Block-Structured Quad Meshing for Supersonic Flow Simulations

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PROBLEM STATEMENT

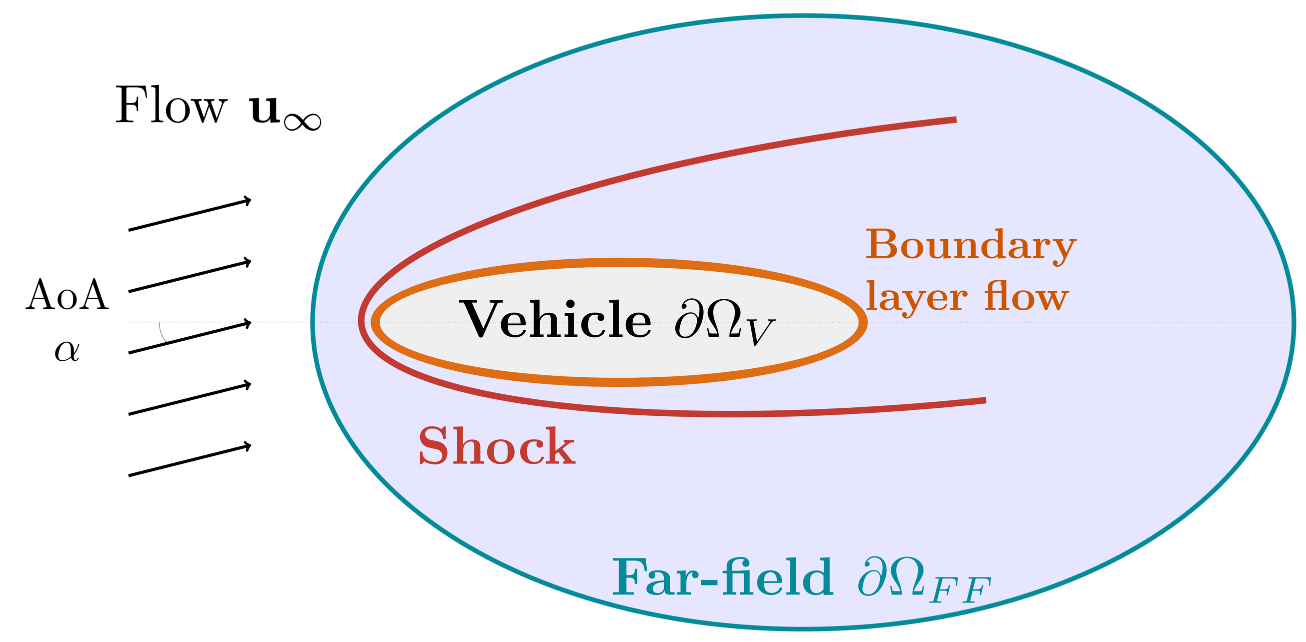


FIGURE 1 – Flow around a supersonic vehicle.

- This work aims to provide a solution to generate meshes automatically for a **legacy Computational Fluid Dynamics** code.
- Our meshing algorithm is freely available and implemented in the open-source C++ meshing framework **GMDS** [1].

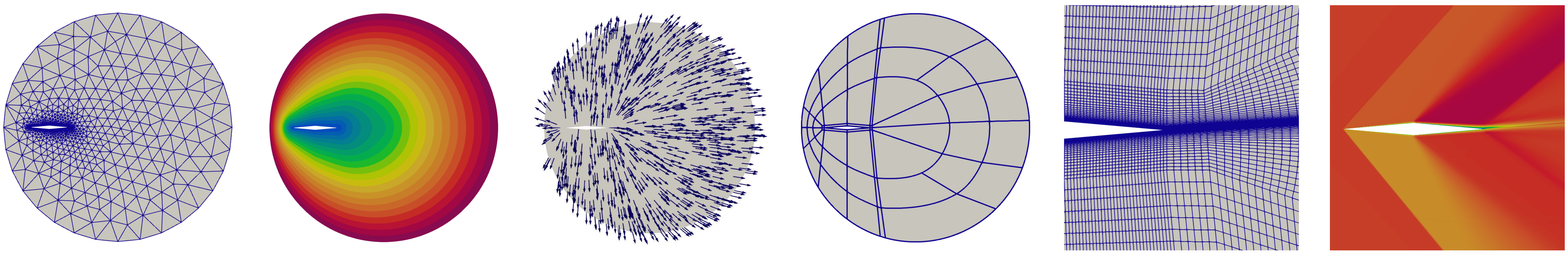
Input meshes of the code

- **Block-structured** meshed
- **Quad** cells only

Hypothesis on domains

- Vehicles are **completely immersed** in the fluid
- Far-field is a **smooth boundary**
- **Single wall** vehicles

