enable high-fidelity simulation for analysis and design in computational engineering. To this end, our research focuses on advancing computational methodologies not only for geometry and meshing but also in scientific computing. Our methodologies lie in the intersection of applied math, computer science, and engineering.

Our aim is mainly motivated by the aviation environmental challenge. To reduce emissions, airplanes will exploit complex interactions between the airframe and propulsion systems. The analysis of these designs is so demanding that it will need new methods for high-fidelity flow simulation.

To help enable high-fidelity analysis, we devise methods for high-fidelity approximation of complex geometry. These approximations use highly accurate and smooth curved polyhedra called high-fidelity meshes. We know that without them, aeronautic engineers will be unable to perform high-fidelity analysis of real designs. Hence, high-fidelity meshes are crucial.

Objectives

- Enabling high-fidelity simulation with curved meshing and unstructured high-order methods.

- High-fidelity geometry representations for simulation.

- 4D space-time simulation

- Checking and optimizing the geometric accuracy of meshes for simulation.

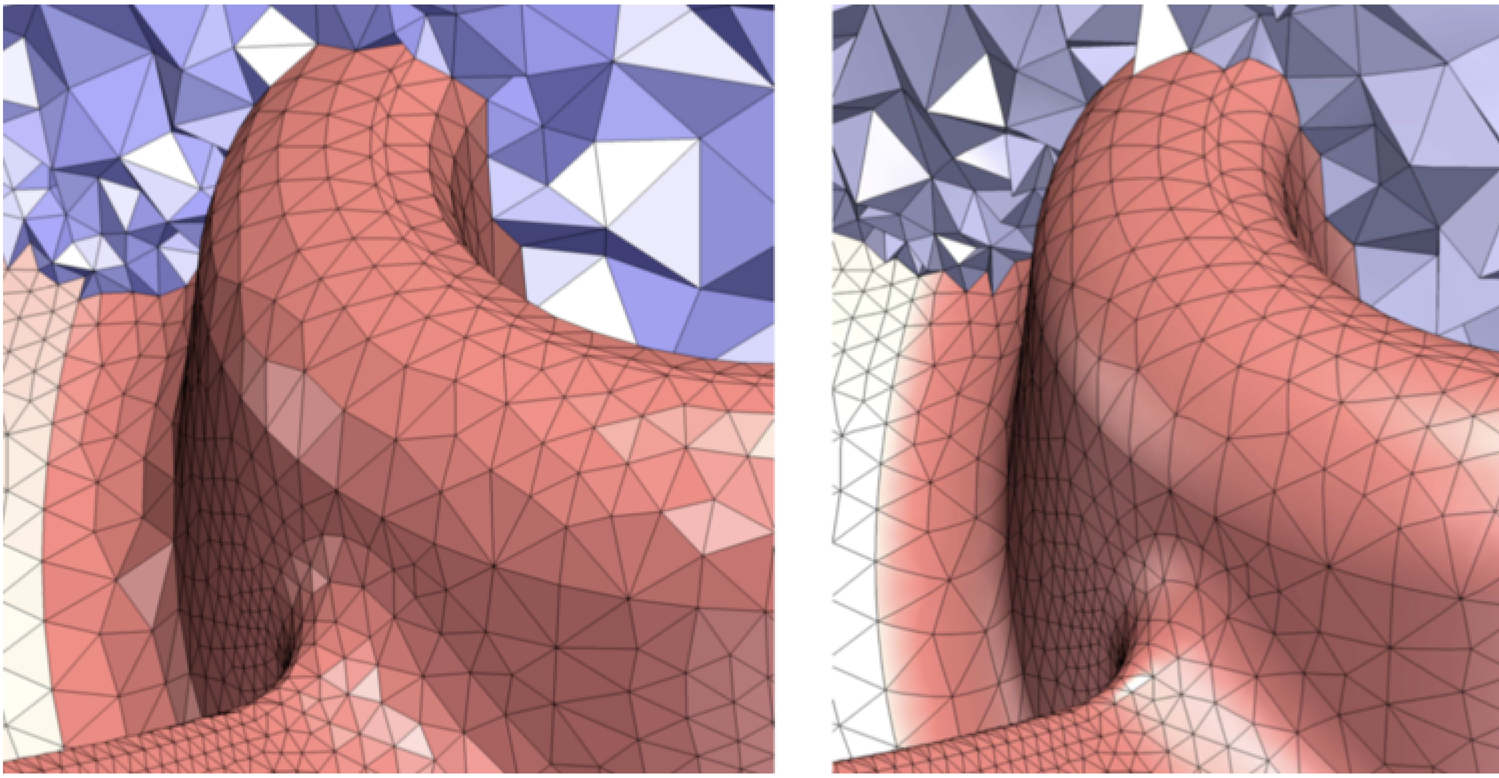
- Curved r-adaptivity

- 2D, 3D & 4D bisection methods

- Nodal representation and numerical integration for high-order methods

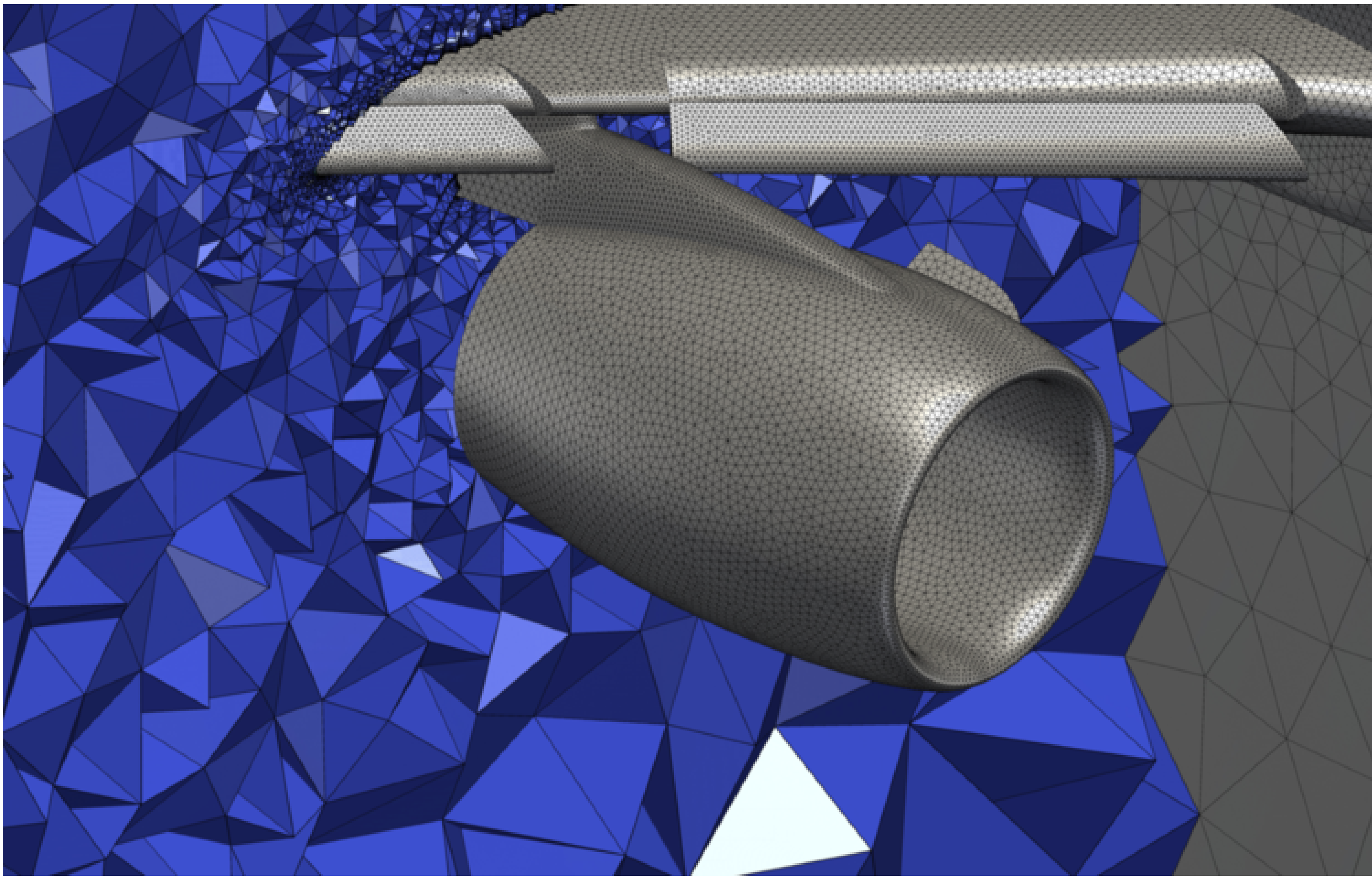
- Large-scale optimization

- Specific-purpose linear and non-linear solvers



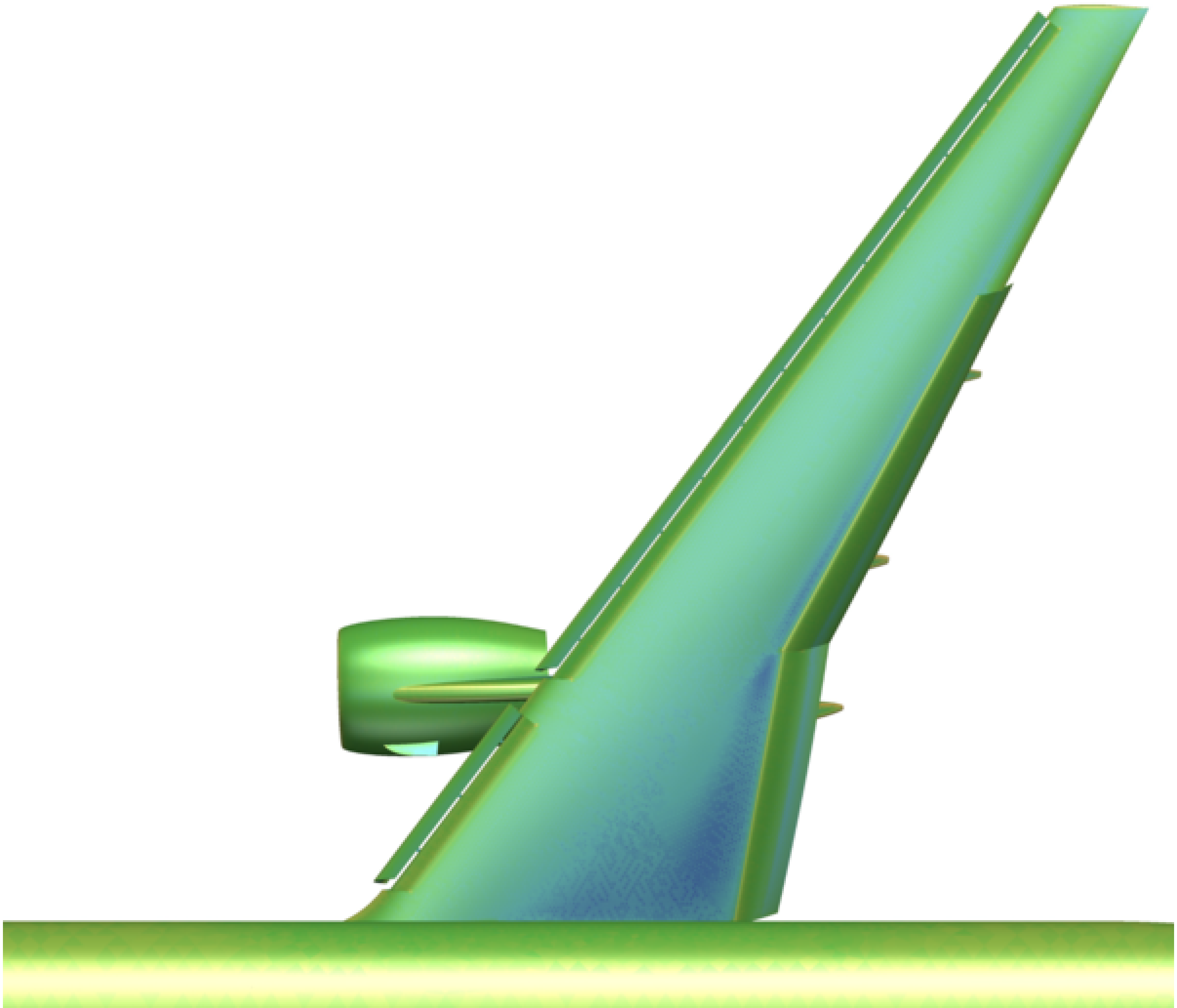
Meshes – (Left) Straight and (Right) Curved

This image illustrates the difference between traditional straight-edged meshes and advanced curved meshes. Straight meshes are simpler to generate but may lack the geometric accuracy required for high-fidelity simulations. In contrast, curved meshes can better capture the true shape of complex geometries, improving simulation accuracy, particularly in aerodynamic applications.



Curved Mesh for the NASA High-Lift Common Research Model

The NASA High-Lift Common Research Model (HL-CRM) is a widely used benchmark in aerodynamic studies, representing a realistic aircraft configuration. This image showcases a high-fidelity curved mesh applied to the HL-CRM, enabling precise computational simulations of complex aerodynamic flows. Such curved meshes are essential for accurate predictions of lift, drag, and overall aircraft performance.



Accuracy for a Cubic Mesh

This visualization highlights the accuracy achieved when using high-fidelity cubic meshes. The geometric precision of these meshes is crucial for computational fluid dynamics (CFD) and structural simulations, where even small inaccuracies can significantly affect results. By optimizing mesh accuracy, the group ensures reliable simulations for engineering applications, particularly in aviation and aerospace research.