The main stages of our approach

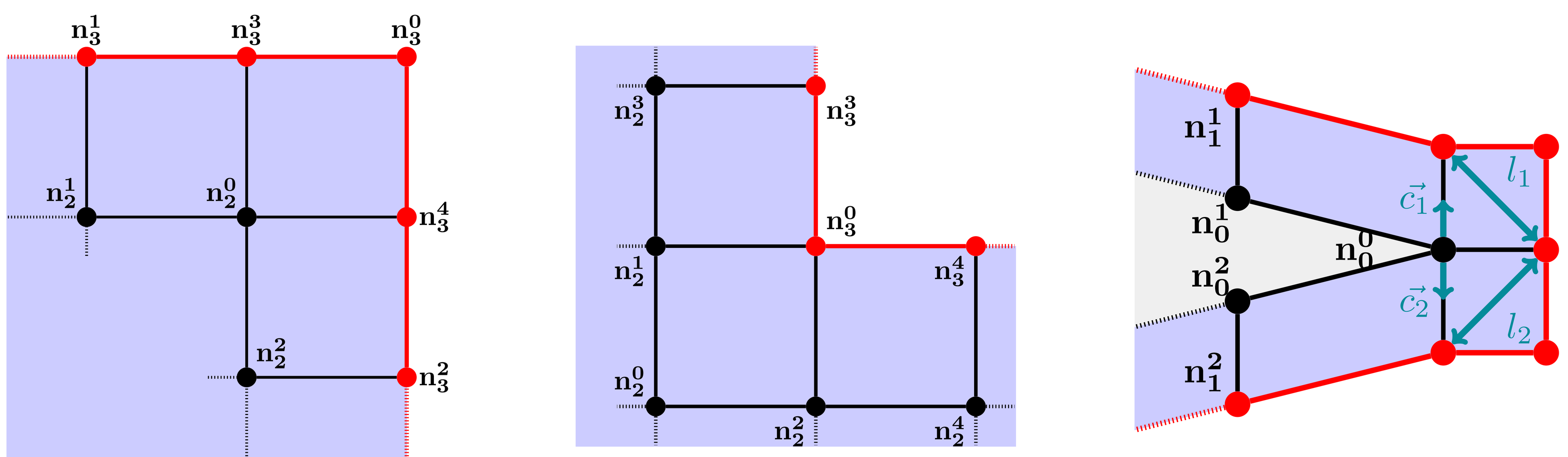


(a) Triangulation (b) Distance field (c) Vector field (d) Blocks (e) Mesh (f) Results

FIGURE 2 – Starting from a triangulation of the domain (a), we first generate and combine distance fields (b) and build a vector field that ensure wall orthogonality and the alignment with the angle of attack (c). Using those fields, we generate curved blocks (d) and a final quad mesh where the element size is carefully controlled in the boundary layer (e). Numerical simulation can then be launched (f).

Block layer generation

- Compute a **distance field** d (Fig. 2.b) by solving an Eikonal equation [2] on a first triangular mesh (Fig. 2.a).
- Compute a **vector field** $\mathbf{v}$ (Fig. 2.c) to lead the blocks extrusion. This field is a combinaision of the distance field to the wall gradient, and a constant vector field corresponding to the angle of attack $\mathbf{u}_\infty$.
- Set the block corner on the wall, based on geometric critera.
- For each block corner n_n^i of the layer n, we compute the ideal position of the next block corner n_{n+1}^i in the layer $n+1$. This is done using the advection of the position of the first block corner along the field $\mathbf{v}$.
- Solve the conflicts due to **expansion** or **shrinking** on the layer [3] (Fig. 3).



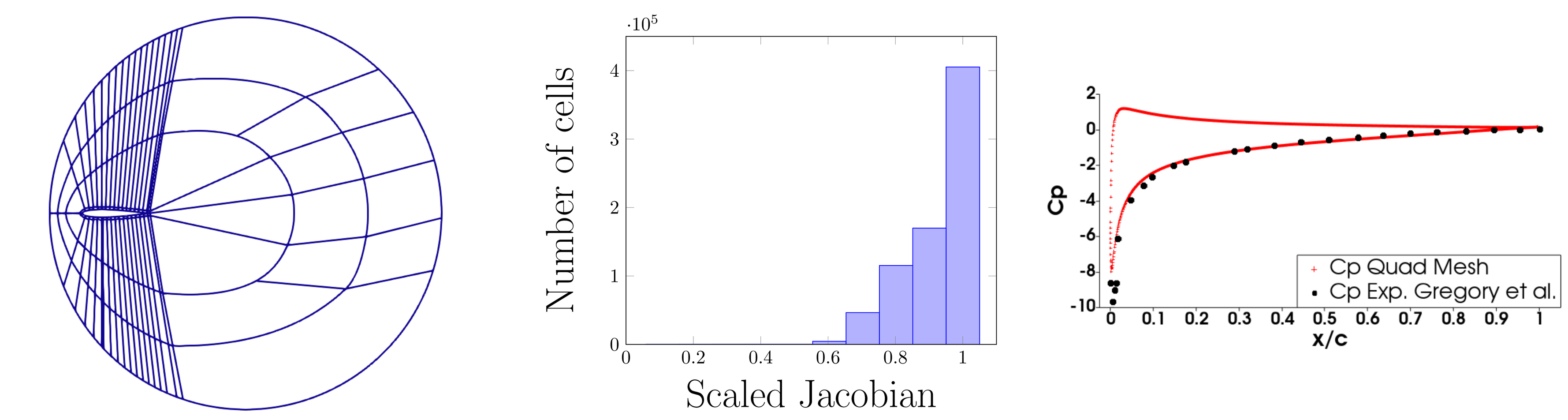
(a) (b) (c)

FIGURE 3 – Block simple insertion (a), double insertion (c) and shrinking (b) on a layer.

From blocks to quads

- Compute the number of mesh edges for each block edge by an **interval assignment** algorithm [4].
- Curve each block edge of the block with **quadratic Bézier curves** (Fig. 2.d).
- Apply a **transfinite** method to generate the mesh in each block (Fig. 2.e).
- Internal block **mesh smoothing** [5] for the blocks of the first layer.

Results and Applications



(a) NACA 0012 blocking (b) Mesh quality (c) Pressure coefficient

FIGURE 4 – Mesh validation with a CFD simulation around the NACA 0012 [6] airfoil. The angle of attack is $\alpha = 15°$.

- Analysis of the flow alignment with $\mathbf{u}_\infty$ (Fig. 4.a) and of the **mesh quality** (Fig. 4.b).
- Validation case on **experimental data-set** (Fig. 4.c) for the NACA 0012 airfoil. The simulations are performed with the open-source multi-physic CFD code SU2 [7].
- Validation case on a supersonic diamond airfoil (Fig. 2.f). The angles of the shocks fit with the analytical solution.

PERSPECTIVES

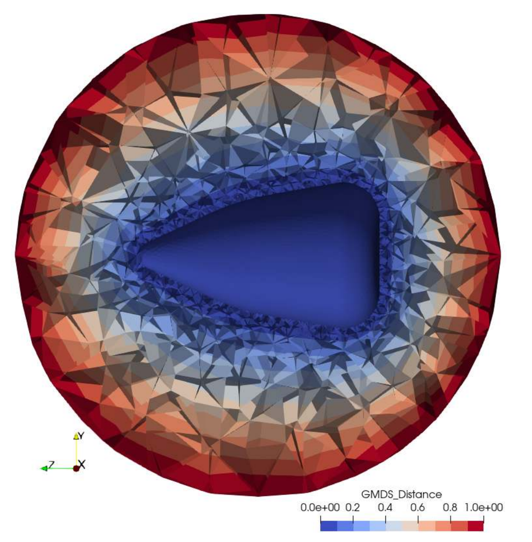


FIGURE 5 – 3D distance field.

This work proposes a solution to automatically generate 2D quadrilateral block-structured meshes dedicated to flow simulation around a single vehicle.

- Improve the mesh size transition.
- Improve the final mesh quality by block and final mesh smoothing.
- Extend the method the the 3D case.
- Switch to high order blocks.

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